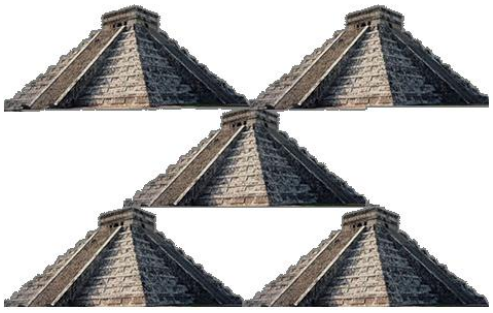
BOOK OF ABSTRACTS

II-VI-2011



15th INTERNATIONAL CONFERENCE ON II-VI COMPOUNDS

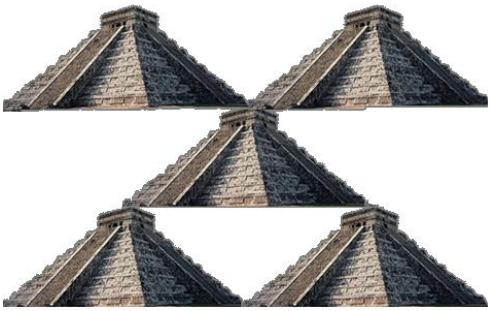
Mayan Riviera – Mexico

21 – 26 August 2011

RIBER Cinvestav INTERCOVAMEX NanoSem

15th INTERNATIONAL CONFERENCE ON II-VI COMPOUNDS

II-VI-2011



Mayan Riviera – Mexico

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The 15th International Conference on II-VI Compounds is organized by Cinvestav (Center for Research and Advanced Studies, Mexico City) at the Mayan Riviera (or Riviera Maya) in the Yucatán Península. It will be the continuation of a successful series of biennial conferences which started in Durham (UK) in 1983. The latest conferences were held in Niagara Falls, USA, 2003; Warsaw, Poland, 2005; Jeju, Korea, 2007 and Saint Petersburg, Russia, 2009. This conference provides a well organized international forum for scientists, students and industry to review and stimulate the progress in basic and applied research on II-VI compounds.

The Conference will cover all aspects of basic and applied research, laying special emphasis on unique physical and material properties of II-VI semiconductors and their nanostructures. The conference is an international forum aimed to review and stimulate the progress in basic and applied research on II-VI semiconductors, to facilitate the exchange of new ideas and to establish new scientific contacts.

The Conference consists of invited talks on topics of current relevance delivered by well known specialists, and oral and posters sessions. We have a special session on Tuesday devoted to the memory of Prof. Jan Gaj, (Univ. of Warsaw) who made significant contributions to II-VI diluted magnetic semiconductors. On Thursday afternoon takes place a Late News session. After the start in Saint Petersburg, on Sunday afternoon we will have three Review Lectures offered by renowned specialists.

The official language of the conference is English.

VENUE: The Mayan Riviera

The Cancun -Tulum Corridor is called Mayan Riviera (or Riviera Maya), it extends for around 60 km south of Cancun in the Mexican Caribbean coast. In this ancient land, where the majestic turquoise Caribbean Sea meets white, cool soft sand beaches, you will also meet the warm and welcoming hospitality of the Mayan people. Here you can dive amazing reefs, snorkel and see wondrous sea life, tour ancient archeological sites, lay all day in a hammock or stroll the walk way lined with shops, sliver, arts and crafts, experience great restaurants and much more!

CONFERENCE COMMITTEES

Conference Chair: **Isaac Hernández-Calderón**, Cinvestav, Mexico.
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Conference Secretary: **Miguel García Rocha**, Cinvestav, Mexico.

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Review Lectures

Tom Myers, *Texas State University* (USA)	**Properties and applications of HgCdTe**
Daniel Wolverson,*University of Bath* (UK)	**Magneto-optical properties of II-VI semiconductors**
Joel Cibert, *Institut Néel -CNRS- Univ. Joseph Fourier* (France)	**History and development of II-VI magnetic semiconductor heterostructures**

Invited Speakers

Andrey Bakin, *Braunschweig University of Technology* (Germany)	**Oxide semiconductors for photovoltaic applications**
Edith Bellet-Amalric, *CEA-CNRS* (France)	**II-VI Nanowires as optical emitters**
Gregory N. Brill, *U.S. Army Research Laboratory*, (USA)	**Hg-based II-VI compounds on non-standard substrates**
Jean Michel Chauveau, *CRHEA-CNRS* (France)	**Homoepitaxial growth and properties of non polar (Zn,Mg)O/ZnO quantum wells**
Alexander Efros, *Naval Research Laboratory* (USA)	**Suppression of blinking in semiconductor nanocrystals**
Shizuo Fujita, *Kyoto University* (Japan)	**Growth, characterization, and device applications of various oxide semiconductors**
Charles Gould, *University of Würzburg* (Germany)	**Magnetic resonant tunneling devices (RTDs): from spin-valves to single electron transistors**
Tae Won Kang, *Dongguk University* (South Korea)	**Physics and Application of Nanorods of II-VI Compound Semiconductors**
Hironori Katagiri, *Nagaoka National College of Technology* (Japan)	**Thin Film CZTS Solar Cells: Research for Sustainable PV Expansion**
Benjamin Piot, *High Magnetic Field Laboratory CNRS in Grenoble*(France)	**High quality 2DEG in CdTe quantum wells for the physics of quantum Hall effect**
Maxime Richard, *Institut Néel, CNRS University J. Fourier* (France)	**Physics of 1-dimensional exciton-polaritons in ZnO microwires**
Shigehisa Tanaka, *Hitachi Central Research Lab.* (Japan)	**Room-temperature CW operation of BeZnCdSe green laser diode**
Yong-Hang Zhang, *Arizona State University* (USA)	**6.1 Å II-VI and III-V materials: A platform for photovoltaic and IR device applications**

Special session devoted to the memory of Prof. Jan Gaj (University of Warsaw)

Invited Speaker:

Piotr Kossacki, *University of Warsaw (Poland)*

Single dot spectroscopy of CdTe based self organized system

Prof. Jan Gaj

Professor Jan Gaj (1943-2011) was a passionate physicist, throughout his life showing extraordinary skills even in his early years. Born in Kraków, he studied Physics at the University of Warsaw. In fact, nearly his entire academic carrier was associated with the Department of Experimental Physics of the University of Warsaw. He was an experimentalist through and through (he always stressed that experimental approach is at the very heart of Physics) and an important member of the group that became known as the Warsaw School of Semiconductor Physics. One of his most prominent achievements as a scientist was the seminal study of optical properties of cadmium manganese telluride, published in 1979, work that helped to put the entire subject of diluted magnetic semiconductors prominently on the map. Most recently his interest turned to self-assembled quantum dots with Mn, where again he has contributed many pioneering concepts.

Apart from doing research in the laboratory, Jan Gaj was an eminent educator – his lectures were invariably crystal clear, illustrated with cleverly designed demonstrations. He even created a series of very popular TV programs devoted to Physics. Not surprisingly, young students to whom he devoted a great deal of his time and attention constantly surrounded him. He was widely recognized internationally: he spent extended periods in laboratories abroad, at Stanford, at universities in Grenoble and Paris, and at Linz. He had a very mellow and agreeable personality: it was not only a pleasure to collaborate with Jan Gaj (Janek, as he was known to his friends), but also just to talk with him about anything at all, e.g., about music, which he truly loved.

His final illness was quite sudden: leukemia was diagnosed only in December 2010, which led to his passing in February of this yea

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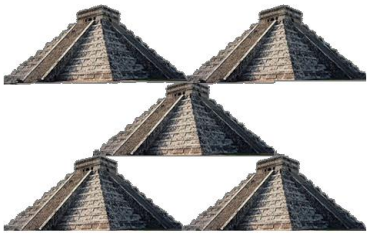

SESSION CHAIRMAN

Session Chairman	Day	Hour
Sergey Ivanov, Ioffe Institute (Russia)	Sunday 21	17:00 – 19:00
Isaac Hernández-Calderón, Cinvestav (Mexico)	Monday 22	09:30 – 10:30
Maria C. Tamargo, CUNY (USA)	Monday 22	11:00 – 13:00
Henri Mariette, CNRS-CEA-UJF (France)	Monday 22	17:00 – 18:30
Akihiko Yoshikawa, Chiba University (Japan)	Tuesday 23	09:00 – 10:30
Aidong Shen, City College of New York (USA)	Tuesday 23	11:00 - 13:00
Jacek Kossut, Polish Academy of Sciences (Poland)	Tuesday 23	17:00 – 18:15
Detlef Hommel, Univ. of Breme (Germany)	Wednesday 24	09:00 – 10:30
Rameshwar Bhargava, Nanocrystals (USA)	Thursday 25	09:00 – 10:30
Masakazu Kobayashi, Waseda University (Japan)	Thursday 26	11:00 – 13:00
Alexey Toropov, Ioffe Institute (Russia)	Thursday 26	17:00 – 18:15
Le Si Dang, CNRS – Université Joseph Fourier (France)	Friday 27	09:00 – 10:30

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SCHEDULE

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	15th Intl. Conference on II-VI Compounds Mayan Riviera - Mexico August 21 – 26, 2011					
Hour	Sunday 21	Monday 22	Tuesday 23	Wednesday 24	Thursday 25	Friday 26
08:00 - 09:00		Registration	Registration	Registration	Registration	
09:00 - 09:15		Opening Session	INVITED05 **Zhang**	INVITED09 **Bellet**	INVITED10 **Tanaka**	INVITED14 **Chauveau**
09:15 - 09:30						
09:30 - 09:45		INVITED01 **Katagiri**	Tu01-Chai	We01-Dang	Thu01 Shen	Fr01-Kuskovsky
09:45 - 10:00			Tu02-Fan	We02-Wojnar	Thu02-Klembt	Fr02-Fregnaux
10:00 - 10:15		INVITED02 **Efros**	Tu03-André	We03-Bounouar	Thu03-Ivanov	Fr03-Kruse
10:15 - 10:30			Tu04-DiNezza	We04-Kümell	Thu04-Sorokin	Fr04- Kłopotowski
10:30 - 11:00		Coffee Break	Coffee Break		Coffee Break	Closing Session
11:00 - 11:15		INVITED03 **Piot**	INVITED06 **Brill**	Excursion	INVITED11 **Fujita**	
11:15 - 11:30						
11:30 - 11:45		Mo01-Shen	Tu05-Doyle		Thu05-Furubayashi	
11:45 - 12:00		Mo02-Toropov	Tu06-Yasuda		Thu06-Krajewski	
12:00 - 12:15		Mo03-Stölzel	Tu07-Itsuno		INVITED12 **Bakin**	
12:15 - 12:30		Mo04-Seyfried	Tu08-Bhat			
12:30 - 12:45		Mo05- Davidson	INVITED07 **Richard**		Thu07-Shubina	
12:45 - 13:00		Mo06- Hernández			Thu-08- Lee	
13.00 - 17:00	Registration 15:00-17:00	Lunch and Beach	Lunch and Beach		Lunch and Beach	
17:00 - 17:15	Review Lectures **Myers** **Wolverson** **Cibert**	INVITED04 **Gould**	INVITED08 **Kossacki**		INVITED13 **Kang**	
17:15 – 17:30						
17:30 - 17:45		Mo07- Debus			Thu09-Achstein	
17:45 - 18:00		Mo08- Fainblat	Tu09-Pacuski		Thu10-Zhang	
18:00 - 18:15		Mo09-Schwan	Tu10-Ivanov		Thu11-Debus	
18:15 - 18:30		Mo10- Gul				
18:30 - 18:45			Poster Session, Snacks and Beer		Poster Session, Snacks and Beer	
18:45 - 19:00						
19:00 - 19:15		Welcome Cocktail				
19:15 - 19:30						
19:30 - 19:45						
19:45 - 20:00						
20:00 - 20:15						
20:15 - 20:30						
20:30 - 21:00					Conference Banquet	
21:00		Social and cultural events				

II-VI 2011

15th Intl. Conference on II-VI Compounds

Mayan Riviera - Mexico
August 21 - 26, 2011

SUNDAY 21

15:00 - 17:00		**REGISTRATION**	
	REVIEW LECTURES		
Presentation	**Presenter**	**Title/*Authors***	**Notes**
Sun-RL01 Sunday 17:00-17:40	**Tom Myers** *Texas State University* *USA*	**Properties and applications of HgCdTe** *Thomas H. Myers*	**Review Lecture**
Sun-RL02 Sunday 17:40-18:20	**Daniel Wolverson** *University of Bath* *UK*	**Magneto-optical properties of II-VI semiconductors** *Daniel Wolverson*	**Review Lecture**
Sun-RL03 Sunday 18:20-19:00	**Joel Cibert** *Institut Néel -CNRS- Univ. Joseph Fourier* *France*	**History and development of II-VI magnetic semiconductor heterostructures** *Joel Cibert, Lucien Besombes, David Ferrand and Henri Mariette*	**Review Lecture**

MONDAY 22

08:00 - 09:00		**REGISTRATION**	
09:00 - 09:30		**OPENING SESSION**	
Mon-Inv01 Monday 09:30-10:00	**Hironori Katagiri** *Nagaoka National College of Technology* *Japan*	**Thin film CZTS solar cells: Research for sustainable PV expansion** *H. Katagiri*	**Invited**
Mon-Inv02 Monday 10:00-10:30	**Alexander L. Efros** *Naval Research Laboratory* *USA*	**Suppression of blinking in semiconductor nanocrystals** *Alexander L. Efros*	**Invited**
10:30 - 11:00		**COFFEE BREAK**	
Mon-Inv03 Monday 11:00-11:30	**Benjamin A. Piot** *Grenoble High Magnetic Field Laboratory* *France*	**High quality 2D electron gas in CdTe quantum well for the physics of quantum Hall effect***B.A. Piot, J. Kunc, K. Kowalik, F.J. Teran, P. Plochocka, D.K. Maude, M. Potemski, C. Betthausen, A. Vogl, D. Weiss, G. Karczewski, T. Wojtowicz*	**Invited**
Mo-01 Monday 11:30-11:45	**Aidong Shen** *The City College of New York* *USA*	**Growth and properties of CdSe/MgSe multiple quantum wells** *A. Shen and M.C. Tamargo*	
Mo-02 Monday 11:45-12:00	**Alexey Toropov** *Ioffe Physical Technical Institute of Russian Academy of Sciences* *Russia*	**Excitonic spectrum of ZnO/ZnMgO quantum wells** *A. A. Toropov, M. A. Bobrov, T. V. Shubina, S. V. Ivanov, A. El-Shaer, A. Bakin, A. Waag, G. Pozina, J. P. Bergman and B. Monemar*	
Mo-03 Monday 12:00-12:15	**Marko Stölzel** *Universität Leipzig* *Germany*	**Luminescence redshift of polar (Mg,Zn)O/ZnO quantum wells: Separating the role of Stokes shift and quantum-confined Stark effect** *M. Stölzel, M. Brandt, A. Müller, G. Benndorf, M. Lorenz, and M. Grundmann*	
Mo-04 Monday	**Moritz Seyfried** *University of Bremen*	**Weak and strong coupling in ZnSe-based monolithic microcavities**	

12:15-12:30	*Germany*	*M. Seyfried, A. Trichet, M. Richard, Le Si Dang, S. Klembt, C. Kruse, D. Hommel and K. Sebald*	
Mo-05 Monday 12:30-12:45	**Richard T. Moug** *The City College of New York* *USA*	**MBE Growth and design of II-VI heterostructures for epitaxial lift-off** *I.A. Davidson, R.T. Moug, E. C. Vallance, M. C. Tamargo and K.A. Prior*	
Mo-06 Monday 12:45-13:00	**Isaac Hernández-Calderón** *Physics Department – Cinvestav* *Mexico*	**Exciton confinement in ultra-thin CdSe quantum wells** *I. Hernández-Calderón, J. A. Lorenzo-Andrade, A. Alfaro-Martínez*	
13:00 - 17:00		**LUNCH**	
Mon-Inv04 Monday 17:00-17:30	**Charles Gould** *University of Würzburg* *Germany*	**Magnetic resonant tunneling devices (RTDs): from spin-valves to single electron transistors** *C. Gould, M. Rüth, R.G. Dengel, D.L. Supp, A. Slobodskyy, T. Slobodskyy, A. Frey, G. Schmidt, K. Brunner, L.W. Molenkamp.*	**Invited**
Mo-07 Monday 17:30-17:45	**Jörg Debus** *TU Dortmund University* *Germany*	**Dynamical control of Mn spin system cooling by photogenerated carriers in a (Zn,Mn)Se/BeTe heterostructure** *J. Debus, A. A. Maksimov, D. Dunker, D. R. Yakovlev, I. I. Tartakovskii, A. Waag, M. Bayer*	
Mo-08 Monday 17:45-18:00	**Rachel Fainblat** *University Duisburg-Essen* *Germany*	**Time-resolved and magneto-optical spectroscopy on Mn2+-doped CdSe nanoribbons** *R. Fainblat, J. Frohleiks, J. H. Yu, T. Hyeon, G. Bacher*	
Mo-09 Monday 18:00-18:15	**Alexander Schwan** *TU Dortmund University* *Germany*	**Long-lived electron and hole spin coherence in ZnSe–based quantum wells***E.A. Zhukov, A. Schwan, D.R. Yakovlev, M.Glazov, A.Waag, M. Bayer*	
Mo-10 Monday 18:15-18:30	**Rubi Gul** *Brookhaven National Laboratory* *USA*	**DLTS measurements of point defects in Cd1-xZnxTe, Cd1-xMnxTe and Cd1-xMgxTe gamma-ray detectors***R. Gul, A. E. Bolotnikov, K. Kim, G. S. Camarda, Y. Cui, A. Hossain, G. Yang, J. Franc and R. B. James*	
19:00 - 20:30		**WELCOME COCKTAIL**	
TUESDAY 23			
08:00 - 09:00		**REGISTRATION**	
Tue-Inv05 Tuesday 09:00-09:30	**Yong-Hang Zhang** *Arizona State University* *USA*	**6.1 Å II-VI and III-V materials: A platform for photovoltaic and IR device applications** *Y.H. Zhang*	**Invited**
Tu-01 Tuesday 09:30-09:45	**Jessica Chai** *Texas State University* *USA*	**Growth of lattice-matched CdSeTe and ZnTeSe alloys on (100) and (211)B GaSb** *J. Chai, K.-K. Lee, K. Doyle, W. Priyantha, J.H. Dinan, T.H. Myers*	
Tu-02 Tuesday 09:45-10:00	**Jin Fan** *Arizona State University* *USA*	**ZnTe/GaSb/ZnTe double-heterostructure for optoelectronic devices** *J. Fan, B. C. Green, X. Liu, D. Ding, J. K. Furdyna and Y.H. Zhang*	
Tu-03 Tuesday 10:00-10:15	**Lionel Gérard** *Institut Néel, CNRS* *France*	**II-VI nanostructures, with type-II band alignment, for photovoltaics** *R. André, E. Bellet-Amalric, L. Besombes, J. Bleuse, C. Bougerol, M. Den Hertog, L. Gérard, H. Mariette and R. Najjar*	
Tu-04 Tuesday 10:15-10:30	**M. J. DiNezza** *Arizona State University* *USA*	**Aluminum diffusion in ZnTe films grown on GaSb substrates for n-type doping** *M. J. DiNezza, X. Liu, Q. Zhang, D. Ding, J. Fan, J. K. Furdyna, Y.-H. Zhang*	

10:30 - 11:00		**COFFEE BREAK**	
Tue-Inv06 Tuesday 11:00-11:30	**Gregory Brill** *U.S. Army Research Laboratory* *USA*	**Hg-based II-VI compounds on non-standard substrates** *G. Brill, Y. Chen, P. Wijewarnasuriya, and N. Dhar*	**Invited**
Tu-05 Tuesday 11:30-11:45	**Kevin Doyle** *Texas State University* *USA*	**Optical and electrical properties of mercury cadmium selenide** *K. Doyle, G. Brill, J. Chai, K. Lee, J. Dinan, T. Myers*	
Tu-06 Tuesday 11:45-12:00	**Kazuhito Yasuda** *Nagoya Institute of Technology* *Japan*	**Fabrication of radiation imaging detector arrays using MOVPE grown thick single crystal CdTe layers on Si substrate** *K. Yasuda, M. Niraula, T. Tachi, N. Fujimura, H. Inuzuka, T. Kondo, S. Namba, S. Muramatsu, and Y. Agata*	
Tu-07 Tuesday 12:00-12:15	**Anne M. Itsuno** *University of Michigan* *USA*	**Experimental progress on HgCdTe LWIR unipolar nBn device** *A.M. Itsuno, J.D. Phillips, S. Velicu*	
Tu-08 Tuesday 12:15-12:30	**Ishwara Bhat** *Rensselaer Polytechnic Institute* *USA*	**Metalorganic vapor phase epitaxial growth of (211)B CdTe on nanopatterned (211)Si** *Shashidhar Shintri, Sunil Rao, Charles D. Schaper, Wendy L. Sarney, Sudhir Trivedi, Priyalal Wijewarnasuriya and Ishwara Bhat*	
Tue-Inv07 Tuesday 12:30-13:00	**Maxime Richard** *Institut Néel, CNRS University J. Fourier* *France*	**Physics of 1-dimensional exciton-polaritons in ZnO microwires** *A. Trichet, F. Médard, G. Pavlovic, N. Gippius, G. Malpuech, Z. Chen, M. Richard, Le Si Dang*	**Invited**
13:00 - 17:00		**LUNCH**	
Tue-Inv08 Tuesday 17:00-17:45	**Piotr Kossacki** *University of Warsaw* *Poland*	**Single dot spectroscopy of CdTe based self organized system** *Piotr Kossacki*	**Invited Special session devoted to Jan Gaj**
Tu-09 Tuesday 17:45-18:00	**Wojciech Pacuski** *University of Warsaw* *Poland*	**Magnetooptical study of excitons in (Zn,Mn)O** *W. Pacuski, J. Suffczyński, P. Osewski, P. Kossacki, A. Golnik, C. Deparis, C. Morhain, E. Chikoidze, Y. Dumont, D. Ferrand, J. Cibert and T. Dietl*	
Tu-10 Tuesday 18:00-18:15	**Sergey Ivanov** *Ioffe Physical Technical Institute* *Russia*	**Heterovalent AlSb/InAs/(Zn,Mn)Te quantum wells with two-dimensional electron channel: MBE growth and spin polarized photocurrents** *S.V. Ivanov, G.V. Klimko, V.V. Bel'kov, Ya.V. Terentyev, I.V. Sedova, A.N. Semenov, V.A. Solov'ev, C. Drexler, P. Olbrich, C. Zoth, V. Lechner and S.D. Ganichev*	
18:30 - 20:30		**POSTER SESSION**	
WEDNESDAY 24			
08:00 - 09:00		**REGISTRATION**	
Wed-Inv09 Wednesday 09:00-09:30	**Edith Bellet-Amalric** *CEA-CNRS* *France*	**II-VI Nanowires as optical emitters** *E. Bellet-Amalric, M. Elouneg-Jamroz, S. Bounouar, M. Den Hertog, C. Bougerol, R. André, Y. Genuist, J.P. Poizat, K. Kheng, and S. Tatarenko*	**Invited**
We-01 Wednesday 09:30-09:45	**Le Si Dang** *CNRS–Université Joseph Fourier,* *France*	**Carrier depletion and exciton diffusion in single ZnO nanowires** *J-S Hwang, F. Donatini, J. Pernot, Le Si Dang, R. Thierry and P. Ferret*	

We-02 Wednesday 09:45-10:00	**Piotr Wojnar** *Polish Academy of Sciences* *Poland*	**Near band edge emission of Te-based nanowire heterostructures** *P. Wojnar, E. Janik, S. Kret, E. Dynowska, L.T. Baczewski, G. Karczewski, T. Wojtowicz*	
We-03 Wednesday 10:00-10:15	**Samir Bounouar** *Institut Néel – CNRS – UJF* *France*	**Room temperature single photon source** *S. Bounouar, M. Elouneg-Jamroz, C. Morchutt, E. Bellet-Amalric, M. den Hertog, R. André, K. Kheng, S. Tatarenko and J.P. Poizat*	
We-04 Wednesday 10:15-10:30	**Tilmar Kümmell** *Universität Duisburg-Essen* *Germany*	**Room temperature single photon emission from a self-organized quantum dot** *T. Kümmell, O. Fedorych, C. Kruse, D. Hommel, G. Bacher*	
11:00		**EXCURSION**	
THURSDAY 25			
08:00 - 09:00		**REGISTRATION**	
Thu-Inv10 Thursday 09:00-09:30	**Shigehisa Tanaka** *Hitachi Ltd., Central Research Lab.* *Japan*	**Room-temperature CW operation of BeZnCdSe green laser diode** *S. Tanaka, S. Fujisaki, J. Kasai, R.Akimoto, T. Hasama, S. Tsuji, H. Ishikawa*	**Invited**
Thu-01 Thursday 09:30-09:45	**Xue Chu Shen** *Fudan University* *China*	**Room temperature degenerate four wave mixing driven by a one-dimensional ZnO polariton laser** *W. Xie, X. C. Shen, and Z. H. Chen*	
Thu-02 Thursday 09:45-10:00	**Sebastian Klembt** *University of Bremen* *Germany*	**Blue monolithic vertical-cavity surface emitter lasing at 444 nm** *S. Klembt, C. Kruse, M. Seyfried, K. Sebald, J. Gutowski and D. Hommel*	
Thu-03 Thursday 10:00-10:15	**Sergey V. Ivanov** *Ioffe Physical Technical Institute* *Russia*	**Structural and optical optimization of ZnSe-based laser heterostructures with graded index waveguide** *S.V. Gronin, I.V. Sedova, S.V. Sorokin, G.V. Klimko, K.G. Belyaev, A.V. Lebedev, A.A. Sitnikova, A.A. Toropov, and S.V. Ivanov*	
Thu-04 Thursday 10:15-10:30	**Sergey Sorokin** *Ioffe Physical Technical Institute of RAS* *Russia*	**Violet-green injection laser converters with pulse output power above 150 mW** *S.V. Sorokin, I.V. Sedova, S.V. Gronin, G.V. Klimko, S.V. Ivanov, E.V. Lutsenko, A.G. Vainilovich, G.P. Yablonskii*	
10:30 - 11:00		**COFFEE BREAK**	
Thu-Inv11 Thursday 11:00-11:30	**Shizuo Fujita** *Kyoto University* *Japan*	**Growth, characterization, and device applications of various oxide semiconductors** *S. Fujita, K. Kaneko, T. Oshima, H. Ito, T. Ikenoue, and T. Igawa*	**Invited**
Thu-05 Thursday 11:30-11:45	**Yutaka Furubayashi** *Shimane University* *Japan*	**Controllability of Mg substitution for ZnMgO films by using MOCVD under moderate conditions** *Y. Furubayashi, Y. Deguchi, N. Nishimoto and Y. Fujita*	
Thu-06 Thursday 11:45-12:00	**Tomasz A. Krajewski** *Polish Academy of Sciences* *Poland*	**Origin of the n-type conductivity in low temperature ZnO thin films** *T. A. Krajewski, G. Luka, K. Dybko, L. Wachnicki, B. S. Witkowski, P. Nowakowski, A. Suchocki, R. Jakiela, E. Lusakowska, M. Godlewski, E. Guziewicz*	
Thu-Inv12 Thursday 12:00-12:30	**Andrey Bakin** *IST - TU Braunschweig* *Germany*	**Oxide semiconductors for photovoltaic applications** *A. Bakin, A. Wagner, A. Behrends, A. Waag*	**Invited**
Thu-07	**Tatiana Shubina**	**Distortion of slow light pulses by excitons in ZnO** *T. V. Shubina, A. A. Toropov, M. M. Glazov, N. A. Gippius, P.*	

Thursday 12:30-12:45	*Ioffe Institute RAS* *Russia*	*Disseix, J. Leymarie, D. Lagarde, G. Pozina, J. P. Bergman, and B. Monemar*	
Thu-08 Thursday 12:45-13:00	**Kyoung-Keun Lee** *Texas State University* *USA*	**Xray photoelectron spectroscopy study of oxide removal using atomic hydrogen for large-area II-VI material growth** *K. Lee, K. Doyle, J. Chai, P. Weerasinghe, J. Dinan, T. Myers*	
13:00 - 17:00		**LUNCH**	
Thu-Inv13 Thursday 17:00-17:30	**Tae Won Kang** *Dongguk University* *South Korea*	**Physics and application of nanorods of II-VI compound semiconductors** *T. W. Kang, S. J. Lee, H. C. Jeon*	**Invited**
Thu-09 Thursday 17:30-17:45	**Alexander A. Achstein** *Technical University of Berlin* *Germany*	**Optical properties of colloidal CdSe nanoplatelets** *A. W. Achtstein, A. Schliwa, M. Artemyev, U. Woggon*	**Late News Session**
Thu-10 Thursday 17:45-18:00	**Yong Zhang** *Univ. Of North Carolina at Charlotte* *USA*	**Time-resolved photoluminescence study of interfacial transitions in ZnO/ZnSe type II core/shell nanowires** *Y. Zhang, J. Bleuse, H. Mariette, Z. Wu, J. Zheng, X. Lin, H. Zhan, S. Li, J. Kang*	**Late News Session**
Thu-11 Thursday 18:00-18:15	**Joerg Debus** *Dortmund University* *Germany*	**Variety of exchange interactions providing spin-flip Raman scattering in CdTe/(Cd,Mg)Te quantum wells** *J. Debus, D. Dunker, V. F. Sapega, D. R. Yakovlev, G. Karczewski, T. Wojtowicz, M. Bayer*	**Late News Session**
18:30 - 20:30		**POSTER SESSION**	
20:45 - 23:00		**CONFERENCE BANQUET**	
FRIDAY 26			
08:00 - 09:00		**REGISTRATION**	
Fri-Inv14 Friday 09:00-09:30	**Jean Michel Chauveau** *CRHEA-CNRES* *France*	**Homoepitaxial growth and properties of non polar (Zn,Mg)O/ZnO quantum wells** *J.-M. Chauveau , M. Teisseire, C. Morhain, H. Chauveau, C. Deparis, B. Vinter*	**Invited**
Fr-01 Friday 09:30-09:45	**Igor Kuskovsky** *City College of CUNY* *USA*	**The role of Mg in controlling the hole confinement energy in ZnTe/ZnSe based quantum dot structure grown by migration enhanced epitaxy** *U. Manna, Q. Zhang, M. C. Tamargo, I. C. Noyan, I. F. Salakhutdinov, G. F. Neumark, I. L. Kuskovsky*	
Fr-02 Friday 09:45-10:00	**Mathieu Fregnaux** *Université Paul Verlaine Metz* *France*	**Size and quality control of fast grown CdS quantum dots** *M. Fregnaux, S. Dalmasso, J.-J. Gaumet, J.-P. Laurenti*	
Fr-03 Friday 10:00-10:15	**Carsten Kruse** *University of Bremen* *Germany*	**ZnTe-based micropillars containing CdTe quantum dots** *C. Kruse, W. Pacuski, T. Jakubczyk, M. Florian, K. Frank, T. Kazimierczuk, A. Golnik, J.A. Gaj, F. Jahnke, A. Rosenauer, and D. Hommel*	
Fr-04 Friday 10:15-10:30	**Łukasz Kłopotowski** *Polish Academy of Sciences* *Poland*	**Charge control and storage in self-assembled CdTe quantum dots** *Ł. Kłopotowski, M. Goryca, V. Voliotis, K. Fronc, P. Wojnar, P. Kossacki, R. Grousson, G. Karczewski, T. Wojtowicz*	
10:30 - 11:00		**CLOSING SESSION**	
POSTER SESSION TUESDAY 23			
Tu-P01 Tuesday 18:30-20:30	**Alexei Toropov** *Ioffe Institute RAS* *Russia*	**Spin injection in heterovalent structure with coupled quantum wells GaAs/AlGaAs/ZnMnSe/ZnSe** *V. Kh. Kaibyshev, A. A. Toropov, F. Liaci, Ya. V. Terent'ev, M. S. Mukhin, G. V. Klimko, S. V. Gronin, I.V. Sedova, S.V. Sorokin and S.V. Ivanov*	

Tu-P02 Tuesday 18:30-20:30	**Takami Abe** *Iwate University* *Japan*	**Epitaxial growth of high-quality MgxZn1-xO films by a plasma-assisted reactive evaporation method using ZnMg alloys as a source material** *T. Abe, A. Nakagawa, M. Tanaka, M. Nakagawa, H. Endo, K. Meguro, Y. Kashiwaba, S. Chiba, T. Ojima, K. Aota, S. Takahashi, M. Daibo, H. Osada, T. Fujiwara, I. Niikura and Y. Kashiwaba*	
Tu-P03 Tuesday 18:30-20:30	**Richard Moug** *City College New York* *USA*	**Selective etching of InGaAs/InP substrates from II-VI multilayered structures** *R. Moug, L. Peng, T. Garcia, H. Sultana, A. Shen and M. Tamargo*	
Tu-P04 Tuesday 18:30-20:30	**Katsuhiko Saito** *Saga University* *Japan*	**Influence of dopant transport rate upon photoluminescence and electrical properties of phosphorus-doped ZnMgTe layers grown by MOVPE** *K. Saito, T. Saeki, T. Tanaka, Q.X. Guo, M. Nishio*	
Tu-P05 Tuesday 18:30-20:30	**Sergey Sorokin** *Ioffe Physical Technical Institute* *Russia*	**Laser characteristics of heterostructures with multiple CdSe QD sheet active region and asymmetric graded index superlattice waveguide** *E. V. Lutsenko, I. V. Sedova, A. G. Vainilovich, N. P. Tarasuk, G. P. Yablonskii, S. V. Sorokin, S. V. Gronin, P. S. Kop'ev, S. V. Ivanov*	
Tu-P06 Tuesday 18:30-20:30	**Wolfram Heimbrodt** *University of Marburg* *Germany*	**Colloidal CdSe/ZnS quantum dots for bionanosensing applications** *S. Friede, T. Niebling, Z. Ali, F. Amin, F. Zhang, W.J. Parak, and W. Heimbrodt*	
Tu-P07 Tuesday 18:30-20:30	**Lyudmiyla Borkovska** *NAS of Ukraine* *Ukraine*	**Modification by thermal annealing of the luminescent characteristics of CdSe quantum dots in gelatin films** *L. V. Borkovska, N. O. Korsunska, T. R. Stara, V. M. Dzhagan, T. G. Kryshtab, O.L. Stroyuk, O. Ye. Raevska*	
Tu-P08 Tuesday 18:30-20:30	**Mohammad Sohel** *CUNY Hostos College* *USA*	**X-Ray photoelectron spectroscopy of white light emitting magic sized CdSe nanocrystals** *M. Sohel, M. C. Tamargo, L. Peng , S. J. Rosenthal*	
Tu-P09 Tuesday 18:30-20:30	**Patricia Rodríguez** *Cinvestav* *Mexico*	**Effect on the optical properties of CdS nanoparticles synthesized with different capping agents** *P. Rodriguez-Fragoso, Y. E. Bravo-Garcia, G. Gonzalez de la Cruz, J. Mendoza-Alvarez, J. Santoyo-Salazar and O. Zelaya-Angel*	
Tu-P10 Tuesday 18:30-20:30	**H. P. Hsu** *National Taiwan University of Science and Technology* *Taiwan*	**Raman scattering characterization of Zn1-x-yBexMgySe crystalline alloys** *D. Dumcenco, S. Levcenco, Y. S. Huang, H. P. Hsu, F. Firszt, K. K. Tiong*	
Tu-P11 Tuesday 18:30-20:30	**Ying Sheng Huang** *National Taiwan University of Science and Technology* *Taiwan*	**Optical characterization of Zn0.35Cd0.44Mg0.21Se crystalline alloy by polarization-dependent contactless electroreflectance measurements** *D. Dumcenco, S. Levcenco, Y. S. Huang, H. P. Hsu, F. Firszt, K. K. Tiong*	
Tu-P12 Tuesday 18:30-20:30	**Gerado Villa-Martínez** *Physics Department - Cinvestav* *Mexico*	**Estimation of the density of electrical carriers of n-ZnSe by photoreflectance spectroscopy** *G. Villa-Martínez, F. Sutara, I. Hernández-Calderón*	
Tu-P13 Tuesday 18:30-20:30	**Yusuke Inagaki** *Tottori University* *Japan*	**New ultraviolet avalanche photodiodes (APDs) of organic (PEDOT:PSS) – inorganic (ZnSSe) hybrid structure** *Y. Inagaki, M. Ebisu, M. Ohtsuki, N.Ayuni, T.Shimizu, T. Abe, H. Kasada, and K. Ando*	
Tu-P14	**Alexander A. Achstein**	**Geometry dependence of two photon absorption in CdS dots**	

Tuesday 18:30-20:30	*Technical University of Berlin* *Germany*	**and rods** *A.W. Achtstein, J. Hennig, M. Artemyev, U. Woggon*	
Tu-P15 Tuesday 18:30-20:30	**Hervé Boukari** *Institut Néel, CNRS &* *Université Joseph Fourier* *France*	**Emission of exciton and emission of exciton and biexciton dressed states in a CdTe quantum dot** *A. Brunetti, C. Le Gall, H. Boukari and L. Besombes*	
Tu-P16 Tuesday 18:30-20:30	**Wolfram Heimbrodt** *University of Marburg* *Germany*	**Band bowing in ZnSexTe1-x and ZnSxTe1-x alloys** *T. Bertram, C. Karcher, H. Klaer, S. Klembt, C. Kruse, D. Hommel and W. Heimbrodt*	
Tu-P17 Tuesday 18:30-20:30	**Vladimir Litvinov** *Ryazan State* *Radioengineering University* *Russia*	**A local study of the energy spectrum of electrons in CdSe/ZnSe QD structures by current DLTS and AFM** *V.G. Litvinov, V.I. Kozlovsky, Yu.G. Sadofyev, N.B. Rybin*	
Tu-P18 Tuesday 18:30-20:30	**Wojciech Pacuski** *University of Warsaw* *Poland*	**Three-dimensional anisotropy studies of CdTe quantum dots** *J. Kobak, W. Pacuski, T. Kazimierczuk, J. Suffczyński, T. Jakubczyk, A. Golnik, P. Kossacki, M. Nawrocki, J.A. Gaj, C. Kruse, D. Hommel*	
Tu-P19 Tuesday 18:30-20:30	**Muranaka Tsutomu** *University of Yamanashi* *Japan*	**Exciton transfer between ZnCdMnSe and ZnCdSe quantum wells** *M. Hishikawa, S. Fukasawa, F. Iwasaki, K. Omori, K. Kodama, T. Muranaka, Y. Nabetani, T. Matsumoto*	
Tu-P20 Tuesday 18:30-20:30	**Ivan-Christophe Robin** *CEA LETI MINATEC* *France*	**Photoluminescence studies of CdS layers for solar cells** *F. Gemain, I. C. Robin, S. Renet, S. Bernardi*	
Tu-P21 Tuesday 18:30-20:30	**David A. Valverde-Chávez** *Physics Department -* *Cinvestav* *Mexico*	**Spectral photoresponse of ZnSe/GaAs heterostuctures with ultra-thin CdSe quantum well insertions** *D. A. Valverde-Chávez, I. Hernández-Calderón*	
Tu-P22 Tuesday 18:30-20:30	**Kunio Ichino** *Tottori University* *Japan*	**Lattice relaxation of ZnS grown on GaP investigated by high-resolution X-Ray diffraction and transmission electron microscopy** *K. Ichino, A. Nishigaki, and A. Yamauchi*	
Tu-P23 Tuesday 18:30-20:30	**Tetyana Kryshtab** *IPN* *Mexico*	**Infrared radiation detection by a piezoelectric heterostructure at room temperature** *T. Kryshtab, V. Deriglazov, R. Savkina, F. Sizov, A. Smirnov, M. Kladkevich, V. Samojlov*	
Tu-P24 Tuesday 18:30-20:30	**Seung Joo Lee** *Quantum-functional* *Semiconductor Research* *Center* *Korea*	**Study of the origin of weak ferromagnetism in Zn1-xCoxO** *Sh. U. Yuldashev, H. C. Jeon , Y. H. Kwon, S. J. Lee, T. W. Kang, and Kh. T. Igamberdiev*	
Tu-P25 Tuesday 18:30-20:30	**K. Sato** *Tottori University* *Japan*	**Stark effects of ZnO thin films and ZnO/ZnMgO quantum wells** *K. Sato, T. Abe, R. Fujinuma, K. Yasuda, T. Yamaguchi, H. Kasada, and K. Ando*	
Tu-P26 Tuesday 18:30-20:30	**Anna Baranowska-Korczyc** *Institute of Physics PAS* *Poland*	**Field effect transistors based on ZnO and core/shell ZnO/ZnS nanofibers** *A. Baranowska-Korczyc, K. Fronc, B. Sikora, I. Kamińska, A. Reszka, K. Sobczak, Ł. Kłopotowski, K. Dybko, W. Paszkowicz, P. Dłużewski, B.J. Kowalski, D. Elbaum*	
Tu-P27 Tuesday 18:30-20:30	**Enrique Josué Chan y Díaz** *CIMAV* *Mexico*	**Transparent conducting Al-doped ZnO thin films grown by Nd:YAG Pulsed-Laser Deposition** *E. Chan y Díaz, J. Arjona-Várguez, A. Duarte-Moller, R. Castro-Rodríguez*	

Tu-P28 Tuesday 18:30-20:30	**Branka Hadžić** *Inst. of Physics, Belgrade University* *Serbia*	**Raman scattering from ZnO doped with CoO nanoparticles** *B. Hadžić, N. Romčević, M. Romčević, I. Kuryliszyn-Kudelska, W. Dobrowolski, U. Narkiewicz and D. Sibera*	
Tu-P29 Tuesday 18:30-20:30	**Toshiki Kawase** *Osaka City University* *Japan*	**Active-layer-thickness dependence of Rabi splitting energies in ZnO microcavities** *T. Kawase, D. Kim, M. Nakayama*	
Tu-P30 Tuesday 18:30-20:30	**V. I. Kushnirenko** *NAS of Ukraine* *Ukraine*	**Luminescent properties of Ag-, Ga-doped ZnO and ZnO–ZnS thin films** *V.I. Kushnirenko, V.S. Khomchenko, L.V. Zavyalova, L.V. Borkovska*	
Tu-P31 Tuesday 18:30-20:30	**Yoichi Nabetani** *University of Yamanashi* *Japan*	**MOVPE growth of ZnO using Zn-MOPD and Zn-TD as Zn source** *Y. Nabetani, T. Kobayashi, M. Kato, T. Muranaka, T. Kato, and T. Matsumoto*	
Tu-P32 Tuesday 18:30-20:30	**Aidong Shen** *City College New York* *USA*	**Plasma-assisted MBE growth of ZnO on GaAs substrate with a ZnSe buffer layer** *Kuaile Zhao, M.C. Tamargo and A. Shen*	
Tu-P33 Tuesday 18:30-20:30	**Stephen Babalola** *Alabama A&M University* *USA*	**Study of metal contact properties of CdZnTe-based nuclear detector by the interfacial layer-thermionic-diffusion (ITD) model** *Stephen Babalola, Aleksey Bolotnikov, Giuseppe Camarda, Godwin Iboyitie, Trent Montgomery*	
POSTER SESSION THURSDAY 25			
Thu-LNP01 Thursday 18:30-20:30	**Toshiyuki Kawaharamura** *Koichi University of Technology* *Japan*	**Study on the behavior of mist droplets and the mechanism in the mist Chemical Vapor Deposition** *T. Kawaharamura, S. Fujita, and T. Hirao*	**Late News Poster**
Thu-P01 Thursday 18:30-20:30	**Ishwara Bhat** *Rensselaer Polytechnic Institute* *USA*	**Blanket and patterned growth of CdTe on (211) Si substrates by metalorganic vapor phase epitaxy** *S. R. Rao, S. S. Shintri, J. K. Markunas, R. N. Jacobs and I. B. Bhat*	
Thu-P02 Thursday 18:30-20:30	**Tsutomu Muranaka** *University of Yamanashi* *Japan*	**Fabrication and characterization of size-controlled ZnSe nanostructures grown by selective MBE on mesa-patterned GaAs(001) substrates** *T. Muranaka, S. Iizuka, K. Sugimoto, S. Hada, Y. Nabetani, T. Matsumoto*	
Thu-P03 Thursday 18:30-20:30	**Katsuhiko Saito** *Saga University* *Japan*	**Influence of source transport rate upon phosphorus doping in ZnTe layer grown by MOVPE** *M. Nishio, X. Han, K. Saito, T. Tanaka, Q.X. Guo*	
Thu-P04 Thursday 18:30-20:30	**Qiang Zhang** *Arizona State University* *USA*	**Influence of Te/Zn flux ratio on doping in ZnTe grown by MBE on GaSb substrates** *Q. Zhang, X. Liu, M. J. DiNezza, W. H. Dettlaff, J. Fan, D. Ding, K. Furdyna, Y.-H. Zhang*	
Thu-P05 Thursday 18:30-20:30	**Frantisek Sutara** *Physics Department - Cinvestav* *Mexico*	**Influence of the composition profile in the excitonic emission of thin graded ZnCdSe quantum wells** *F. Sutara, I. Hernández-Calderón*	
Thu-P07 Thursday 18:30-20:30	**Alexey Shakhmin** *Ioffe Physical Technical Institute* *Russia*	**Cathodoluminiscence of ZnSe-based II-VI green laser heterostructures** *A.A. Shakhmin, I.V. Sedova, S.V. Sorokin, M.V. Zamoryanskaya*	

Thu-P08 Thursday 18:30-20:30	**Koshi Ando** *Tottori University* *Japan*	**Degradation mechanism and Current-Pulse-Width control in II-VI and III-N compound blue-UV - white LEDs** *Y. Harada , K. Ando , S. Nakagawa, H. Sakamoto, S. Saiful, T. Kaga, T. Abe, and H. Kasada*	
Thu-P09 Thursday 18:30-20:30	**Gerado González de la Cruz** *Cinvestav* *Mexico*	**Synthesis of CdSe nanoparticles immersed in an organic matrix of amylopectin by means of r.f. sputtering** *E. Campos-González, P. Rodríguez-Fragoso, G. Gonzalez de la Cruz, J. Santoyo-Salazar, O. Zelaya-Angel*	
Thu-P10 Thursday 18:30-20:30	**Augustinas Galeckas** *University of Oslo* *Norway*	**Time-resolved spectroscopy of carrier dynamics in graded ZnCdxO multilayer structures** *M. Trunk, V. Venkatachalapathy, T.C. Zhang, A. Azarov, A. Galeckas, A. Kuznetsov*	
Thu-P11 Thursday 18:30-20:30	**Robert Gerten** *Universitaet des Saarlandes* *Germany*	**Profiling unusual diffusion by scanning photoluminescence** *R. Gerten, F. Strauß, H. Wolf, M. Deicher, Th. Wichert*	
Thu-P12 Thursday 18:30-20:30	**Yoichi Nabetani** *University of Yamanashi* *Japan*	**Structural and optical characters of ZnTeO alloys grown by MBE** *Y. Nabetani, K. Hiramatsu, N. Saegusa, T. Suzuki, D. Yoshinaga, T. Muranaka, T. Kato, and T. Matsumoto*	
Thu-P13 Thursday 18:30-20:30	**Frank Peiris** *Kenyon College* *USA*	**Exploring the dielectric functions of MBE-grown GaMnAs using temperature-dependent spectroscopic ellipsometry** *F. C. Peiris, Z. J. Weber, N. Mandal, X. Liu and J. K. Furdyna*	
Thu-P14 Thursday 18:30-20:30	**Christine Chory** *Carl von Ossietzky University Oldenburg* *Germany*	**Synthesis and characterization of novel organically linked II-VI semiconductor nanoparticles** *Ch. Chory, C. Feser, I. Riedel, J. Parisi*	
Thu-P15 Thursday 18:30-20:30	**Hervé Boukari** *Institut Néel, CNRS & Université Joseph Fourier* *France*	**Optical Stark effect and dressed excitonic states in Mn-doped CdTe quantum dots** *C. Le Gall, A. Brunetti, H. Boukari and L. Besombes*	
Thu-P16 Thursday 18:30-20:30	**Hervé Boukari** *Institut Néel, CNRS & Université Joseph Fourier* *France*	**Electron-nuclear spin dynamics in CdTe quantum dots** *C. Le Gall, A. Brunetti, H. Boukari and L. Besombes*	
Thu-P17 Thursday 18:30-20:30	**David Ferrand** *CNRS-CEA* *France*	**Magnetic polarons in (Cd,Mn)Te/(Zn,Mg)Te single magnetic quantum dots** *P. Stepanov, D. Ferrand, H. Boukari, H. Mariette and J. Cibert*	
Thu-P18 Thursday 18:30-20:30	**Lyudmiyla Borkovska** *NAS of Ukraine* *Ukraine*	**Study of thermal stability of CdSe/ZnSe quantum dot heterostructures** *L.V. Borkovska, N.O. Korsunska, V.I. Kushnirenko, T.R. Stara, T.G. Kryshtab*	
Thu-P19 Thursday 18:30-20:30	**Edyta Piskorska-Hommel** *University of Bremen* *Germany*	**The structural characterization of the CdSe/ZnSe quantum dots using x-ray spectroscopic methods** *E. Piskorska-Hommel, V. Holý, O. Caha, A. Gust, C. Kruse, J. Falta, and D. Hommel*	
Thu-P20 Thursday 18:30-20:30	**Adrián Alfaro-Martínez** *Physics Department - Cinvestav* *Mexico*	**Photoluminescence study of the peak splitting of the excitonic emission of CdSe fractional monolayer quantum dots** *A. Alfaro-Martínez, M. García-Rocha, I. Hernández-Calderón*	
Thu-P21 Thursday 18:30-20:30	**C. Rice** *University of Bath* *United Kingdom*	**Investigation of exchange interactions between excitons and magnetic ions as a function of translational wavevector in Cd1-xMnxTe quantum wells** *C. Rice, L. C. Smith, J. J. Davies, D. Wolverson, M. Wiater, G. Karczewski and T. Wojtowicz*	

Thu-P22 Thursday 18:30-20:30	**C. Rice** *University of Bath* *United Kingdom*	**Towards spin-charge texture in magnetic semiconductors** *C. Rice, D. Wolverson, A. Moskalenko, S. J. Bending, G.Karczewski, T.Wojtowicz*	
Thu-P23 Thursday 18:30-20:30	**Adán López-Rivera** *University of Los Andes* *Venezuela*	**Neutron diffraction research of crystal lattice local nanodistortions in diluted magnetic semiconductors $Zn_{1-x}Co_xS$ and $Zn_{1-x}Co_xSe$** *T.P. Surkova, S.F. Dubinin, V.I. Maximov, S.A. Lopez-Rivera*	
Thu-P24 Thursday 18:30-20:30	**Masakazu Kobayashi** *Waseda University* *Japan*	**X-ray pole figure analysis of ZnTe layers grown on lattice mismatched substrates** *M.Kobayashi, Y. Kumagai, T.Baba, and S.Imada*	
Thu-P25 Thursday 18:30-20:30	**Takayuki Maejima** *Tottori University* *Japan*	**Local-strain induced structural-instability of nitrogen acceptor and its influence on p-type conduction-control in homo-epitaxially grown ZnO by MBE** *T. Maejima, K. Ando, K. Katoh, M. Takazaki, R. Natsume, T. Masamoto, T. Matsuo, A. Akiyama, T. Ohno, K. Fujino, H. Nakamura, Y. Yamazaki, J. Yoshikawa, T. Abe, and H. Kasada*	
Thu-P26 Thursday 18:30-20:30	**Shen Xuechu** *Fudan University* *China*	**The observation of strong coupling between exciton and photon in ZnO whispering gallery cavity at high temperature and its tuning** *S. F. Zhang, H. X. Dong, L. X. Sun, W. Xie, X. C. Shen, Z. H. Chen*	
Thu-P27 Thursday 18:30-20:30	**Elzbieta Guziewicz** *Institute of Physics, Polish Academy of Sciences* *Poland*	**Study of stoichiometry of ZnO films grown at low temperature** *E. Guziewicz, A. Stonert, R.A. Wilhelm, W. Lisowski, M. Krawczyk, J.W. Sobczak, A. Jablonski, L. Wachnicki, T.A. Krajewski, G. Luka, B.S. Witkowski, R. Jakiela, M. Godlewski*	
Thu-P28 Thursday 18:30-20:30	**Wolfram Heimbrodt** *University of Marburg* *Germany*	**Optical properties of the inorganic-organic hybrid: pentacene on ZnO** *J. Helzel, S. Jankowski, M. El Helou, G. Witte, and W. Heimbrodt.*	
Thu-P29 Thursday 18:30-20:30	**Tsutomu Muranaka** *University of Yamanashi* *Japan*	**Nitrogen doping on ZnO films grown by plasma-assisted MBE and its effects to the transport properties of TFTs** *T. Muranaka, Y. Ushiyama, N. Marumo, T. Horii, S. Sano, K. Mizuguchi, Y. Sakurai, Y. Nabetani, T. Matsumoto*	
Thu-P30 Thursday 18:30-20:30	**Jean Michel Chauveau** *CNRS-CRHEA* *France*	**Influence of crystal orientation on nitrogen incorporation in high quality ZnO films** *D. Tainoff, J.-M. Chauveau, C. Deparis, B. Vinter, M. AlKhalfioui, M. Teisseire, Christian Morhain*	
Thu-P31 Thursday 18:30-20:30	**Hideo Takeuchi** *The University of Shiga Prefecture* *Japan*	**Circular polariscopic analysis of a ZnO wafer for highly sensitive and speedy evalua-tion of residual strains: Its relation with x-ray diffraction pattern and topography** *Hideo Takeuchi*	
Thu-P32 Thursday 18:30-20:30	**N. Korsunska** *Institute of semiconductor physics of NASU* *Ukraine*	**The influence of annealing on structural and luminescence characteristics of ZnS:Cu** *Yu. Yu. Bacherikov, N. Korsunska, V. Kladko, N. Baran, A. Kuchuk, A. Zhuk, T. Kryshtab*	

All posters will be exhibited from Tuesday to Thursday.

Sun-RL01
Sunday 17:00-17:40

Properties and applications of HgCdTe

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Since its introduction in the early 1970s, HgCdTe has been the preferred detector material of the global infrared (IR) industry. HgCdTe has proven to be a versatile material, being nearly lattice-matched over its composition, covering wavelength ranges from < 2 μμ το > 15 υμ, and allowing the production of sophisticated device architectures. The unfortunate lack of a large area lattice-matched substrate has hampered the commercialization of HgCdTe, and has led to a large body of work on heteroepitaxy growth on Si, Ge, and GaAs, among other substrates. This review will cover the basic properties of HgCdTe, present a brief comparison to "competitor" materials, provide a discussion of the types of device architectures possible, discuss heteroepitaxial growth, and explore potential routes to other Hg-based II-VI materials.

Sun-RL02
Sunday 17:40-18:20

Magneto-optics of II-VI semiconductors

Daniel Wolverson[+]
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A brief tutorial introduction to spin-dependent optical processes in semiconductors will be given, indicating how magnetic fields may be used in optical experiments to probe a range of semiconductor phenomena. This will focus more on the fundamental physics than on details of any particular experimental techniques, but the basic elements of experimental systems will be mentioned briefly.
Examples drawn from the literature and from the author's own work will then be used to illustrate the application of specific magneto-optical techniques to II-VI semiconductor systems; techniques will include magneto-photoluminescence and magneto-reflectivity, spin-flip Raman scattering, and spin quantum beats, and the systems discussed will include bulk semiconductors, quantum wells and quantum dots. There will be a brief mention of coherent techniques (for example, involving microwave as well as optical fields).
This talk will conclude with brief remarks on future perspectives and in particular those offered by the dilute magnetic semiconductors, which are the subject of the following talk.

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Sun-RL03
Sunday 18:20-19:00

History and development of II-VI magnetic semiconductor heterostructures

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This lecture aims at bringing some basic knowledge about diluted magnetic semiconductor heterostructures which appear in several presentations of this conference.
Diluted magnetic semiconductors are a good example of the interest of studying non-mainstream semiconductors such as the II-VI's. It has been known since the end of the 1970's that substituting Mn into bulk II-VI semiconductors gives rise to exceptional magneto-optical properties, due to a dramatic spin-dependent shift of the bands (the "giant Zeeman effect"). Heterostructures – first, quantum wells – appeared later, essentially thanks to molecular beam epitaxy. The most studied systems are based on CdTe and to a lesser extent ZnSe. The case of the wider bandgap II-VI's, including the oxides, rises practical difficulties (of growth first, but also due to the radiative transfer to excitations within the d-shell of Mn) and it reveals a different, less intuitive behavior of the spin-carrier coupling.
Magneto-optical spectroscopy has been the principal tool, with a special emphasis put on using the giant Zeeman effect as an adjustable parameter to address a broad range of subjects pertinent to any semiconductor heterostructure (from the morphology of the interface to electronic properties), as well as on studying specific features such as the formation of the magnetic polaron.
Modulation doping opened new avenues, such as carrier induced ferromagnetism, new configurations for the two-dimensional electron gas and its excitations, and transport properties. Also, a wider range of nanostructures is now available, with quantum dots (including the extreme case of a single magnetic impurity, and resonant tunneling diodes) and even quantum wires.

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1. J. Cibert, L. Besombes, D. Ferrand, and H. Mariette, in “Spintronics”, edited by Tomasz Dietl, David Awschalom, Maria Kaminska and Hideo Ohno, Volume 82 of Semiconductors and Semimetals, Elsevier (2008)

Mon-Inv01
Monday 09:30-10:00

Thin film CZTS solar cells: research for sustainable PV expansion

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Cu_2ZnSnS_4 (CZTS) is one of the promising materials for low cost thin film solar cells, because of a suitable band gap energy around 1.5 eV, and the large absorption coefficient over 10^4 cm^{-1}**.** CZTS is fabricated by substituting the half of the rare metal indium with zinc and the other half with tin in $CuInS_2$ system. All constituents of this film are abundant on the crust of the earth, and they are not toxic. In 1996, we reported a fabrication process of CZTS films by sulfurization of E-B evaporated precursors. We formed a new type of thin film solar cells having the structure of SLG/Mo/CZTS/CdS/ZnO:Al/Al and achieved the conversion efficiency of 0.66 % for the first time. Conversion efficiency was gradually increased by the modification of the fabrication process. This consists of the optimization of the back contact and the window layer as well as the development of the high quality CZTS absorber. In order to produce the high quality CZTS absorber, the stacking order of precursor was investigated. Then, using the multi-period precursor, we fabricated the CZTS absorber with preferable morphology. From theses results, we confirmed that the film morphology had large influence to the conversion efficiency as well as the composition ratio. After that, we introduced the 3-phased co-sputtering system with annealing chamber. Nowadays, the conversion efficiency increased to over 6.7 % [1] by optimizing many and many parameters in this system. Quite recently, using CZTS compound target, we achieved over 6.4 % efficiency with CZTS films prepared by the single sputtering followed by sulfurization.

In this presentation, we will survey the development of CZTS-based thin film solar cells achieved in our laboratory and show the latest related topics.

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1. H. Katagiri, K. Jimbo, S. Yamada, T. Kamimura, W.S. Maw, T. Fukano, T. Ito and T. Motohiro: *Appl. Phys. Express* **1**, 041201 (2008).

Mon-Inv02
Monday 10:00-10:30

Suppression of blinking in semiconductor nanocrystals

Alexander L. Efros
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Colloidal nanocrystals randomly turn their photoluminescence (PL) "off" and "on" under continuous light illumination, despite intensive research efforts aimed at suppressing this phenomenon. Today there is a consensus that the blinking is caused by extra electrons or holes that repeatedly charge, and then neutralize, the NC. When a charged NC is excited by a photon the additional energy is not re-emitted as PL, but instead triggers a process known as "non-radiative Auger recombination" during which this energy is acquired by an extra electron or hole. The rate of Auger recombination is orders of magnitude faster than the rate of radiative recombination that produces PL in neutral NCs. As a result, PL is completely suppressed, or "quenched," in charged NCs.

Recently, the soft-confinement (CdZnSe/ZnSe) nanocrystals have been grown that show complete absence of single molecule photoluminescence blinking [1]. Other remarkable photophysical properties these nanocrystals exhibit include unique multi-peaked photoluminescence spectra, and unusually short photoluminescence lifetimes. These properties are consistent with the novel observation of charged exciton recombination in colloidal nanocrystals, and thus are quite unlike any of the typical nanocrystals currently being studied.

We will explain why Auger processes are so efficient in standard NCs and how they have been recently suppressed in the non-blinking NCs [2].

[1] X. Wang, X. Ren, K. Kahen, M. A. Hahn, M. Rajeswaran, S. Maccagnano-Zacher, J. Silcox, G. E. Cragg, Al. L. Efros, and T. D. Krauss, *Nature* **459**, 686 (2009)
[2] G. E. Cragg and Al. L. Efros, *NanoLetters* **10,** 313 (2010).

Mon-Inv03
Monday 11:00-11:30

High quality 2D electron gas in CdTe quantum well for the physics of quantum hall effect

B.A. Piot[1], J. Kunc[1], K. Kowalik[1], F.J. Teran[1], P. Plochocka[1], D.K. Maude[1], M. Potemski[1,+], C. Betthausen[2], A. Vogl[2], D. Weiss[2], G. Karczewski[3], T. Wojtowicz[3]

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In a quantizing magnetic field, the physics of a two-dimensional electron gas at very low temperatures can be determined by electron-electron interactions which dominate over the single particle physics. This leads to new collective ground states, such as the well-known Fractional Quantum Hall effect, the itinerant quantum Hall ferromagnet, or peculiar spin textures known as Skyrmions…

Until very recently, the observation of subtle many body effects in the quantum Hall regime has exclusively been possible in high purity 2D systems embedded in GaAs or Silicon. In this talk, we will present recent results obtained in high mobility 2D electron gas realized in CdTe quantum wells, including the (many-body) enhancement of the spin gap in fully occupied Landau levels [1], as well as the observation of the Fractional Quantum Hall effect at mK temperatures [2].

The high quality of the 2D electron gas in CdTe offers a promising single valley "model system" to study delicate many-body effects in the presence of a significant Zeeman energy, which can be further modulated by the incorporation of Mn magnetic ions.

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1. J. Kunc, K. Kowalik, F. J. Teran, P. Plochocka, B. A. Piot, D. K. Maude, M. Potemski, V. Kolkovsky, G. Karczewski, and T.Wojtowicz Phys. Rev. B **82**, 115438 (2010)
2. B. A. Piot, J. Kunc, M. Potemski, D. K. Maude, C. Betthausen, A. Vogl, D. Weiss, G. Karczewski, and T. Wojtowicz, Phys. Rev. B **82**, 081307 (R) (2010)

Mo-01
Monday 11:30-11:45

Growth and properties of CdSe/MgSe multiple quantum wells

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One approach to realizing ultrafast switching operation is to utilize ultrafast carrier relaxation in intersubband (ISB) transitions in semiconductor low-dimensional quantum structures, such as quantum wells (QWs). The intrinsic ultra-short excited carrier lifetime in QWs is further enhanced in II-VI semiconductors by the higher ionicity and thereby stronger electron-phonon interaction. We have shown that ZnCdMgSe-based II-VI quantum structures lattice-matched to InP are good candidates for ISB devices working in the short wavelength infrared (IR) range and demonstrated the electroluminescence in the mid-IR range from ZnCdMgSe-based quantum cascade structures [1,2]. The short wavelength reach of an ISB device is limited by the conduction band offset (CBO) in the QWs. For ZnCdMgSe-based quantum structures lattice-matched to InP, the largest CBO is 1.12 eV [3], which could facilitate ISB transition down to about 1.8 μm. To further extend the device operation to the telecommunication wavelength region, material system with even larger CBO must be used. Considering that less than 60% of the CBO can be used for ISB transition, a QW system with a CBO of at least 1.35 eV must be employed to achieve operation at 1.55 μm, which is essential for applications in optical communications. CdSe/MgSe QWs are materials that can provide such a large CBO. We report here the growth of the CdSe/MgSe multiple QWs by molecular beam epitaxy (MBE).

The growth was performed in a dual chamber Riber MBE system. 40 periods of CdSe/MgSe QWs were grown on InP substrates with thin ZnCdSe and InGaAs buffers. Although MgSe prefers rocksalt crystal structure and a 3% lattice mismatch exists between MgSe and CdSe, no phase separation occurred and the growth proceeded through a two-dimensional growth, as indicated by a streaky RHEED pattern throughout the growth. The structural and optical properties of the samples were characterized by x-ray diffraction and photoluminescence measurements. Detailed characterization results will be presented at the conference.

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Mo-02
Monday 11:45-12:00

Excitonic spectrum of ZnO/ZnMgO quantum wells

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ZnO/ZnMgO quantum wells (QW) are promising heterostructures for designing ultraviolet light-emitting devices. Besides, optical spectroscopy of excitons in the QW structures can be a powerful tool for accurate determination of important fundamental parameters, such as effective masses of electrons and holes, band offsets, spontaneous and piezoelectric polarization, as well as parameters of electron-hole exchange interaction. The knowledge of these factors in the ZnO/ZnMgO system has been rather poor yet. Especially disadvantageous is the lack of precise data relevant to the effective masses of carriers in split valence bands (A, B, and C). Nevertheless, the reproducible fabrication of high-quality ZnO/ZnMgO QWs allowing observation of distinct narrow excitonic lines has yet been a challenge. A relatively poor quality of the currently fabricated ZnO/ZnMgO QW structures is caused by a low solubility limit of rocksalt MgO into a wurtzite ZnO lattice matrix, which results in strong fluctuations and lateral inhomogeneity of the Mg composition in $Zn_{1-x}Mg_xO$ barrier layers. As a consequence, the excitonic spectrum recorded in the QW structures suffers from strong inhomogeneous broadening that prevents resolving any fine excitonic structure.

In this work we focus on fabrication and optical studies of high-quality ZnO/ZnMgO QW structures demonstrating distinct excitonic resonances involving transitions between quantum-confined levels of electrons and A- and B- holes. The series of structures containing a single ZnO/ZnMgO QW were grown on Al_2O_3 by radical source molecular beam epitaxy. An optimized sequence of MgO and ZnO buffer layers was deposited at different temperatures prior to growing the QW structure in order to accommodate lattice mismatch and ensure fabrication of atomically-flat interfaces. The width of the QW varies in different structures between 2 and 4.5 nm, and the Mg concentration in the ZnMgO barriers was kept below the solubility limit (<15%). Time-resolved photoluminescence (PL) spectroscopy was employed to identify the observed PL bands as the emission of localized excitons in the ZnO/ZnMgO QW and ZnMgO barriers, as well as of impurity-bound excitons in different buffer layers. Furthermore, PL excitation (PLE) spectra were obtained by detecting PL intensity within the emission band of the QW excitons and varying the quantum energy of the exciting light across the region of the QW exciton resonances. As a result, the resonance energies and relative intensities are obtained for a number of excitonic resonances observed in the QW of different width. By comparing experimental results with a variational calculation of excitonic energies and oscillator strengths, we attribute the peaks in the PLE spectra as excitonic transitions involving first and second levels of both A- and B- holes and one or two levels of electrons, depending on the QW width. The data fitting provides a consistent set of parameters, including effective masses of A- and B- holes in ZnO, intrinsic electric fields within the QW, and strength of the electron-hole exchange interaction.

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Mo-03
Monday 12:00-12:15

Luminescence redshift of polar (Mg,Zn)O/ZnO quantum wells: Separating the role of Stokes shift and quantum-confined Stark effect

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The luminescence properties of polar quantum wells (QWs) are determined besides confinement effects by a red-shift caused by the Stokes shift and the quantum-confined Stark effect (QCSE). For the first time we separate these two effects, by analyzing recombination for polar QW structures with and without a distinct QCSE.

The c-oriented (Mg,Zn)O/ZnO QWs have been grown by pulsed laser deposition (PLD) on a-plane sapphire and ZnO substrates. Series of samples differing in well width and Mg content in the barrier layers have been systematically investigated. A low laser fluence applied to the target in the PLD process leads to smooth interfaces, while for increasing fluence an intermixing of the layers at the QW interfaces and therefore a diminishing of the QCSE is observed [1].

The samples have been investigated by transmission measurements and time-integrated and time-resolved photoluminescence. Samples without influences of the QCSE emit clearly above the free exciton transition energy in bulk ZnO due to confinement effects. The emission of QWs showing a distinct QCSE is red-shifted by up to 250 meV due the change in the potential landscape in the presence of an internal electric field, generated by the different polarization of ZnO and (Mg,Zn)O. The dynamics of the QW luminescence also shows clear differences. The decay changes from a single exponential decay and decay times of about 400 ps for QWs without a distinct QCSE to a stretched-exponential decay function and average decay times of up to microseconds for the QWs influenced by the internal electric fields. The field can be evaluated in dependence on the Mg-content in the barrier layers. Transmission measurements allow the determination of the Stokes shift which varies from 24 to 64 meV for QW widths ranging from 4 to 1.25 nm. For QWs with a distinct QCSE temperature dependent measurements show that the Stokes shift is overestimated at low temperatures as the absorption maximum is not influenced, while the QW luminescence is red-shifted by the electric field.

In addition, the red-shift caused by the QCSE allows to observe the transition of the luminescence spectrum from QW to bulk material. For a wedge-shaped QW (with laterally varying thickness) the QW luminescence decreases and the bulk donor-bound exciton transition increases for increasing well width.

This work is supported by the European Social Fund (ESF) and the Graduate School BuildMoNa.

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Mo-04
Monday 12:15-12:30

Weak and strong coupling in ZnSe-based monolithic microcavities

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ZnSe-based microcavities (MCs) are particularly well suited for the investigation of photon-exciton coupling in semiconductors under high excitation due to the large screening density in this material system. The strong exciton-photon coupling and the large exciton binding energy are advantageous for achieving a large Rabi-splitting energy which increases with the number of quantum wells (QWs) as active material. This should make investigations of the strong coupling regime at elevated temperatures posssible. In this contribution we will present results on the optical properties of monolithic MCs containing three or 16 QWs in order to perform experiments in the weak and strong coupling regime. The QWs are located at the antinode position of a λ (2λ in case of 16 QWs) cavity and sandwiched in between two distributed Bragg reflectors. To allow for the variation of the detuning δ between the cavity photon and exciton energies in the strong coupling regime the corresponding sample has been intentionally grown with a cavity thickness gradient along the wafer. From both samples cylindrically shaped micropillars with various diameters were prepared by focused ion beam milling. The samples were characterized by photoluminescence and reflectivity measurements. The Bragg oscillations, the cavity resonance as well as the spectral position of the lower and upper polariton can nicely be reproduced by theoretical calculations. By taking reflectivity spectra at different sample positions thus yielding $\delta<0$, $\delta=0$, and $\delta>0$ situations, one observes an anticrossing behavior of the lower and upper polariton resonance energies, with a large Rabi splitting energy of ~40 meV. At zero detuning the planar sample shows a clear indication for a polariton lasing threshold associated with a distinct narrowing in k-space and spectral distribution of the polariton dispersion with increasing excitation density (measurements performed at T=7 K). For larger negative detunings no threshold-like behavior could be observed. This is in coincidence with a polariton relaxation becoming less with increasing detuning as indicated by the pronounced scattering of polaritons to higher k values with increasing excitation densities. The influence of the lateral confinement on the optical properties in the pillar MCs is investigated for both types of sample configurations. For the weak coupling regime, besides the occurrence of discrete resonator modes a reduction of the photonic laser threshold with reduced mode volume was observed. In the strong coupling regime, the lateral optical confinement results in the formation of discrete polariton states. Indications for the softening of the k-conservation were found which may result in a more effective polariton condensation in optimized structures and in polariton lasing at elevated temperatures.

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Mo-05
Monday 12:30-12:45

MBE growth and design of II-VI heterostructures for epitaxial lift-off

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II-VI semiconductor devices are typically grown on commercially available III-V substrates, which have bandgaps far smaller than the epitaxial II-VI layers. This is inconvenient for many experiments and applications, especially those that require the transmission of light through the epitaxial layers [1]. However, by introducing a sacrificial layer into the structure it is then possible to perform post growth processing to remove the epitaxial layers and transfer them to a different substrate. This has many advantages as it allows the new substrate to be selected without consideration as to its suitable for semiconductor growth.

We have previously demonstrated that MgS can successfully be used as a sacrificial layer in epitaxial liftoff for II-VI heterostructures lattice matched to GaAs [1,2]. To date, we have demonstrated that after lift-off epitaxial layers can be transferred onto glass, fused silica, and lithium niobate [1-4] and we believe that this could be extended to almost any substrate material so long as it is chemically compatible with the material being deposited. Additionally, we have also shown that it is possible to construct high Q micro-cavities by depositing material directly onto dielectric mirrors [5,6].

In contrast to MgS, the other magnesium chalcogenides do not dissolve in HCl. MgSe will react and form selenium, an insoluble product which inhibits etching. Here, we report for the first time success in adapting the lift-off technique to use MgSe as a sacrificial layer for heterostructures lattice matched to InP. Samples consisting of 100-150nm $Zn_{0.54}Cd_{0.46}Se$/Xnm MgSe/100-150nm $Zn_{0.54}Cd_{0.46}Se$, where X is between 3-10nm, have been grown at CUNY by MBE on an lattice matched InGaAs buffer on InP wafer [7] and subsequently etched at Heriot-Watt. Small samples up to 5mm square have been successfully lifted.

In this paper we will discuss the effectiveness of a range of different solution strengths and the preliminary characterisation of the lifted layers.

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Mo-06
Monday 12:45-13:00

Exciton confinement in ultra-thin CdSe quantum wells

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CdSe quantum wells (QWs) with thickness of a few monolayers have been the subject of many studies for long time [1-4]. They have been grown employing different epitaxial methods, the interest on these systems ranges from the knowledge of the properties of the single quantum wells and $(ZnSe)_m(CdSe)_n$ superlattices to the elaboration of digital alloys. Heterostructures based on submonolayer CdSe coverages have also been studied for many years [5, 6]. By using atomic layer epitaxy (ALE) we have shown that with CdTe and CdSe ultra-thin quantum wells (UTQWs), with thickness in the 1 to 4 ML range, most of the red-blue spectral region can be covered. We found that the emission of the CdSe UTQWs can be tuned by changing the substrate temperature due to the Cd substitution by Zn atoms during the epitaxial growth, this results in an alloyed ZnCdSe UTQW [7]. Photoluminescence experiments indicate a single excitonic peak, with absence of thickness fluctuations, the temperature dependence indicate the presence of potential fluctuations due to small (around 1 – 2 %) composition inhomogeneities. A self-homogenization of the CdSe/ZnSe interface is demonstrated by the growth of UTQWs finished with fractional MLs, only a single peak is observed [8]. These UTQWs present an interesting peculiarity, a decrease of the full width at half maximum (FWHM) of the excitonic peak as the CdSe coverage is reduced. This can be explained mainly in terms of alloy broadening, strain effects and composition fluctuations. However, confinement effects play also an important role. By studying the degree of confinement of the excitons (in terms of the electron and hole confinement) a contribution to that behavior can be clearly described. The results are also relevant for the design of heterostructures containing multiple UTQWs, since the thickness of the barrier to uncouple (or couple) them depends on the well thickness.

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Mon-Inv04
Monday 17:00-17:30

Magnetic resonant tunneling devices (RTDs): From spin-valves to single electron transistors

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In this talk, I will review a series of recent results revolving around all-II-VI magnetic semiconductor based resonant tunneling structures. First I will show that while bulk (Zn,Mn)Se is paramagnetic, bound magnetic polaron states which form in the vicinity of potential fluctuations at quantum wellinterfaces induce microscopic magnetic order which lifts the degeneracy of the spin-split resonant tunneling states. Although there is no macroscopic magnetization, the resulting resonant tunneling current is highly spin polarized at zero magnetic field due to the zero field splitting. Detailed modeling demonstrates that the local spin polarization efficiency exceeds 90% without an external magnetic field.

Our model proves that a correct treatment of contact resistance effects is essential to capturing even the essence of the properties of real devices. The data also suggests that while it is tempting to neglect effects of the emitter layers in a magnetic field due to their small (bulk) Zeeman splitting, the emitter states are important for the device properties and a feedback mechanism enhancing the magnitude of emitter effects is in place.

I will then go on to show how, making use of the same model, we can quantitatively describe the function of a full spin valve comprised of two of these RTDs in series. Finally, I will show how miniaturization of such an RTD device, fitted with a proper gate, leads to the realization of a 3-terminal single electron transistor.

Mo-07
Monday 17:30-17:45

Dynamical control of Mn spin system cooling by photogenerated carriers in a (Zn,Mn)Se/BeTe heterostructure

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The magnetization dynamics of the Mn spin system in an undoped $Zn_{0.99}Mn_{0.01}Se$/BeTe quantum well with a type-II band alignment was studied by a time-resolved pump-probe photoluminescence technique. The Mn spin temperature was evaluated from the excitonic giant Zeeman shift in an external magnetic field of 3 T. The relaxation dynamics of the Mn spin temperature to the equilibrium temperature of the lattice after the pump-laser-pulse heating can be accelerated by the presence of free electrons. These electrons, generated by a control laser pulse, mediate the spin- and energy-transfer from the Mn spin system to the lattice and bypass the relatively slow direct spin-lattice relaxation of the Mn ions (hundreds of μs) [1].

In the past years the dynamical magnetic properties of diluted magnetic semiconductors resulting from spin-spin and spin-lattice relaxation mechanisms have been intensively investigated, e.g., the spin diffusion in heteromagnetic semiconductor structures has been reported [2]. An additional channel for spin- and energy-transfer from the Mn spin system into the lattice is provided by free electrons, which can be considerably more efficient than the direct spin-lattice relaxation channels. The electron concentration can be varied in time domain by, e.g., short and intense laser pulses, as it has been realized in (Zn,Mn)Se/(Zn,Be)Se quantum wells with a type-I band alignment. However, due to the short recombination time of the photogenerated carriers in these structures of about 100 ps it was not possible to reach the condition of the cold carrier system and to clearly detect the effect of the carrier-assisted cooling of the Mn spin system by photogenerated carriers.

Here, we report on the dynamically controllable acceleration of spin-lattice relaxation, leading to a cooling of the Mn spin system, by generation of photocarriers in a $Zn_{0.99}Mn_{0.01}Se$/BeTe heterostructure with a type-II band alignment. The cooling effect of the Mn ions can be attributed to the spatial separation of the thermalized electrons and holes in the $Zn_{0.99}Mn_{0.01}Se$ and BeTe layers, respectively. This results in very long radiative recombination times of about 100 ns for photocreated electrons. The relaxation process of the Mn spin system can be accelerated on the nanosecond time scale by optical tuning of the electron concentration in the $Zn_{0.99}Mn_{0.01}Se$ layers and by the temporal application of the impact pulse.

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Mo-08
Monday 17:45-18:00

Time-resolved and magneto-optical spectroscopy on Mn^{2+}-doped CdSe nanoribbons

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Future spintronic and spin-photonics technologies will require a portfolio of techniques for manipulating spins in semiconductor nanostructures. One key ingredient is the magnetic exchange interaction between magnetic ions embedded in the semiconductor with the electronic states of the host material. This interaction is expected to increase with quantum confinement. Chemical routes represent a quite flexible approach for the synthesis of nanomaterials with size- and shape-controlled quantum confinement. Recently, we demonstrated that three-dimensional quantum confinement drastically enhances the carrier exchange field in Mn^{2+}-doped CdSe nanocrystals. Optical excitation results in a 2-step dynamic formation of an ordered spin complex with signatures of laser-induced magnetization up to room temperature [1].
Here, we concentrate on time-resolved and magneto-optical studies on low dimensional Mn^{2+}-doped CdSe quantum-well nanoribbons. The quantum-well structured nanoribbons (thickness ~1.4 nm, width 50 nm, length 1~2 μm) have been prepared by a solution-phase chemical approach, where an efficient incorporation of manganese up to 10 % is achieved by a nucleation controlled doping process [2]. The absorption spectrum is dominated by two pronouced resonance peaks related to the heavy hole-(hh) and the light hole (lh)-exciton transition with an energy controlled by the strong quantum confinement due to the extremely small thickness of the nanoribbons.Exciting the nanoribbons resonant to the absorption peaks with a picosecond laser pulse results in a Stokes-shifted photoluminescence emission composed of both the internal Mn^{2+} transition and near bandgap emission. For the latter, a transient energy shift of about 45 meV is observed within 650 ps which is independent on the excitation energy. This is related to an energy transfer process within the nanoribbons and/or between the nanoribbons within the stack. Most interesting, we are able to detect a clear magnetic circular dichrosium (MCD) signal for both absorption resonances indicating an efficient incorporation of magnetic ions into CdSe nanoribbons. For the hh-exciton transition, a Giant Zeeman splitting is observed with a low field g gfactor of up to 600 [2]. A sign reversal of the MCD signal is found between the hh- and the lh-exciton resonances, which we relate to the specific spin structure of the involved exciton states.

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Mo-09
Monday 18:00-18:15

Long-lived electron and hole spin coherence in ZnSe–based quantum wells

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Coherent spin dynamics of electrons and holes have been studied by a picosecond pump&probe Kerr rotation technique in ZnSe-based quantum well (QW) structures with a binary material of QW. Samples with low-density two-dimensional electron and hole gas have been choosen. Long-living spin coherence both of holes (≈1ns) and electrons (up to 32 ns) was observed at low temperatures when the resident carriers are localized by potential fluctuations induced by QW width variations. Two sets of samples were have been examined: (1) structures with ZnSe/$Zn_{0.82}Be_{0.08}Mg_{0.10}Se$ single QW (thickness varying from 7 to 19 nm) surrounded by an additional $Zn_{0.71}Be_{0.11}Mg_{0.18}Se$ barriers were nominally undoped having concentration of resident electrons (2DEG) of $5x10^9 cm^{-2}$; (2) structure containing ZnSe/$Zn_{0.89}Mg_{0.11}S_{0.18}Se_{0.82}$ single QW with concentration of two dimensional hole gas (2DHG) of $3x10^{10}$ cm^{-2}. The time-resolved pump-probe Kerr rotation technique with selective excitation of the trion or exciton states was used to study the coherent spin dynamics of the electrons and holes. Experiments were performed in magnetic fields 0–5 T applied in the plane of the structure (the Voigt geometry). The sample temperature was tuned in a range 1.8–270 K. The long-lived electron spin beats with dephasing time up to 32 ns at 1.8K have observed in the structure with 2DEG under resonant trion excitation. In case of the resonant excitation of the exciton (detection at trion resonance) the maximum dephasing time was 21ns. The oscillations of Kerr rotation signal have apparent up to room temperature. The spin dephasing rate increases linearly with temperature in the temperature range 10 - 170K. It means that Dyakonov-Perel spin relaxation mechanism on k-linear spin splitting of the conduction band dominates for these temperatures. The observed decrease of the zero-field peak in the signal of the resonant spin amplification relatively to the other peaks we assign to the anisotropic spin relaxation of electrons at high levels of excitation. The long-lived hole spin beats with dephasing time ≈1ns (T=1.8K and B=0.5T) have observed in the structure with 2DHG. The electron spin beats with fast spin relaxation time ≈10 ps have observed simultaneously with hole spin beats at magnetic field B≈3T. An additional above-barrier illumination leads to appearance of long-lived electron spin beats, while the amplitude of the hole beats was decreasing.

Mo-10
Monday 18:15-18:30

DLTS Measurements of point defects in $Cd_{1-x}Zn_xTe$, $Cd_{1-x}Mn_xTe$ and $Cd_{1-x}Mg_xTe$ Gamma-ray detectors

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The growth of cadmium zinc telluride (CZT) crystals from the melt successfully yields semi-insulating material, suitable for high-efficiency and high-performance room-temperature radiation detectors. To achieve high resistivity material, dopants are typically added during the crystal growth for electrical compensation. It is observed that the added dopant(s) causes some new point defects that can act as traps for charge carriers. These defects play a role as trapping- and recombination-centers, and hence contribute towards the degradation of the detector by lowering the average lifetime of the charge carriers. To ensure high performance and good efficiency for II-VI radiation detectors such as CZT, these defects must be minimized. In most cases the first step involves identification of their nature and origin through electrical measurements. In this research, we report the defects observed in doped $Cd_{1-x}Zn_xTe$, $Cd_{1-x}Mn_xTe$ and $Cd_{1-x}Mg_xTe$ crystals via the current-mode deep level transient spectroscopy (I-DLTS) technique. The results are found to depend on the material and the type of dopant added for compensation.

Tue-Inv05
Tuesday 09:00-09:30

6.1 Å II-VI and III-V materials: A platform for photovoltaic and IR device applications

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Semiconductor materials and devices have experienced very rapid development in the past more than half a century. However, there still remains a lack of closely lattice-matched materials and substrates suitable for the grand integration of various kinds of optoelectronic devices such as photovoltaic, IR light emitting and imaging devices on a single chip. We have recently proposed a new material platform: the 6.1 Å II-VI (HgMgZnCd)(SeTe) and III-V (AlGaIn)(PAsSb) semiconductor materials lattice-matched to GaSb and InAs substrates [1-5]. These materials have direct bandgaps covering a very broad energy spectrum from far IR (~0 eV) to UV (~3.4 eV). This feature is not achievable by any other known lattice-matched semiconductors on any commercially available substrates. Such a unique material platform enables new light emitting devices, multi-junction solar cells, multi-color photodetectors and FPAs, and facilitates monolithic integration of various materials without misfit dislocations to ensure the best quality for device applications. This talk will focus on the latest progress of the MBE growth of the materials and their potential device applications to ultra-high efficiency solar cells and IR photodetectors.

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Tu-01
Tuesday 09:30-09:45

Growth of lattice-matched CdSeTe and ZnTeSe alloys on (100) and (211)B GaSb

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There has been a resurgence of interest in the growth of II–VI materials that are lattice-matched to 6.1 A III–V substrates such as GaSb and InAs.[1] A variety of II–VI materials such as CdSe, ZnTe and HgSe are nearly lattice-matched to the 6.1 A III–V substrates. Thus, epitaxial layers grown on those substrates are expected have a low-density of misfit dislocations. With the advent of high quality, large area GaSb and InAs, this approach would enable the growth of high quality large area II-VI layers with a broad spectrum of band gaps and other properties, leading to uses as solar cell or infrared detector materials, for example.

To date, work has consisted primarily of growth of the binary compounds CdSe or ZnTe on these III-V substrates. However, in order to achieve the lowest defect densities in thick layers (beyond the critical thickness), better lattice matching must be achieved. This can be done by starting with CdSe and adding small amounts of Te, or ZnTe and adding small amounts of Se to form lattice-matched ternaries. Cd,Zn:SeTe quaternary compounds would also achieve this goal. It is not clear which of these alloys would be the best lattice-matched substrate. Prior work on lattice-mismatched Cd,Zn:SeTe alloys indicate that surface morphology and defect content depends on alloy composition, with not all ternary or quaternaries of equal lattice constant being equivalent.[2]

In this presentation we will present the results of growth of CdTeSe and ZnTeSe on both (100) and (211)B GaAs. Atomic force microscopy, high resolution x-ray diffraction, defect etch microscopy and other characterizations will be presented for lattice-matched alloys grown on both orientations.

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Tu-02
Tuesday 09:45-10:00

ZnTe/GaSb/ZnTe double-heterostructure for optoelectronic devices

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Recently a new materials platform consisting of 6.1 Å semiconductors grown on GaSb and InAs substrates was proposed for optoelectronic devices [1,2]. This materials platform contains both II-VI (MgZnCdHg)(SeTe) and III-V (InGaAl)(AsSb) compound semiconductors, which have direct bandgaps spanning the entire energy spectrum from far-IR (~0 eV) up to UV (~3.4 eV). The broad range of bandgaps and material properties of this platform make it very attractive in a wide range of applications in optoelectronics, such as photodetectors, solar cells, laser diodes, and light emitting diodes. Among the possible unique devices based on this 6.1 Å materials platform, we propose here a novel ZnTe/GaSb/ZnTe double-heterostructure for use in light-emitting devices.

The semiconductors ZnTe and GaSb are very well lattice-matched with a lattice mismatch of only 0.13%. Consistently with this, a very low density of misfit dislocations is found to be generated in their epitaxial growth [2]. Additionally, the ZnTe/GaSb type-I band-edge alignment provides good carrier confinement of both electrons and holes, which is critical to the performance of high-efficiency light emitting devices. Furthermore, the large difference in refractive index between ZnTe and GaSb (2.7 and 3.9, respectively at 0.7eV [3]) leads to improved optical confinement of the guided optical modes in semiconductor lasers. For example in mid-IR Sb-based lasers, calculations reveal increases of the optical confinement factor ranging from 20% to 100% depending on the waveguide core thickness, when lattice-matched ZnTe replaces conventional $Al_xGa_{1-x}As_ySb_{1-y}$ cladding layers. A corresponding reduction in the laser threshold is expected with even greater improvements in longer-wavelength devices. Key to the realization of such devices is the successful growth of high-quality ZnTe/GaSb/ZnTe heterostructures.

In this paper, we will report our recent experimental study on the MBE growth of a set of the proposed ZnTe/GaSb/ZnTe double-heterostructures and their material properties. High resolution X-ray diffraction (XRD) and photoluminescence (PL) are used to study the structural and optical properties of the grown samples. Pendellösung fringes are clearly observed in XRD patterns, indicating high quality single crystal epitaxial layers with smooth and flat interfaces. Strong PL emission is also observed at low temperatures. It is therefore reasonable to conclude that the proposed ZnTe/GaSb/ZnTe double-heterostructures have great potential for optoelectronic device applications.

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Tu-03
Tuesday 10:00-10:15

II-VI nanostructures, with type-II band alignment, for photovoltaics

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In solar cells, based on direct bandgap semiconductors (GaAs, CdTe, CdSe…) light absorption is very efficient compared to the case of silicon. It is positive for material savings, which is of importance when considering using rare elements, but it is also a favorable condition for electron-hole radiative recombination, shortening of carrier lifetime and of diffusion length... Then, to fully benefit from those materials as absorbers for photovoltaic (PV), it is necessary to get rid of their drawback by designing structures which hinder too large radiative losses. For that purpose, we study nanostructures based on pairs of semiconductors which exhibits the so-called type-II, or staggered, band alignment: the maximum energy of the valence band and the minimum energy of the conduction band are located at opposite sides of the two materials interface. Excitons photo-generated in the vicinity of such an interface are then spontaneously dissociated.

We have mainly focused on the CdSe/ZnTe pair because the CdSe bandgap (1.7eV) is adapted to the solar spectrum and because of their low lattice parameter mismatch. Nevertheless CdSe/ZnTe is not the only option: a type-II configuration is generally achieved with II-VI heterostructures when modulating element VI: additional results on the ZnTe/ZnSe and ZnO/CdSe interfaces will also be discussed.

We have grown, by MBE, different kinds of samples: simple CdSe/ZnTe 2D interfaces, superlattices and core-shell nanowires. We have been working on tellurium surface segregation and on the related lack of abruptness of composition. The formation of alloys may be an issue regarding the optimization of the band structure for PV because the bandgap of the alloys can be well below the bandgap of any of their binary components. The structural properties of the samples were characterized by High Resolution X-ray Diffraction and High-resolution transmission electron microscopy (HR-TEM).

Regarding optical properties, we have measured, by time resolved photoluminescence, the efficiency of the electron-hole separation in type-II superlattices. The measured decay time can be above 100 ns for the interface optical transition, i.e. 3 orders of magnitude slower than the typical PL decay time for the constitutive materials taken separately. This is a direct consequent of the weak overlap of the electron and hole wavefunctions. We have also studied the effect of the CdSe absorber thickness which has to be thinner than the diffusion length to fully benefit from the type-II effect, but kept thick enough to significantly absorb light.

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Tu-04
Tuesday 10:15-10:30

Aluminum diffusion in ZnTe films grown on GaSb substrates for n-type doping

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The major challenge for ZnTe-based p-n junction devices is n-type doping. The highest reported electron concentration is 4×10^{18} cm^{-3} for Al-doped ZnTe grown by MBE on ZnTe substrates [1]. Although we have successfully grown high-quality undoped ZnTe films on less expensive GaSb substrates by MBE [2], we have not been able to grow n-type material using conventional *in situ* Al doping. On the other hand, solid-source thermal diffusion of Al into a p-type ZnTe substrate has been used as an *ex situ* doping method, and green LEDs with a power efficiency of 0.15% at room temperature have been demonstrated [3]. Few Hall effect or resistivity measurement results have been reported for n-type ZnTe doped by thermal diffusion. In this work, the electrical properties of ZnTe grown on GaSb substrates and doped by Al thermal diffusion are investigated.

ZnTe films are grown in a dual-chamber MBE system as explained previously [2]. A thin Al layer is deposited onto the ZnTe film either *in situ* using an effusion cell or *ex situ* using an electron beam evaporator. The Al is diffused into the ZnTe *ex situ* by heating the samples in a tube furnace for up to 5 hours and at temperatures up to 420 °C. The device structure incorporates a p-type ZnTe layer below the diffused region, so a p-n homojunction is created. Current-voltage and electroluminescence measurements are performed to characterize the p-n junction. The Al layer is then removed using a chemical etch. Hall effect, resistivity, and PL measurements are used to characterize the electrical properties and quality of the n-type region. This region is electrically isolated from the conductive GaSb substrate by the ZnTe p-n homojunction, which is necessary for Hall effect and resistivity measurements. The successful characterization of n-type ZnTe films doped by diffusion may give insight into developing *in situ* doping methods that require little or no post-growth processing. If the doping problem can be solved, the ZnTe film grown on GaSb will be promising as a material platform for II-VI based LEDs. These LEDs would utilize a heterostructure design to improve efficiency and would comprise (Mg, Cd)ZnSeTe alloys lattice matched to GaSb. More detailed results will be reported at the conference.

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Tue-Inv06
Tuesday 11:00-11:30

Hg-based II-VI compounds on non-standard substrates

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Hg based II-VI compounds are of interest to the U.S. Army due to their infrared (IR) applications over numerous different wavelength bands. Specifically, $Hg_{1-x}Cd_xTe$ is a direct bandgap, tunable semiconductor that has been fielded in numerous 1st generation high performance systems. However, specifications from next generation systems require even better performance, multicolor, and larger array sizes for increased resolution and target identification. Currently, the Army Research Laboratory (ARL) is studying HgCdTe material grown on alternative substrates in order to achieve a scalable technology for the future. A key aspect of this work is in understanding and mitigating dislocations within the material incorporated due to the extremely large lattice mismatch (19%) between HgCdTe and the scalable substrate of choice, Si. By utilizing thermal cycle annealing (TCA), ARL has demonstrated a consistent and reproducible 10 times reduction in dislocation density with respect to as-grown material. Although, very encouraging, ARL recognizes that there is no guarantee that this technology will ultimately yield focal plane array (FPA) performance that matches that of HgCdTe grown on smaller area, yet lattice-matched substrates. With that in mind, ARL is also pursuing a parallel research course by studying $Hg_{1-x}Cd_xSe$ grown on GaSb substrates. HgCdSe is also a tunable IR detecting material, but has the advantage over HgCdTe that a scalable, commercially available, and lattice-matched substrate already exists, specifically GaSb. By studying II-VI epitaxy on a III-V substrate, we hope to open up a new class of materials suitable for next generation electro-optic applications. ARL's research efforts on both HgCdTe and HgCdSe will be discussed.

Tu-05
Tuesday 11:30-11:45

Optical and electrical properties of mercury cadmium selenide

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Currently, the material of choice for infra-red focal plane arrays (IRFPAs) is mercury cadmium telluride (HgCdTe). However, a fundamental drawback of HgCdTe is the lack of scalable, high quality substrates. The current substrate of choice, cadmium zinc telluride, is not available in large sizes from domestic suppliers, and HgCdTe layers grown on more scalable substrates such as silicon have a large number of dislocations due to lattice mismatch.

Because of these limitations, mercury cadmium selenide (HgCdSe) has been proposed as an alternative. HgCdSe has bandgap tunable across the IR spectrum and is closely lattice matched to bulk substrates such as gallium antimonide (GaSb) and indium arsenide (InAs). GaSb is of particular interest since bulk substrates are available in large sizes from domestic suppliers.

To that end, Texas State University and the Army Research Laboratory have begun studying the growth and properties of HgCdSe. A series of HgCdSe samples have been grown on GaSb and zinc telluride on silicon substrates under varying Cd/Se and Hg/Se flux ratios, as well as different growth temperatures. Layers were characterized through various optical and electrical techniques such as Fourier Transform Infrared Spectroscopy (FTIR), photo-conductance decay (PCD), variable-field Hall (VFH) and quantitative mobility Spectrum Analysis (QMSA). FTIR analysis shows a correlation between the Cd/Se flux ratio and layer composition. Preliminary Hall data shows a trend between growth parameters and carrier concentration with lower n-type carrier concentrations achieved for layers grown at higher temperatures.

Tu-06
Tuesday 11:45-12:00

Fabrication of radiation imaging detector arrays using MOVPE grown thick single crystal CdTe layers on Si substrate

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We report the fabrication of 2-D X-ray, gamma ray imaging detector arrays that possess energy discriminating capabilty using single crystal thick CdTe epitaxial layers grown directly on (211)Si substrates in a metal organic vapor phase epitaxy (MOVPE) system.

Radiation detectors that can be operated at room temperature are presently fabricated using melt-grown bulk CdTe, CdZnTe crystals. Despite their promising results, use of these detectors in imaging is very limited due to the difficulty of the growth of large area and uniform bulk crystals. The MOVPE growth of CdTe layers on Si substrates is a promising method to grow large-area and uniform crystals required for the imaging applications. Besides, this growth technique offer flexibilities to control the thickness and electrical properties of the grown layers, hence imaging detectors with improved performances can be achieved.

We used a unique Si substrate pretreatment method to achieve high crystalline quality thick single crystal CdTe layers directly on (211) Si substrates[1]. The growth was performed using dimethylcadmium and diethyltellurium precursors. More than 260 μm-thick layers, with a growth rate varying from 40 to 70 μm/h, were routinely obtained. The XRD pattern showed the grown layers were (211) orientated single crystals. The detector was fabricated in a p-CdTe/n-CdTe/n^+-Si heterojunction diode structure by growing a typically 5-μm-thick iodine-doped n-CdTe buffer layer followed by the growth of 95-μm-thick undoped p-like CdTe layer. The heterojunction diode exhibited good rectification property and its energy discriminating capability was confirmed by detecting gamma peaks from ^{241}Am radioisotope. For the imaging detector application, a 2-D pixel-type detector array was developed using a mechanical saw based pixel pattering technique. Pixels were defined by cutting the deep vertical trenches on the CdTe layers in the X-Y direction, and to eliminate the charge sharing problem between the neighboring pixels, depth of the vertical trenches were extended down to the Si substrate. All pixels exhibited a good rectification property, with reverse bias leakage current varying from 1 to 3 μA/cm^2 at 250 V applied bias at room temperature. Detail results on the detector array fabrication, and characterization will be presented.

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Tu-07
Tuesday 12:00-12:15

Experimental progress on HgCdTe LWIR unipolar nBn device

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Infrared imaging technology today continues to rely on high-performance HgCdTe p-n junction photodiodes for applications spanning from the short wavelength (SWIR) to long wavelength (LWIR) infrared spectral ranges. However, thermal generation issues and processing challenges limit the improvement of the current technology. Recently, an alternative unipolar device design known as the nBn structure initially demonstrated in III-V type-II heterojunction systems has shown promise of increasing operating temperature and reducing cryogenic cooling requirements [1]. The nBn structure integrates engineered energy barriers to manipulate majority carrier current flow and provides potential opportunities to achieve simplified device structures or more complex epilayer structures for multi-spectral detection without the need for p-type doping. The design of the n-type, unipolar device reduces SRH generation-recombination (G-R) processes in the depletion region in addition to reducing overall dark current density by controlling single carrier current flow via a wide bandgap barrier layer in the conduction band. This nBn architecture may also be applicable to HgCdTe, offering a significant advantage over typical p-n junctions by eliminating requirements for p-type material and thus, avoiding well-known issues related to achieving *in-situ* p-type doping in HgCdTe using conventional molecular beam epitaxy (MBE) growth techniques.

In our previous work, we utilized numerical modeling to calculate the current-voltage, optical response characteristics, and detectivity values for HgCdTe nBn and p-n junction devices with cutoff wavelength of 12 μm for varying temperatures from 50 K to 300 K. Our simulations demonstrate similar dark current density, responsivity, and detectivity values within 10% for the LWIR HgCdTe nBn detector compared with standard p-n junction structure for temperatures from 50 K to 95 K.

Here we propose a novel, II-VI HgCdTe type-I material implementation of the unipolar nBn structure based on optimized parameters determined by our initial simulation studies. Preliminary data on the MBE growth of the HgCdTe LWIR nBn structure with cut-off wavelength of 12.5 μm at 80 K shows controlled doping concentration and Cd-composition achieved in the respective layers corresponding to the optimal values. The structure exhibits $3x10^5$ cm^{-2} etch pit density and a lightly doped $5x10^{14}$ cm^{-3} n-type active layer. We will report on the progress of preliminary fabrication and device characterization of this bandgap-engineered nBn structure and present the results of current-voltage and spectral response characteristic measurements.

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Tu-08
Tuesday 12:15-12:30

Metalorganic vapor phase epitaxial growth of (211)B CdTe on nanopatterned (211)Si

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There is a crucial need to grow high quality epitaxial CdTe on (211)Si, which is used as a buffer layer for subsequent growth of HgCdTe, presently the material of choice in the USA for fabricating IR based focal planar arrays (IR-FPAs). With the progress made so far, CdTe films with threading dislocation (TD) density as low as mid-10^5 cm^{-2} are routinely obtained by MBE and MOVPE. The TD density needs to be further reduced by at least an order of magnitude for the devices to work in the LWIR region. Epitaxial CdTe growth on nanopatterned Si offers a promise, since the confinement obtained due to nanopatterning provides new pathways for defect annihilation. The goal of the present work is to study the feasibility of using nanopatterned Si for the CVD growth of epitaxial (211)B CdTe.

At the SPIE 2010 conference in San Diego, we had presented epitaxial growth of CdTe on nanopatterned Ge/(211)Si, but the initial Ge growth and the nanopatterning of Ge/(211)Si needed improvement possibly due to poorer Ge surface morphology. Here, we present the direct growth of Ge and CdTe on nanopatterned SiO_2/(211)Si substrates since patterning of SiO_2 on Si is presumably easier. Patterning of 3" SiO_2/Si wafers was carried out at Transfer Devices Inc using nanotransfer lithography with water soluble templates to produce circular holes of ~400 nm and a pitch of ~540 nm. The oxide thickness was ~60 nm. Selective Ge and CdTe growth was carried out on these SiO_2/Si substrates using custom-built CVD reactor equipped with precursors for the growth of Ge, ZnTe and CdTe. Epitaxial CdTe directly on Si is challenging, hence selective Ge was first grown by As passivation of exposed Si. Selectivity was achieved in the temperature range of 575-675^oC. Selective CdTe was then grown inside the holes. Pressure and temperature were invariably varied between 25-100 torr and 350-495^oC respectively to achieve CdTe selectivity. In addition, in-situ annealing was carried out to improve the crystal quality. Once the islands merged, the conditions were changed to get higher growth rates. The films were characterized by SEM, AFM, XRD and TEM. A comparison of the CdTe films grown on nanopatterned and non-patterned (211)Si showed an improvement in the crystal quality due to patterning.

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Tue-Inv07
Tuesday 12:30-13:00

Physics of 1-dimensional exciton-polaritons in ZnO microwires

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In semiconductor nanostructures like microcavities, when the so-called exciton-photon strong coupling regime is reached, the proper eigenstates of the system are mixed exciton-photon states called exciton-polaritons. This last decade, 2-dimensional microcavity exciton-polaritons in the quantum degenerate regime have shown fascinating properties e.g. polariton lasing, Bose-Einstein condensation and superfluidity [1]. Recently, new systems and new geometries are being developed in order to study the polariton physics of dimensionality D<2 [2] and at higher temperature [3]. In order to achieve both goals at the same time, one needs to fabricate large bandgap materials nanostructures, of quality good enough to reach the strong coupling regime.

Recently, we have shown that ZnO microwires grown by rather simple methods were leading to 1-dimensional strong coupling regime with outstanding characteristics. At room temperature, Rabi splitting of 200meV is reported together with an unprecedented figure of merit of 50 (ratio of Rabi splitting to polariton linewidth) [4]. This very large Rabi splitting has interesting consequences both on linear and nonlinear properties of microwires polaritons. For instance, we have shown that polaritons with excitonic fraction up to 65% are decoupled from the thermal phonon bath, even at room temperature. Upon increasing optical excitation, polariton lasing is observed in the 1-dimensional strong coupling regime. Due to the large Rabi splitting as compared to the gain spectrum, this mechanism involves a polariton state 95% excitonic.

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Tue-Inv08
Tuesday 17:00-17:45

Single dot spectroscopy of CdTe based self organized system

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The talk summarizes the recent activity in the group of Prof. Jan Gaj. I will discuss the results of the optical studies related to exciton dynamics in the system of a single plane of self organized CdTe/ZnTe quantum dots. First, the various regimes of the optical excitation of the quantum dots will be recalled. Then the asymmetrical in-plane inter-dot coupling will be discussed [1]. Their studies involve several experimental techniques, in particular photoluminescence excitation (PLE), second-order single photon correlation, and optical orientation. Identification of individual coupled QD pairs will be described. Each pair contains an absorbing dot, identified by a sharp PLE resonance assigned to a neutral exciton transition, and a second, emitting dot, characterized by several PL lines related to its different charge states. Energy and exciton spin transfer dynamics will be discussed. The influence of the anisotropy will be exploited to achieve circular-to-linear and linear-to-circular polarization conversion in the single QDs and in coupled QD pairs. The probability of finding coupled dot pairs will be discussed for different regimes of QDs growth.

Finally, the spontaneously coupled pairs of quantum dots will be shown to be useful in the spin manipulation of the single magnetic impurity. Optical writing of information on the spin state of the Mn ion is demonstrated [2], using the orientation of the Mn spin by spin-polarized carriers transferred from the neighboring quantum dot. The characteristic time and possible mechanisms of Mn spin orientation will be discussed. The storage time of the information on the Mn spin is found to be strongly modified by application of a static magnetic field.

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Tu-09
Tuesday 17:45-18:00

Magnetooptical study of excitons in (Zn,Mn)O

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A magnetooptical study of $Zn_{1-x}Mn_xO$ was performed [1] in order to better understand the effect of the strong *p-d* exchange interaction on the valence band of wide bandgap diluted magnetic semiconductors (DMSs). According to a recent model [2], magnetic ions induce the formation of localized states in the bandgap but affects also delocalized states in the valence band which are involved in the optical transitions.

We observe excitonic transitions in reflectivity and photoluminescence, that shift towards higher energies when the Mn concentration increases and split nonlinearly under the magnetic field. Excitonic shifts are determined by the *s,p-d* exchange coupling to magnetic ions, by the electron-hole *s-p* exchange, and the spin-orbit interactions [3,4,5]. A quantitative description of the magnetoreflectivity findings indicates that the free excitons A and B are associated with the Γ_7 and Γ_9 valence bands, respectively, the order reversed as compared to wurtzite GaN. Furthermore, our results show that the magnitude of the giant exciton splittings, specific to dilute magnetic semiconductors, is unusual: the magnetoreflectivity data is described by an effective exchange energy difference $|N_0\beta^{(app)}-N_0\alpha^{(app)}| = 0.2 \pm 0.1$ eV, what points to small and positive $N_0\beta^{(app)}$. It is shown that both the increase of the gap with *x* and the small positive value of the exchange energy $N_0\beta^{(app)}$ corroborate the theory [2] describing the exchange splitting of the valence band in a non-perturbative way, suitable for the case of a strong p-d hybridization. Finally, we discuss the origin of opposite circular polarizations of excitonic reflectivity and photoluminescence, found for $Zn_{1-x}Mn_xO$ in the magnetic field.

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Tu-10
Tuesday 18:00-18:15

Heterovalent AlSb/InAs/(Zn,Mn)Te quantum wells with two-dimensional electron channel: MBE growth and spin polarized photocurrents

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Realization of the concept of semiconductor spintronics needs in fabrication of heterostructures possessing simultaneously high electron mobility, ferromagnetic properties at high temperatures, and strong spin-orbit interaction (SOI) [1]. Two former requirements have been met successfully in heterostructures containing GaMnAs, although further rise of the Curie temperature implies obtaining the higher material quality which is difficult to achieve in the low temperature growth. The latter demand shifts the focus onto materials with the strong SOI and large g-factor, like e.g. InAs. Additionally, beside magnetic effects, incorporation of Mn in III-Vs is accompanied by emergence of high hole concentration which hampers formation of DMS heterostructures with a 2D electron channel.

The paper reports on the original concept of DMS heterostructures with the 2D electron channel in a hybrid AlSb/InAs/(Zn,Mn)Te quantum well (QW) containing the III-V/II-VI heterovalent interface and modulation-doped with Mn in the II-VI part. The structures seem to satisfy all the above requirements. They were grown by MBE in a two-chamber setup STE3526 (SemiTEq, Russia), using the technology developed earlier for growth of the coherent InAs-based hybrid QW heterostructures exhibiting quantum-confined photoluminescence and electron transport [2]. Special cares were taken to preserve a 2D growth mode during deposition of II-VI layers on InAs. The studied structures contained both MnTe δ-layers (1-2 monolayers) and ZnMnTe alloy layers placed at different distance from the InAs QW. The hybrid QWs have demonstrated so far the low-temperature electron densities higher and mobilities noticeably lower than the reference pure III-V InAs QWs. To study the influence of Mn^{2+} ions on magnetic properties of the 2D electron gas spin polarized photocurrents excited by microwave radiation were measured in the in-plane magnetic field at low temperatures. The currents are proportional to the Zeeman splitting in the InAs QW [3]. Exchange interaction of 2D electrons with Mn^{2+} ions in the barriers, allowed due to the small distance between them, was found to result in a steep rise of the spin polarized photocurrent and changing its polarity. The amplitude of the photogalvanic effect correlates well with the structure design.

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Wed-Inv09
Wednesday 09:00-09:30

II-VI nanowires as optical emitters

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Application of quantum dots (QDs) as nano-emitters requires control of dots structural and chemical quality, as well as density and location. The nanowire (NW) geometry offers several advantages as compared to Stranski-Krastanov growth as it enables the fabrication of well defined 1D nanoscale heterostructures. Once this control is achieved, II-VI QDs insertions are good candidates to achieve high temperature operation thanks to their large exciton binding energies and strong carrier confinement [1].

In this contribution we report on the epitaxial growth of II-VI NWs by molecular beam epitaxy using gold as catalyst. A special emphasis is done on ZnSe NWs with CdSe QD insertions system. First results on tellurides will also be presented.

Complementary transmission electron microscopy (TEM) based techniques are used to study the crystalline structure, chemical composition and size of the NWs and the QDs . NWs exhibit very uniform diameter close to 10 nm. The QDs size is tuned from 1.5 to 15 nm. Their density is around $10^9 cm^{-2}$. The surface preparation and the orientation of the substrate (100) or (111)B influence the crystallographic quality, growth direction and crystallographic structure of the NW and QD insertion. The QD can be inserted both in a polar [111] direction where piezoelectric effects can play a role, and in a non-polar [100] direction.

μ-photoluminescence measurements (at T=4K) on single CdSe/ZnSe NWs exhibit sharp peaks corresponding to the exciton (X) and the biexiton (XX) emissions. As expected, a blueshift of the luminescence is observed for decreasing quantum dot size. The comparison of calculated photoluminescence energy and experimental data indicates that the quantum dots consist of a $Zn_xCd_{1-x}Se$ ternary alloy rather than pure CdSe [2].

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We-01
Wednesday 09:30-09:45

Carrier depletion and exciton diffusion in single ZnO nanowires

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In this work, we used cathodoluminescence (CL) measurements at low temperature (5K) to investigate carrier depletion and exciton diffusion in single ZnO NW Schottky diodes. Our NWs were grown by MOCVD on sapphire substrates, with typical lengths and diameters of 5 μm and 200 nm, respectively. Electrical contacts to single ZnO NWs were realized, employing a single step e-beam lithography technique based on low temperature CL imaging [1]. This process has shown to provide high yield of NW diodes with high quality electrical contacts, as illustrated in Fig.1 by the omega-shapes of both Schottky (Ni/Au) and ohmic (Ti/Au) contacts. The intensity distribution of the CL of the D_0X line at 3.359 eV was mapped out over the whole NW device for various applied biases, and displayed in Fig.2 (intensity scale increasing from white to black). It can be seen that the CL region is strongly reduced on the Schottky side with increasing reversed bias, due to the expansion of the depletion region. In fact the most remarkable feature is the linear voltage dependence observed for the depletion width. This unusual electrostatic behavior, as compared to the much weaker square root dependence in conventional 3D devices, will be discussed in this presentation. We will also show how exciton diffusion along the NW length can be extracted from CL data in Fig.2.

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We-02
Wednesday 09:45-10:00

Near band edge emission of Te-based nanowire heterostructures

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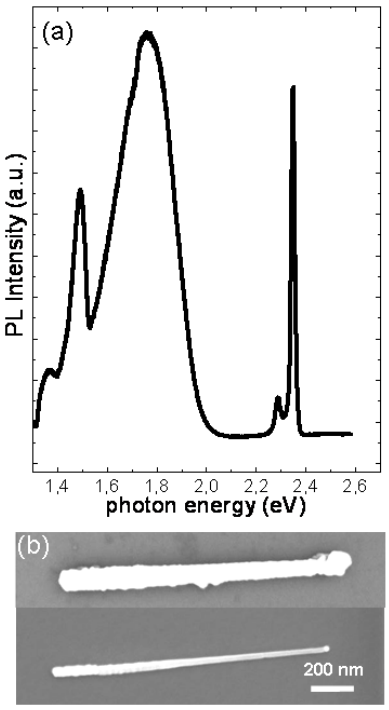

Fig 1. (a) photoluminescence from ZnTe/ZnMgTe core-shell nanowires with a clear near band edge emission at 2.35 eV, T=3 K, exc. 405 nm (b) SEM images of a nanowire with (upper part) and without ZnMgTe (lower part) shell

Nanowires are characterized by a considerable surface to volume ratio. This property can be used to build effective nanosensor. On the other hand, the surface defects may degrade the performance of such devices. In particular, the presence of surface states, which act as a trap for free carriers, results in the appearance of free carriers depletion regions close to the surface. Consequently, the electron transport and optical properties are affected. This is manifested, for example, as a considerable decrease of the near band edge emission [1].

In this work, we present a method to decrease the surface effects of ZnTe nanowires by adding a ZnMgTe shell. A typical photoluminescence (PL) spectrum from ZnTe nanowires consists of a defect related emission at 1.8 eV without any emission at energies close to the band edge of ZnTe - 2.39 eV. The presence of a ZnMgTe shell, i.e., semiconductor with a larger energy gap, results in the appearance of a strong emission in the spectral region of interest (Fig 1 (a)). Moreover, we show that the intensity of this emission increases with increasing thickness of the shell, which additionally supports the interpretation in terms of the surface states passivation.

ZnTe nanowires are grown by molecular beam epitaxy by employing the vapor-liquid-solid growth mechanism induced by gold catalysts. Afer the growth of 1.5 μm long ZnTe nanowires at 400°C, the temperature is cosiderably reduced to 250°C - 300°C for the deposition of the ZnMgTe shell. At such a low temperature the growth occurs mostly in the radial direction of the nanowire and results in an average ZnMgTe shell thickness of 18 nm (29 nm) after 10 min (15 min) deposition, Fig 1. (b).

X-ray diffraction analysis and transmission electron microscopy performed at high resolution reveal the monocrystalline character of the ZnMgTe shell. This property seems to be crucial for the passivation of the surface, since polycrystalline shell does not induce the appearance of the near band edge emission.

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We-03
Wednesday 10:00-10:15

Room temperature single photon source

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We have obtained single photons at room temperature (T=300K) from a CdSe quantum dot inserted in a ZnSe nanowire fabricated by molecular beam epitaxy. This is the first time that single photons are produced at room temperature from an epitaxially grown semi-conductor structure.

As a confirmation of the very robust temperature behavior of these dots, we have found that non-radiative recombinations appear with an activation energy as high as 150 meV.

In this presentation, we will also present detailed photo-luminescence spectroscopy of these objects. Temperature dependent lifetime measurements on the excitonic transition [1] have allowed us to extract the dark-bright exciton splitting with rather large values ranging from 4 to 11 meV indicating a rather small size of the dot in agreement with high resolution TEM measurements.

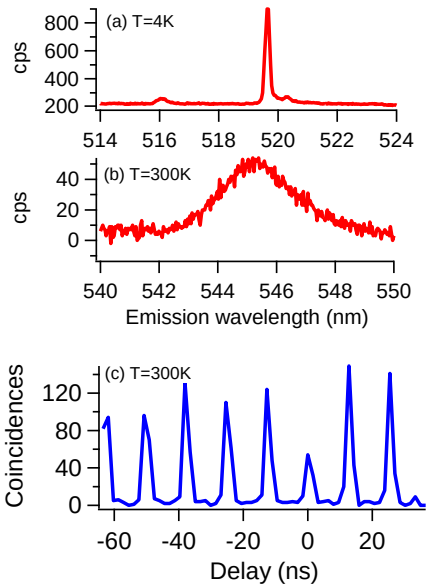

Fig. Spectrum in counts per second (cps) at T=4K. (a) T=300K. (b) Antibunching at T=300K (c).

Additionally photon correlation spectroscopy has enabled us to identify the coexistence of charged and neutral state of the quantum dot [1]. In particular we have identified several lines coming from the charged biexciton. The lower state of the charged biexcitonic transition is the excited trion: we were able to access its fine structure and to probe its spin relaxation dynamic.

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We-04
Wednesday 10:15-10:30

Room temperature single photon emission from a self-organized quantum dot

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Solid state single photon sources represent central devices for quantum information technology. A variety of concepts has come up during the last years, most of them based on colloidal quantum dots, color centers and on self organized semiconductor quantum dots. The latter are especially attractive as they can be easily integrated into electrically driven devices and in fact, electrically driven sources of single and even entangled photons have been implemented. However, no room temperature single photon emission is demonstrated for any kind of self-assembled quantum dots up to now, neither for electrical nor for optical pumping. For operation under ambient conditions, wide-bandgap II-VI single quantum dots are expected to be ideally suited as they provide a much better carrier confinement. Introducing self-assembled CdSe quantum dots embedded in a specially designed barrier, we have been able to achieve efficient room temperature emission from a single quantum dot both under optical [1] and electrical operation [2].

In this contribution, we report for the first time on single photon emission from a single, epitaxially grown quantum dot at room temperature. For the devices, self organized CdSe quantum dots are formed on ZnSSe barriers und additionally embedded between MgS barriers to provide high quantum efficiency at elevated temperatures. Nanoapertures down to 150 nm allow for optically addressing single quantum dots by using the 457 nm line of an Ar^+ laser for excitation. In photoluminescence, we can track the single quantum dot emission up to room temperature, with an intensity of the emission decreasing by only a factor of 3 between 4 K and 300 K. In accordance with earlier findings [2], we detect a significant broadening of the single quantum dot emission lines up to nearly 28 meV due to exciton-phonon interaction.

Photon correlation measurements were performed using a Hanbury-Brown_Twiss-Setup. Even under continuous wave excitation, a striking antibunching behavior at room temperature is found. Second-order correlation measurements reveal a surprisingly low value of $g(2)(\tau) = 0.15$ for zero time delay. This confirms the high potential of these quantum dots for future single photon emitting devices operating under ambient conditions.

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Thu-Inv10
Thursday 09:00-09:30

Room-temperature CW operation of BeZnCdSe green laser diode

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Recently, green laser diodes have been received much attention because they enable novel devices such as micro-projectors or vivid color displays when used in combination with red and blue laser diodes. Although several approaches using III-nitride-based semiconductors and their successful laser operations with wavelength of over 500 nm have already been reported, their threshold currents still increase as their lasing wavelengths approach to the pure green region. ZnSe based compound semiconductors are also promising materials for the green laser diodes. In particular, Be containing ZnSe based mixed crystals are expected to overcome the problem of limited lifetime of II-VI-based laser diodes [1,2].
In this study, a room temperature continuous-wave operation over 540 nm was demonstrated with a BeZnCdSe quantum-well laser diode. The schematic structure of the fabricated laser diode is shown in Fig. 1. The light output power and voltage-current characteristics of a fabricated laser diode with a 5-μm-wide mesa are shown in Fig. 2. Its threshold current density was as low as 1.3 kA/cm^2. This result indicates this material system is advantageous in realizing a green laser diode with low power consumption.

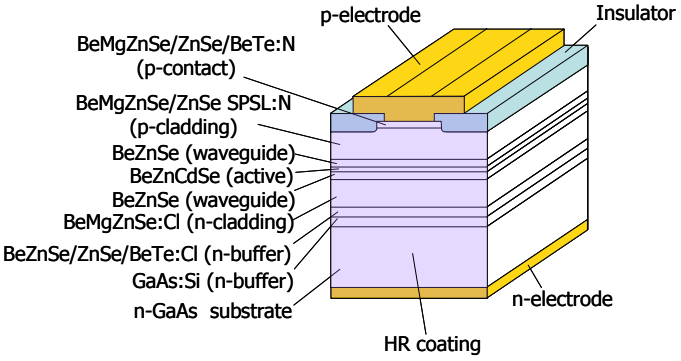

Fig. 1. Schematic structure of the fabricated laser diode

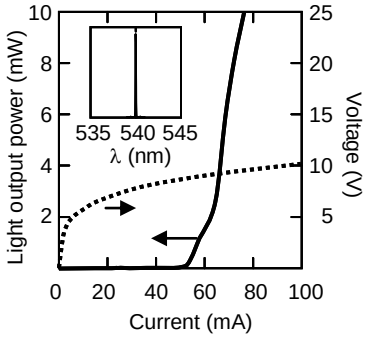

Fig. 2. Light output power and voltage-current characteristics

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Thu-01
Thursday 09:30-09:45

Room temperature degenerate four wave mixing driven by a one-dimensional ZnO polariton laser

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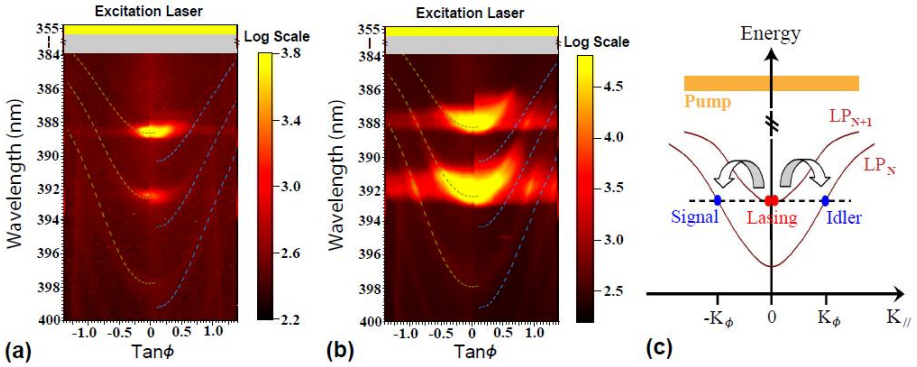
Excitonic polaritons—the quasi-particles formed by the strong coupling between photons and excitons—are elementary excitations in semiconductors. Polariton parametric scattering processes have attracted much attention in recent years [1-3]. Unlike the classical nonlinear optical effects, the nonlinearity of excitonic polariton parametric scattering processes originates from the Coulomb interaction among polaritons instead of the transient interaction among virtual states. Therefore, these processes usually have high conversion efficiency and low pump threshold, for which reason they have great potential in novel optical device application.

In this work, we demonstrate the room temperature polariton degenerate four wave mixing (DFWM) oscillation in a ZnO one-dimensional whispering gallery [3, 4] microcavity [see Fig.1(b)]. Using a semi-classical Boltzmann equation, we describe the dynamics of polariton parametric scattering process and extract the polariton-polariton interaction coefficient. Compared to polariton parametric processes observed at low temperature in planar microcavities, our system has two important advantages: Firstly, the polariton lasing induced DFWM instead of resonant excitation makes this nonlinear effect be realized more easily. Secondly, the DFWM of polariton is achieved at room temperature, this is highly desirable for device applications, such as entangled polariton/photon sources for room temperature operation.



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Thu-02
Thursday 09:45-10:00

Blue monolithic vertical-cavity surface emitter lasing at 444 nm

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A fully epitaxial vertical-cavity surface-emitting laser (VCSEL) emitting in the blue spectral region based on ZnSe quantum wells (QWs) has been realized. The binary QWs offer a reduced inhomogenous broadening of the excitonic emission and a higher stability against degradation compared to ZnCdSe QWs. To achieve this, a new distributed Bragg reflector (DBR) approach has been developed using ZnMgSSe (instead of ZnSSe [1]) layers with Mg ≤ 35% as high-refractive-index material and MgS/ZnCdSe superlattices as the low-index material. This allows for the realization of the stopband in the blue/violet spectral region from 400 to 460 nm. A main challenge is to achieve smooth DBR interfaces when the Mg content of the quaternary ZnMgSSe is higher than 20%. Furthermore, lattice matched growth to the GaAs substrate requires precise control of deposition parameters during the VCSEL growth run. High-resolution X-ray diffraction (HRXRD) measurements are performed for calibration of the composition. In order to determine the exact quarter-wave thickness of each layer, the use of in-situ reflectometry turned out to be crucial.

The laser structures consist of an 18-pair bottom DBR, a λ-cavity with three ZnSe QWs and a 15-pair top DBR. The Mg content in the DBRs and the material surrounding the QWs is 22%. A second sample has been prepared in order to increase the fraction of pump power absorbed within the cavity. Thus the Mg content in the material surrounding the QWs has been reduced to 14% to shrink the bandgap and therefore achieving a higher absorption coefficient at the excitation energy. This second structure shows stimulated emission at an energy of 2.79 eV (444 nm) at 4 K, the lasing threshold energy is 6.8 pJ. For the excitation a pulsed Ti-Sa-Laser emitting at 2.99 eV (415 nm) is used. The threshold behaviour of the blue VCSEL structures will be compared to results obtained for green VCSELs [1].

In addition, micropillars have been etched out of the planar structure using focused-ion-beam (FIB) milling. The three-dimensional optical confinement in the pillar microcavity results in the observation of discrete resonator modes spectrally overlapping the QW emission. The fundamental mode centered at 2.796 eV has been clearly identified for a pillar diameter of 2.8 μm. A quality factor of 3270 can be determined from the spectral width of the fundamental mode.

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Thu-03
Thursday 10:00-10:15

Structural and optical optimization of ZnSe-based laser heterostructures with graded index waveguide

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Recently the possibility of using ZnSe-based laser structures as active elements of integral violet-green II-VI/III-N laser converters utilizing excitation by commercial blue-violet InGaN pulse LDs has been demonstrated [1]. It is well known that both degradation stability and operation lifetime of II-VI laser heterostructures grown on GaAs substrates are mainly governed by the density of extended defects [2]. Here we present the latest results on optimization of structure design and growth conditions of II-VI laser heterostructures with graded index waveguide (GIW) [3], providing the compensation of elastic stresses in the structure, reduction of the extended defect density, and increase in the quantum efficiency.

The II-VI laser heterostructures were grown by molecular beam epitaxy (MBE) on GaAs (001) buffer epilayers at a temperature T_S=270-280°C using a double-chamber MBE setup STE 3526 (SemiTEq, Russia). The typical structure consists of bottom (1-1.5 μm) and top (10-20 nm) ZnMgSSe claddings, Zn(Mg)SSe/ZnSe GIW composed of short-period strained superlattices (SL), and an active layer based on single or multiple electronically-coupled CdSe/ZnSe QD sheets. The using of the SL GIW provides both the gradual band gap reduction to the active region and improvements in carrier transport without variation of growth parameters (beam fluxes, T_S). The structural and optical properties of the laser structures were studied using the XRD, TEM, luminescence microscopy (LM) and PL. The ZnSSe/ZnSe width ratio in the main ZnSSe/ZnSe SL has been chosen to compensate the compressive strains induced by the ZnMgSSe/ZnSe GIW SLs, which is confirmed by the respective Θ–2Θ XRD rocking curves. The estimation of the optimum composition of $Zn_{1-x}Mg_xS_{1-y}Se_y$ alloys gives x=0.12 and y=0.17, providing the ~100 arc. sec. lattice mismatch at RT. Efficiency of carrier transport in GIW was evaluated from the analysis of variation of the PL peak intensity ratios between the active region and the constituent SLs vs temperature. Due to optimization of the structure design and procedure of initial growth stage the density of extended defects in II-VI/III-V laser heterostructures was reduced down to 10^4 cm^{-2}. The intensity of the PL from QDs in different laser structures of similar design correlates well with the extended defects densities measured by using LM. Summarizing, the optimization is expected to lead to further improvements in parameters of green laser converters as well as increase in their degradation stability.

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Thu-04
Thursday 10:15-10:30

Violet-green injection laser converters with pulse output power above 150mW

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Compact semiconductor green lasers (λ~530-550 nm) are strongly required for fabrication of low-cost, high resolution pico-projectors which can be incorporated in smartphones, digital cameras, media players, laptops etc. In spite of significant progress in development of green InGaN laser diodes (LDs) grown on free-standing GaN substrates (λ=523-525 nm, cw operation mode, output power of 38-50 mW, WPE of 2.2-2.3%) [1, 2], alternative ways to obtain green lasers are still of a great importance because the InGaN LDs demonstrate rather high threshold current density (J_{th}~9 kA/cm^2 [2]) steeply increasing with λ.

One of the alternative is a blue-green laser converter composed of the II-VI laser heterostructure optically pumped by the emission of a blue-violet InGaN pulse LD. The maximum earlier reported values of pulse output power and quantum efficiency of the converter were 65mW and 14%, respectively [3]. Here we present the latest results on fabrication of high-efficiency violet-green laser converters based on optimized II-VI laser heterostructures with graded-index superlattice (SL) waveguide (GIW) [4].

The II-VI heterostructures were grown by molecular beam epitaxy (MBE) on two-chamber MBE setup STE3526 (SemiTEq) and consist of bottom 1.3μm ZnMgSSe cladding, Zn(Mg)SSe/ZnSe SL GIW, and active layer based on multiple electronically-coupled CdSe/ZnSe QD sheets. The structure design was optimized using the calculations of optical confinement factors in the plane wave approximation. The commercial A^3N pulse LD (λ=416 nm, τ_p=50 ns, $P_{exc\ max}$=1.6 W) was used as a pumping source. The maximum value of the pulse output power of 154mW (at λ=543nm) and quantum conversion efficiency of 25.4% have been achieved at the excitation level of P_{exc}~1.0W for the structure with 5QDs sheets in the active layer and asymmetric GIW waveguide. The threshold excitation power as low as 320mW has been demonstrated, which is about twice less than in Ref. [3]. The comparison of the injection converters based on II-VI laser heterostructures having different waveguide design will be done.

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Thu-Inv11
Thursday 11:00-11:30

Growth, characterization, and device applications of various oxide semiconductors

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Oxide semiconductors are gaining marked interest as abundant and multifunctional materials for novel devices. ZnO has been a pioneer of the II-VI oxide semiconductors and the world-wide efforts to apply this unique material to actual devices are going on. This trend has also led a lot of researchers to the development of various oxide semiconductors.

One of our interests has been for Ga_2O_3, which possesses wide bandgap of about 5 eV. Interestingly, Ga_2O_3 bulk substrates have already been available, and therefore the research for Ga_2O_3 has been able to be conducted based on planar processes of the bulk substrates and homoepitaxial growth. We showed deep ultraviolet sensors detecting not only very weak light in flame [1] but also strong output power of mercury lumps without severe degradation of the device. MBE homoepitaxial growth led to step-flow growth of Ga_2O_3 and $(AlGa)_2O_3$for Al content of upto 0.4 [2].

From the viewpoint of crystal growth, a basic reaction of oxide semiconductors is oxidation of metal, which can occur easily. This encourages us the development of simple, safe, cost-effective, and environmental-friendly growth methods, rather than MBE or MOCVD. We have investigated the mist-CVD technique where water or alcohol solution of safe precursors has been applied as a reaction source transferred in the form of mist particles applying ultrasonic power to the solution. We showed step-flow homoepitaxial growth of ZnO [3], composition control of ZnMgO [4], and highly-crystalline corundum-structured Ga_2O_3 on sapphire substrates [5]. $(GaFe)_2O_3$ alloys [6] exhibited ferromagnetic properties upto room temperature. We will show at the conference the most up-to-date results on properties of various oxide semiconductors grown by the mist-CVD, together with the potential of this technology for device fabrication.

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Thu-05
Thursday 11:30-11:45

Controllability of Mg substitution for ZnMgO films by using MOCVD under moderate conditions

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Ternary $Zn_{1-x}Mg_xO$ alloy (ZnMgO) is one of the promising candidates for low-cost electronic and optoelectronic devices, including light emitting devices (LED) and high electron mobility transistors (HEMT) [1]. Among growth techniques of ZnMgO films, metal-organic chemical vapor deposition (MOCVD) has some advantages in mass production. As a Mg source in MOCVD, bis (methylcycropentadienyl) magnesium ($(C_5H_4CH_3)_2Mg$; $(CpMe)_2Mg$) is one of the suitable materials. Although high Mg concentration was achieved previously by using $(CpMe)_2Mg$ [2, 3], requirement of high vacuum and/or high temperature should provides disadvantages from a viewpoint of the cost during growth. Therefore, we have investigated a controllability of Mg concentration in ZnMgO films under moderate conditions.

ZnMgO thin films on Al_2O_3 (0001), ZnO (0001) (+*c*), and quartz substrates were grown by using MOCVD method with a rotation disk vertical flow reactor, under a total pressure of 100 hPa. $(CpMe)_2Mg$, diisopropylzinc ($(i\text{-}Pr)_2Zn$) and tertiary butanol (*t*-BuOH) were used as Mg, Zn and O sources, respectively. The optimal substrate temperature was found to be 400 ^oC. Secondary ion mass spectrometry (SIMS) measurement revealed that Mg content *x* was able to be controlled up to 0.24 with a high homogeneity of Mg distribution. Results of photomuninescence spectroscopy for ZnMgO films on both of substrates showed linear increase of the energy bandgap with respect to Mg content *x* up to 3.9 eV, which was consistent with previous reports[4]. This experiment demonstrates that wide bandgap engineering for ZnMgO system could be realized by MOCVD method without a high vacuum nor high temperature.

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Thu-06
Thursday 11:45-12:00

Origin of the *n*-type conductivity in low temperature ZnO thin films

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The control of zinc oxide electrical properties still remains a scientific challenge with regard to the possible applications of this material in the huge number of electronic devices e.g.: non-volatile 3D memories, hybrid structures with organic materials, sensors or transparent electrodes in solar cells. Therefore, the role of different defects contributing to the oxide's conductivity is nowadays a hot topic for a discussion.

In the present work the authors demonstrate that the low temperature Atomic Layer Deposition process allows one to grow the ZnO thin films with well controlled electrical properties. In such layers neither the incorporated hydrogen atoms nor the oxygen vacancies seem to be the dominant donor, as it is theoretically and experimentally shown for other examined cases of the ZnO material [1, 2]. This observation is confirmed by the photoluminescence (PL) and Secondary Ion Mass Spectroscopy (SIMS) investigations as we see therein an anticorrelation between the presence of hydrogen atoms and the increasing electron concentration in the obtained ZnO films.

The low temperature (LT) Hall effect investigations revealed the average activation energy of a shallow donor at the level of E_D = (30 ± 5) meV for the films with high crystallinity. This value is attributed (e.g in [3]) to the zinc interstitials (Zn_i) in ZnO. In the RT PL measurements of these films a red light emission occurs, being a fingerprint of the Zn_i defect. Moreover, a small amount of the excessive Zn atoms was detected via Electron Dispersive X-ray Spectroscopy, what also confirms the presence of this defect in the examined layers, as stated in [4]. The LT Hall mobility measurements show the competition between two scattering centers: ionized impurities and grain boundaries. This proves a relevant role of the interstitial Zn atoms, contributing to the high *n*-type behavior of ZnO grown by ALD at low temperature.

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Thu-Inv12
Thursday 12:00-12:30

Oxide semiconductors for photovoltaic applications

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Photovoltaics exibit enormous growth aiming to extremely high power capacities per year. Therefore nontoxicity and abundance of the materials in the earth are among the key requirements to the photovoltaic materials. Some of the materials presently used in photovoltaics, like CdTe, III/Vs and CIGS ($CuInGaSe_2$), may not be abundant enough for large scale use in solar energy systems. From this point of view such semiconductors as ZnO, ZnS, Cu_2O are of special interest for photovoltaics.

ZnO nanopowders and aligned ZnO nanowire arrays are considered as potential candidates for a variety of novel applications in different fields like catalysis, sensing and energy harvesting, for instance as electrodes in dye sensitized solar cells (DSSCs). DSSCs based on ZnO nanopowders will be discussed. Replacement of these nanopowder layers through one dimensional single-crystalline structures like ZnO nanowires would reduce defect densities and therefore improve device quality. A novel two-step approach for the growth of ZnO nanowire arrays with a length of up to 30 µm on FTO substrates with a growth rate of about 20 µm per hour will be discussed. The fabricated nanowires arrays were used as electrodes for the manufacturing of dye sensitized solar cells. It would be an advantage concerning solar cell stability and efficiency to avoid implementation of organic materials which is essential for DSSCs. Combination of ZnO with Cu_2O is one of the promising approaches for the next generation photovoltaics. Theoretical calculations predict efficiencies of such solar cells up to 18%. For a long time the maximal efficiencies did not exceed 1,8 %. A remarkable recent breakthrough in this area has been the demonstration of ZnO/Cu_2O thin film solar cell with efficiency of 3,83% [1]. Nevertheless, the fabricated device is still far from commercial applications. The promising for photovoltaic applications (Zn,Cu)(O,S) material system is discussed.

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Thu-07
Thursday 12:30-12:45

Distortion of slow light pulses by excitons in ZnO

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Variation of the group velocity near excitonic resonances in semiconductors slows down the light transfer and disturbs the shape of light pulses [1]. These phenomena are important for a set of devices used for optical communication and data processing [2]. Here we report on the studies of slowed light in ZnO, which possesses numerous lines of donor bound excitons (DX). The absorption spectrum of these excitons is probed for the first time by time-of-flight spectroscopy via local distortion of the pulse shape at different energies. The parameters of exciton-polaritons, inherent for bulk ZnO, are derived from the simulation of the overall curvature and attenuation of the pulses [3].

The time-of-flight experiments were performed using the pulses of a tunable ps laser propagating through high-quality ZnO crystals of different thicknesses (L=0.3-2 mm) and a Hamamatsu streak camera. The series of pulse replicas reflected from the sample boundaries were recorded and analyzed as well. The delay of the higher-energy edge of a strongly curved pulse approaches 1.6 ns at 3.374 eV for L=0.3 mm. To model the pulse distortion, the initial spectrum of the laser pulse is approximated as a Gaussian. The amplitude and phase of the pulse are given by the Fourier transform at the boundary of the crystal. The electric field in the spatial point L at the moment t is found in accordance with the general theory of the electromagnetic field propagation [4]. The dielectric function of ZnO is determined taking into account all resonant lines. The simulation demonstrates that the general curvature and pulse delay follows the optical dispersion controlled by the exciton-polariton resonances. The influence of the bound excitons is local, namely, they provide dips cutting the pulses into several parts and induce extra light retardation nearby. The number of the DX lines resolved by the time-of-flight spectroscopy is 18 in the 3.356-3.374 eV range, being higher than in photoluminescence (PL) spectra. The strongest D^0X_A and D^0X_B lines possess the oscillator strength of $5\cdot10^{-6}$ and $2\cdot10^{-6}$, respectively, while this parameter can be as low as $1\cdot10^{-9}$ for the minor lines. The oscillator strength of A and B exciton-polaritons is found to be 0.0072 and 0.012, respectively. Two severe limitations are discovered: i) The homogeneous width of these resonances must be as small as 3 μeV; ii) the inhomogeneous width cannot exceed 0.5 meV for the A excitonic series. Otherwise, it would be not possible to observe the transmitted light up to 3.374 eV.

In this modeling, we consider exclusively the data on the processes taking place inside the crystal, namely, cw transmission and pulse propagation. Note that the derived parameters are different from those obtained from the analysis of both reflection and PL data. This discrepancy suggests that broadening and deterioration of the excitonic resonances takes place at the crystal surface. We believe that our studies will draw attention to the time-of-flight spectroscopy as a new opportunity to investigate the fine structure of an excitonic spectrum and to determine true bulk parameters of semiconductors.

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Thu-08
Thursday 12:45-13:00

X-ray photoelectron spectroscopy study of oxide removal using atomic hydrogen for large-area II-VI material growth

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Atomic hydrogen has been used to clean a variety of substrates prior to epitaxial growth of semiconductors and has proven efficacious for the preparation of substrates for subsequent growth of II-VI compounds by molecular beam epitaxy (MBE). In this presentation we will discuss the use of atomic hydrogen for low temperature removal of oxides and other overlayers from GaSb and InSb, and present the results of a detailed x-ray photoelectron spectroscopy (XPS).

Chemical mechanical polishing of compound semiconductor substrates forms an oxide over-layer on the substrate surface and this undesirable oxide layer must be removed before initiating MBE growth. Although thermal desorption of the surface oxides in the MBE growth chamber can be used with most III-V's just prior to growth, oxide desorption on the low-temperature antimonides is problematic. The antimonides are able to form, depending on the polishing or processing technique, a variety of surface oxides that desorb at a variety of temperatures. In particular, the Sb-oxides thermally desorb at relatively low (~ 400^{o}C) while Ga_2O or In_2O must thermally convert to the monoxide prior to desorption, with subsequent secondary reactions with the surface that leads to a metal-rich surface unless an Sb overpressure is present. To make matters worse, the indium oxides desorb at temperatures that are only a few degrees below the melting point of the InSb wafer. Also, it is not always convenient to have a large Sb flux available for substrate preparation if the ultimate goal is to produce II-VI epilayers. This suggests the need for other methods to remove the surface oxides for epitaxial growth and device processing

In this paper, we demonstrate how to prepare the GaSb and InSb substrates before growing epitaxial layers. Atomic hydrogen cleaning is used to remove the oxide layers from GaSb and InSb substrates, resulting in Sb stable condition with less thermal damage on surface compared to the normal thermal cleaning. . XPS was used to measure overlayer composition both after etching and during atomic hydrogen cleaning. Results of subsequent overlayer growth will be presented.

Thu-Inv13
Thursday 17:00-17:30

Physics and application of nanorods of II-VI compound semiconductors

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Even though II-VI compound semiconductors are superior to other similar compound semiconductor such as III-nitride in terms of physical property[1,2], it has been known that the development of devices using II-VI compound semiconductors has been fallen behind. In particular, the physical characteristic of ZnO is more remarkable than its competitor, III-V compound semiconductor GaN. Thus ZnO has been considered to have a great potential for the applications of electric and optical devices. However there were no much noticeable development in optical components application by using ZnO so far due to the main flaw that p-doping is not possible with ZnO.

ZnO Nanorods is known to have great prospects in the fundamental physical sciences and in novel nanotechnological applications[3,4]. Because of the large band-gap and structural confinement of ZnO Nanorods, the fabrication of visible, UV optoelectronic devices having a relatively low power consumption is potentially feasible. Nanorods have been the focus of considerable attention because they have the potential to answer fundamental questions about one-dimensional systems and are expected to play a central role in applications ranging from molecular electronics to novel scanning microscopy probes. We intend to demonstrate that ZnO Nanorods which are extracted by II-VI compound semiconductors can develop optical components as well as electron devices after overcoming the weakness of p-doing infeasibility.

We report a simple method for instant CVD, PLD and even spray pyrolysis method so far for creating ZnO Nanorods. Structural characterization of the ZnO Nanorods by X-ray Diffraction and transmission electron microscopy indicates that the Nanorods are preferentially oriented in the c-axis direction. Photoluminescence characteristics of the Nanorods show a strong UV light emission peaking at room temperature. These II-VI Nanorods structures offer opportunities for investigations of the fundamental science, and they hold promise for potential applications in next-generation devices operating at room temperature. And also we are going to display that various interesting devices including Blue LED, FED and Solar Cell can be produced from ZnO Nanorod in more simpler manner without the existing complicated growth procedures.

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Thu-09
Thursday 17:30-17:45

Optical properties of colloidal CdSe nanoplatelets

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Colloidal CdSe nanoplatelets of cubic phase represent a novel material system of two-dimensional colloidal nanocrystals, i.e. colloidal quantum wells. In contrast to MBE grown quantum wells, those platelets show a much higher quantum yield and have thus a high potential for usage in photonic devices, like quantum well lasers or sensors. Compared to conventional CdSe dots, the proposed CdSe platelets show a much narrower ensemble emission (about 30meV FWHM), which makes them very attractive for narrow band emitters or gain media. In this study, we present numerical calculations of the platelets quantum well exciton energies including coulomb interaction and compare them with the experiment. Single particle spectroscopy is applied to overcome inhomogeneous broadening in ensemble and reveal an excitonic substructure in the photoluminescence emission spectra (PL). Temperature-dependent measurements of the PL spectra show a low exciton-LO-phonon coupling strength and therefore a small phonon broadening in the CdSe platelet emission.
Numerical calculations have been performed to understand the influence of thickness quantization and lateral size variation on the cubic CdSe nanoplatelets. Due to a large surface to volume ratio, the exciton energies show a strong impact of dielectric confinement on exciton states. Coulomb interaction corrected numerical simulations reproduce this effect very well. The thickness quantization to integer CdSe monolayers leads to a only lateral size distribution, resulting in narrow PL emission.
Single particle PL studies in addition to a comprehensive study of their optical properties were performed to identify neutral and charged exciton states. The observed spectral shift in temperature dependent PL measurements can be explained within a phonon Bose model with a low electron-average-LO phonon interaction strength a_B of about 7meV. The temperature dependence of the observed ensemble emission linewidth can be modeled with a LO-phonon induced broadening mechanism. A value of about 15meV is obtained for the exciton-LO phonon coupling strength, significantly weaker than for hexagonal CdSe (49meV). This low value is besides the low inhomogeneous broadening of approx. 30meV the reason for the narrow emission of the CdSe platelets even in ensemble as compared to conventional CdSe dots. The influence the observed low LO phonon coupling and defects on the recombination of heavy hole excitons will be discussed based on an exciton migration model. It can be seen, that a phonon assisted migration process is of relevance for the transfer of excited excitons to local radiative centers. An Arrhenius analysis of the occurring activation energies shows that these states are located about 4meV below the band edge.
Due to the colloidal synthesis process, the production of nanoplatelets could be scaled to industrial amounts easily. This makes them an interesting Media for optoelctronic applications, in all the ranges, were conventional epitaxial quantum wells are already used.

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Thu-10
Thursday 17:45-18:00

Time-resolved photoluminescence study of interfacial transitions in ZnO/ZnSe type II core/shell nanowires

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Wide bandgap semiconductors (E_g >> 2 eV) are typically used as transparent conductive electrodes, passivation layers, and carrier transporters in many optoelectronic devices, such as LEDs and PV cells. For the solar cell, conversional wisdom would suggest to find a semiconductor with a bandgap in the range of 1.0 – 1.6 eV to serve as the absorber layer for a single junction solar cell, because the Shockley-Queisser detailed balance theory predicts that under one sun a semiconductor with its bandgap in this range has an energy conversion efficiency limit > 30% and the limit decreases when moving out of this range. However, it has been recently predicted that when two large bandgap semiconductors (e.g., ZnO and ZnSe or GaN and GaP), which on their own neither of them can be an efficient light absorber, form a type II heterojunction, it can absorb a much broader spectrum of light than they are alone, due to the type II interfacial transition, as though the heterojunction has a much lower bandgap than any of the components. Therefore, an array of type II heterojunctions of two large bandgap materials, core-shell nanowires in particular, can potentially make an efficient solar cell.[1] One could view this approach as two large bandgap components mutually sensitizing each other. Very recently, the first demonstration of a solar cell based on this idea has been reported, using a ZnO/ZnSe core/shell nanowire array.[2] It has been found that the threshold of the photo-response is as low as 1.6 eV, much below the bandgap of either component (3.3 and 2.7 eV, respectively). The device also has an open circuit voltage of 0.7 V, which is among the highest reported values for the nano-structured PV devices. Other signatures of the type II transition have also been observed, including below bandgap absorption and photo-luminescence. In this work, we will report another key feature of the type II interfacial transtion, that is, the long PL decay time.

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Thu-11
Thursday 18:00-18:15

Variety of exchange interactions providing spin-flip raman scattering in CdTe/(Cd,Mg)Te quantum wells

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The dynamics of carrier spins in semiconductor nanostructures attracts considerable interests due to the possibilities of spin storage, transfer and processing of information. For spintronic applications, the understanding of the basic interactions between carrier spins is essential, since these interactions determine the information transfer, spin relaxation and, in turn, spin decoherence. The coupling between two localized carrier spins is mainly based on two different mechanisms: magneto-dipole and exchange interaction. The exchange interaction consists of isotropic and anisotropic components, while the anisotropic exchange changes the characteristics of the carrier spin dynamics considerably being in most cases a major drawback. Thus, the detailed experimental study of the anisotropic exchange between electrons and between holes in semiconductor nanostructures, which is lacking in details so far, is very essential to enhance the possibilities within the frame of spin dynamics.

Here, we report on the investigation of different types of exchange interactions in initially weakly p-doped CdTe/(Cd,Mg)Te quantum wells. The anisotropic exchange interactions of photocreated excitons with localized electrons and heavy-holes as well as the mutual direct exchange coupling between resident heavy-holes are studied by resonant spin-flip Raman scattering. As the type of the resident carriers in the CdTe quantum well can be tuned from holes to electrons by additional above-barrier illumination [1], the competition between the spin interactions in the positively and negatively charged excitons is highlighted. By changing the power density of the above-barrier illumination the probability of the spin-flip Raman scattering processes is enhanced by several orders of magnitude, but it can be also fully reduced. Up to now, anisotropic exchange has been only studied for carriers bound to defect ions, however, this tunability allows the simultaneous study of the anisotropic exchange interactions of resident electrons and holes without the necessity of the formation of particle complexes bound to defect ions. In that context, the various spin-flip Raman scattering mechanisms are discussed by means of their polarization selection rules, angular and magnetic field dependencies. Hereby, the mixing of the heavy-hole and light-hole states also come into play for explaining the exchange induced flip of the resident electron spin in the negatively charged exciton complex.

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Fri-Inv14
Friday 09:00-09:30

Homoepitaxial growth and properties of nonpolar (Zn,Mg)O/ZnO quantum wells

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ZnO-based quantum wells have attracted much attention due to their opportunity of combining band gap engineering, with large excitonic binding energies. So far studies on ZnO have mainly focused on films grown in (0001) orientation. The wurtzite ZnO layers exhibit built-in electric fields along the c-axis, affecting the electronic properties. Non-polar surfaces are of interest since the c-axis of the layer lies in the growth plane in this case. It is expected that QWs structures can be grown without any screening of the exciton binding energies. This property is demonstrated in ZnO/ZnMgO heterostructures grown on sapphire [1].

Unfortunately wide band gap nonpolar QWs grown on sapphire usually exhibit a large density of stacking faults, reducing the emission efficiency [2]. ZnO bulk substrates are commercially available in nonpolar orientations. Unfortunately, the as-received substrates require a dedicated annealing procedure to achieve atomically flat surfaces [3].

In this presentation we show a drastic improvement of the structural properties when the QWs are grown on ZnO substrates: no residual strain, smooth interfaces, no extended defects, reduced surface roughness, reduced X-Ray FWHM. A strong enhancement of the photoluminescence (PL) properties is also demonstrated compared to heteroepitaxial QWs[4]. In addition the polarization dependent PL evidences the expected selection rules in these orientations [5]. Then we shall compare the different nonpolar orientations (*m*- or *a*-planes). The PL intensity of an *m*-plane QW is constant as a function of the temperature up to RT [6]. Our results demonstrate the interest of homoepitaxial QWs for bright UV emission applications.

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Fr-01
Friday 09:30-09:45

The role of Mg in controlling the hole confinement energy in ZnTe/ZnSe based quantum dot structure grown by migration enhanced epitaxy

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Introduction of sub-monolayer quantities of Te in ZnSe led to formation of type-II ZnTe quantum dots (QDs) embedded in ZnSe, which co-exist with Te isoelectronic centers [1]. The carrier confinement in type-II system such as Zn-Se-Te is independent of the band gaps of the underlying materials, rather depends on the band offsets. For advancing the bi-polar doping in Zn-Se-Te system, where ZnSe can be radially doped p-type and ZnTe can be radially doped p-type, we have modified the ZnTe QD band-offset by incorporating sub-monolayer quantities of Mg along with Te. Incorporation of Mg in Zn-Se-Te system, while increases the band gap, lowers the valence band maximum relative to that of ZnTe, thus reduce the valence band offset with ZnSe due to absence of cation core *d* electrons in MgTe. This is expected to reduce the hole confinement energy and the enhance the p-type conductivity in Zn-Se-Te system where a net acceptor concentrations in the order of 10^{18} was achieved previously [2, 3] without observation of free carriers due to a large hole confinement energy within the QDs.

Here, we report the results of the high resolution x-ray diffraction and photoluminescence (PL) spectroscopy, and Hall effect measurements of nitrogen-doped Zn(Mg)Te/ZnSe QD multilayer structures, grown by incorporating sub-monolayer quantities of Mg along with Te periodically during growth. The thickness, composition, strain and relaxation of the multilayers are determined by comparing the experimental spectra to simulated ones for the allowed (004) and quasi-forbidden (002) reflections. We also investigate the activation processes involved in PL quenching of the QDs, and their lateral and vertical correlations from reciprocal space mapping. Excitation intensity dependent PL study shows that these multilayer structures form QDs with type-II band alignment. The p-type conductivity at room temperature is obtained with observed a hole free carrier concentration in the order of ~10^{16} cm^{-3}.

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Fr-02
Friday 09:45-10:00

Size and quality control of fast grown CdS quantum dots

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The synthesis of high quality II-VI semiconductor quantum dots (QDs) is fundamental for developing new devices in several applications such as biomarkers, solar cells or blue-UV lasers. These emerging technologies are funded on the size-dependent optical properties of the QDs.

Consequently, it is a crucial aspect to get insight about different ways for syntheses of there nanosized particles. In this work, we use two different QD elaboration methods: i) a single source precursor thermal growth methodology and ii) a microwave synthetic route. Using both protocols, high quality small QDs (Ø< 5 nm) are produced. Both growing techniques offer the advantage to be simple and fast: 2 hours (i) and less than 25 minutes (ii) in duration, growth temperatures do not exceed 280°C.

For both elaboration procedures, we report a unique physics/chemistry cross-disciplinary study on these small size QDs: mass spectrometry (MS) technique provides background data about composition, size and stability of particles; crystalline structure and size distribution of the QDs are obtained from X-ray diffraction (XRD) and transmission electron microscopy (TEM); room temperature (RT) optical spectrometry of nanodispersions - photoluminescence (PL) and absorption – reveals quantum size effects.

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Fr-03
Friday 10:00-10:15

ZnTe-based micropillars containing CdTe quantum dots

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Semiconductor microcavities (MCs) can be used to tailor the photonic density of states if light is confined on the wavelength scale. By combining them with semiconductor nanostructures like quantum dots (QDs), light-matter interaction can be studied in a controlled manner and utilized for several applications. Here we report on the realization of Te-based MCs reaching a high quality (Q) factor of several thousands for the first time and a novel deposition technique for CdTe QDs. A promising application is the insertion of single Mn ions into the QDs for investigations concerning quantum information science. Furthermore, the structures can be used for the realization of a yellow vertical-cavity surfaceemitting laser (VCSEL), e.g. for data transmission based on plastic optical fibers (POFs).

The growth of the structure was performed by molecular beam epitaxy (MBE) on GaAs substrate. Prior to the growth of the microcavity structure a 1 μm thick fully relaxed ZnTe buffer layer has been deposited, which acts as a quasisubstrate with the natural ZnTe lattice constant. The two DBRs (20 periods bottom DBR, 18 periods top DBR) consist of 53 nm thick ZnTe layers as the high refractive index material and 18 period MgSe(1.3 nm)/ZnTe(0.7 nm)/MgTe(0.9 nm) triple superlattices for the low index layers (for details concerning DBRs see [1]). The 212 nm thick ZnTe cavity contains a single CdTe quantum dots sheet at the antinode position of the optical mode, i.e. the field maximum. The QDs are formed by a Zn induced reorganization of a thin CdTe layer. The CdTe layer is deposited using migration enhanced epitaxy (MEE), i.e. the alternating supply of Cd and Te interupted by a pause as well as the ZnTe cap layer which covers the QDs. Investigations using transmission electron microscopy (TEM) reveal a typical lateral size of 5 - 10 nm and a height of 2 nm for the QDs.

Micropillars of different diameter have been prepared out of the planar cavity by focused ion beam (FIB) milling. Micro-photoluminescence (μPL) measurements show discrete optical modes with a Q factor up to 3100. The cavity modes were computed using a vectorial transfer matrix method and show a good agreement with the experiment. The use of GaSb as a substrate allows pseudomorphic growth of the MC structures which leads to a reduced defect density. The properties of samples deposited on GaAs and GaSb will be compared.

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Fr-04
Friday 10:15-10:30

Charge control and storage in self-assembled CdTe quantum dots

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We present charge control in single CdTe quantum dots embedded in a field-effect structure. It allows us to investigate Coulomb interactions, which determine the charge distributions. Moreover, we use this device to demonstrate electron storage in an ensemble of dots. We study the dynamical properties of charge leakage and device switching – both crucial for potential applications in high speed devices.

In order to exploit the potential of quantum dots (QDs) for applications in information processing, the tunability of the QD charge state is essential. It is done routinely in the InGaAs system and has lead to observations of such effects as Coulomb blockade, dynamic nuclear polarization, and coherent preparation of a QD spin state. Charge storage in QDs allows to develop schemes for dynamical manipulation and readout of quantum information from these nanostructures. However, data on charge control and storage in II – VI systems is scarce. In this report, we demonstrate charging of a single CdTe dot in ZnMgTe barrier embedded in a field-effect structure. We analyze the quantum confined Stark shifts of photoluminescence (PL) transitions, which allows us to access charge distributions related to different excitonic complexes. We find that the electron wave function is stiffer than that of the hole [1]. This conclusion is corroborated with a time-resolved PL study, where the electron-hole wave function overlap determines the PL lifetime [1]. From both cw and time-resolved experiments we conclude that in this II – VI sytem the exciton wave function is not a simple product of electron and hole wave functions but rather a Coulomb-correlated one.

We also demonstrate that electrons can be written, stored, and read out from these dots after as long as 10 miliseconds. We show that their escape mechanism is related to tunneling out of the dots and that the dynamics of this process is self-consistently dependent of the electron density as it generates an additional electric field, which screens out the applied one [2]. A semi-classical model based on a WKB approximation quantitatively reproduces the experimental results for dots with different sizes and explains results as a function of the write time [2]. Moreover, we analyze the switching dynamics of the device and address the role of the build-up of the screening field and hole diffusion from the back contact.

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Tu-P01
Tuesday 18:30-20:30

Spin injection in heterovalent structure with coupled quantum wells GaAs/AlGaAs/ZnMnSe/ZnSe

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Performing injection of spin polarized charge carriers is mandatory for the realization of most of the components proposed for spin electronics. The main limiting factor of spin injection efficiency is the relaxation of spin polarization during the transport process of the carriers from the injector into the active region of the device. In order to minimize spin polarization losses, shortening of the carrier transport time is required; this can be achieved by tunneling transport in coupled quantum wells.

In this work we investigate the phenomenon of tunneling spin injection in a heterovalent structure A^3B^5/A^2B^6 grown by molecular beam epitaxy and comprising a ZnMnSe diluted magnetic semiconductor spin injector as well as two coupled non-magnetic GaAs/AlGaAs quantum wells. Spin injection is achieved by tunneling of photoexcited spin-polarized electrons from the ZnMnSe injector first into the thin, and then into the wide GaAs quantum well.

The parameters of the spin injection were obtained by comparing the dependence of the degree of circular polarization of the low temperature emission spectra under external magnetic field (up to 4.5T) parallel to the growth axis, for both the heterovalent structure and a reference isovalent non-magnetic sample (structure without ZnMnSe-injector layer), on the photoexcitation energy: 3.29 eV – above ZnMnSe absorption edge, 2.33 eV – under this edge and 1.78 eV – under AlGaAs absorption edge.

Modeling of the light absorption and carrier transport processes allowed distinguishing two contributions to the circular polarization degree: one due to the diffusion of electrons from the AlGaAs barrier, and the second one caused by tunneling injection from the ZnMnSe layer. Partial polarization of electrons generated within the barrier under magnetic fields occurs due to the noticeable intrinsic electron g-factor in AlGaAs [1]. An upper limit to the loss of spin polarization under an external magnetic field of 4.5 T (we suppose that the electrons generated in ZnMnSe layer are fully spin-polarized) and under assumption than $\tau_s >> \tau$ was estimated at about 60%, where τ_s is the spin polarization lifetime of the electrons and τ is the radiative recombination time of the excitons. A more realistic lifetime ratio of $\tau_s / \tau \sim 1$ yields a value of ~ 20% for the loss estimation.

The obtained results testify the attractiveness of such heterovalent A^3B^5/A^2B^6 structures as part of devices providing effective tunneling transport of spin-polarized charge carriers.

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Tu-P02
Tuesday 18:30-20:30

Epitaxial growth of high-quality $Mg_xZn_{1-x}O$ films by a plasma-assisted reactive evaporation method using ZnMg alloys as a source material

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Epitaxial growth of high-quality $Mg_xZn_{1-x}O$ films was achieved by a plasma-assisted reactive evaporation (PARE) method using ZnMg alloys. Use of ZnMg alloys as the source material reduced the number of growth parameters to be controlled. Composition of Mg in $Mg_xZn_{1-x}O$ films grown by using this method strongly depended on composition of Mg in ZnMg alloys. The crystal structure of $Mg_xZn_{1-x}O$ films with $x \leq 0.24$ was wurtzite and the band gap energy of $Mg_{0.24}Zn_{0.76}O$ films was 3.83 eV.

$Mg_xZn_{1-x}O$ films were grown on Zn-faces of single crystal ZnO substrates by the PARE method [1]. ZnMg alloys with several Mg compositions (7.5, 15, 25, 30 wt%) were prepared as starting metals of Zn and Mg. Mixed vapors of Zn, Mg, and ZnMg etc. evaporated from a crucible containing pellets of ZnMg alloy passed through the plasma area of O_2 gas excited by radio frequency (RF) of 13.56 MHz. Pressure in the growth chamber and RF power applied to the plasma were 0.1 – 0.2 Pa and 50 – 150 W, respectively. The temperature of substrates was 600 - 750 ˚C during the growth of $Mg_xZn_{1-x}O$ films. The growth rate of films was 3.0 – 3.5 nm/min and film thickness was 600 – 800 nm. Composition of $Mg_xZn_{1-x}O$ films was determined by EDX analysis. The crystal structure of $Mg_xZn_{1-x}O$ films was determined by XRD. Surface morphology of $Mg_xZn_{1-x}O$ films was observed by using AFM. Band gap energy of $Mg_xZn_{1-x}O$ films was estimated from the reflectance spectrum measured at room temperature.

Mg composition in $Mg_xZn_{1-x}O$ films increased with increase in the composition of Mg in ZnMg alloys from 7.5 to 30 wt%. The maximum value of x in the $Mg_xZn_{1-x}O$ films was 0.24. The peak position of XRD from $Mg_xZn_{1-x}O$ (0002) of a wurtzite structure shifted to high angle with increase of Mg composition in $Mg_xZn_{1-x}O$ films, and a rock salt structure was not observed. FWHM values of the XRD peak of $Mg_xZn_{1-x}O$ films were 40-50 arcsec. The root mean square roughness of the surface of $Mg_xZn_{1-x}O$ films was 1.0 nm or less. The band gap energy increased from 3.38 to 3.83 with increase of x in the $Mg_xZn_{1-x}O$ films from 0.01 to 0.24.

High-quality $Mg_xZn_{1-x}O$ films were epitaxially grown by the PARE method using ZnMg alloys. This new method is more controllable than are other methods and is useful for preparation of devices based on ZnO compounds such as UV-LEDs.

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Tu-P03
Tuesday 18:30-20:30

Selective etching of InGaAs/InP substrates from II-VI multilayered structures.

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II-VI hetrostructures and devices are predominantly grown on commercially available III-V substrates. These substrates have absorption energies lower than that of the deposited layer; a problem for some device applications or when transmission measurements are required. By removing the epilayers from the substrate their properties are unhindered by the substrate.

Removal of epitaxial layers has been demonstrated regularly in III-V materials using both selective etching and lift-off techniques [1]; the use of a MgS sacrificial layers for lift-off has been shown to be successful in removing II-VI epilayers from GaAs substrates [2]. A large proportion of II-VI device research consists of structures grown on InP, thus an alternative method of substrate removal is required. Currently, a sacrificial layer of MgSe is being examined for use in the lift-off of II-VI structures from InP substrates. However, for some applications, this technique is not an option, as it negates the use of MgSe within the device structure. As an alternative, selective wet etching of the III-V substrate is presented here.

For the fabrication of high quality epitaxial structures interface preparation is crucial to reduce crystalline defects and maintain excellent structural quality. Lattice matched buffer layers of InGaAs are typically grown on InP prior to the deposition of the II-VI epilayer to ensure the surface is atomically flat and terminated by As [3]. This presents a problem as this layer also has an absorption coefficient such that it will absorb at the wavelengths generated by II-VI materials. There are already techniques reported for removal of InP substrates using various mechanical and chemical processes, however there are little studies on the appropriate etchant and etching conditions for removal of InGaAs without damaging the II-VI layer.

In this paper various solutions for etching of InGaAs are investigated. Etch rates for both InGaAs and II-VI epilayers were measured using step profile characterization. An etch solution of H_3PO_4:H_20_2:H_2O (1:1:6) was found to have the best selectivity ratio of 40:1. With this etch solution and some simple processing techniques, samples of varying complexity have been removed from the InGaAs/InP substrate and transferred to glass slides. Little structural change was observed after substrate removal. PL spectra were taken before and after etching exhibiting similar features for both. Transmission measurements were taken to obtain refractive index and absorption values for several multilayer structures.

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Tu-P04
Tuesday 18:30-20:30

Influence of dopant transport rate upon photoluminescence and electrical properties of phosphorus-doped ZnMgTe layers grown by MOVPE

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$Zn_{1-x}Mg_xTe$ ternary alloy is a candidate material for optoelectronic devices in green-to-blue spectrum region. Nominally undoped $Zn_{1-x}Mg_xTe$ epitaxial layers have been successfully grown on (100) ZnTe substrates by metalorganic vapor phase epitaxy (MOVPE) using dimethylzinc (DMZn), bis-methylcyclopentadienyl-magnesium ($(MeCp)_2Mg$) and diethyltelluride (DETe), and the growth parameters for control of Mg composition and for improvement of optical property were revealed [1,2]. However, intentional doping is essential for device applications, there is lack of doping study of MOVPE grown $Zn_{1-x}Mg_xTe$ layer. As for ZnTe layer, tris-dimethylaminophosphorus (TDMAP) is considered to be a suitable dopant source for achieving p-type doping over a wide range of carrier concentration with high optical quality [3]. In this study, we investigated the effects of dopant transport rate upon photoluminescence (PL) and electrical properties of phosphorus (P)-doped $Zn_{1-x}Mg_xTe$ layer grown by MOVPE using TDMAP. Mg composition x was focused on small value less than 0.1 in order to facilitate grasping the influence of Mg in P-doping. The growth of P-doped $Zn_{1-x}Mg_xTe$ layers was performed on semi-insulating gallium-doped (100) ZnTe substrates by using a horizontal-type atmospheric pressure MOVPE system. The growth conditions were chosen to obtain $Zn_{1-x}Mg_xTe$ layers with a slight Mg composition x around 0.07 by referring to the previous studies [1,2]. Photoluminescence spectra at 4.2 K of as-grown layers were considerably changed by adding TDMAP, consistent with the fact that the carrier concentration of the layers was increased from 8×10^{13} cm^{-3} to $(2\sim3)\times10^{16}$ cm^{-3}. The spectra were characterized by P acceptor-related excitonic and donor-acceptor pair emissions together with weak free exciton emission, indicating p-type $Zn_{1-x}Mg_xTe$ (x~0.07) layers of good quality. By the post-annealing treatment in nitrogen, the carrier concentration was significantly enhanced, similar to the case of P-doped ZnTe [3]. The carrier concentration for both as-grown and post-annealed layers shows saturated tendency with TDMAP transport rate. The maximum carrier concentration of the post-annealed layers is as high as 2×10^{19} cm^{-3}. Then, a use of TDMAP may be useful for obtaining highly conductive p-type $Zn_{1-x}Mg_xTe$ layer. Also, the annealing treatment seems to be more effective for P-doped $Zn_{1-x}Mg_xTe$ (x~0.07) than P-doped ZnTe.

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Tu-P05
Tuesday 18:30-20:30

Laser characteristics of heterostructures with multiple CdSe QD sheet active region and asymmetric graded index superlattice waveguide

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(Zn)CdSe/ZnSe quantum dot (QD) undoped heterostructures optically pumped by emission of InGaN laser diodes are promising candidates for creation of compact lasers emitting in the 500-550 nm spectral region [1]. These lasers are of great demand for numerous applications like handheld laser projection multimedia systems etc. Recently we have demonstrated the high external quantum efficiency (50%) II-VI lasers with multiple electronically-coupled CdSe/ZnSe QD sheets [2] as well as the ultralow threshold (1.5 kW/cm^2) single QD sheet lasers with graded index superlattice (SL) waveguide (GIW) specially designed to promote effective charge carrier transport into the active region [3].

This paper reports on comprehensive studies of laser parameters of optimized structures combining active region with five electronically-coupled QD sheets and the Zn(Mg)SSe/ZnSe SL GIW. Moreover, to enhance the optical confinement factor the asymmetric GIW shoulders were proposed according to numerical calculations of the wave equation. The optimized lasers structures emitting in the spectral range of 545-551 nm were grown by molecular-beam epitaxy on GaAs substrates using a two-chamber STE3526 setup (SemiTEq). Laser chips made by cleaving were excited in transversal optical pumping geometry by radiation of a pulsed N_2-laser (λ=337.1 nm, τ_p=10 ns).

Internal laser parameters were determined by measuring laser threshold and reciprocal differential quantum efficiency as functions of the cavity length. The values of the internal quantum efficiency, internal optical loss, characteristic gain and transparency threshold were estimated to be η_i =80.5%, α_i=3.2 cm^{-1}, ΓG_0=135 cm^{-1} and I_T=1.35 kW/cm^2, respectively. Thus, lasers of the novel design demonstrated the highest internal quantum efficiency ever reported for II-VI lasers and high enough characteristic gain. Based on the defined parameters, the values of minimal threshold pulse power and corresponding optimal cavity length were determined as prerequisites for application the structure in a violet-green laser converters [1]. It was shown that the minimal threshold power decreased significantly (more than by 20%) in comparison with similar heterostructures with the flat-band waveguide, while the optimal cavity length is 70-110 μm.

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Tu-P06
Tuesday 18:30-20:30

Colloidal CdSe/ZnS quantum dots for bionanosensing applications

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Semiconductor quantum dots are promising candidates for the utilization of nanosensing systems in the wide field of biotechnology. We report on colloidal CdSe/ZnS quantum dots that are providing a basis for time resolved bionanosensing techniques. The inorganic core-shell dots have been coated with amphiphilic polymers in order to enable a transfer into aqueous solution. Subsequently, the polymers have been functionalized by fluorophore molecules. In such geometry the dye molecules act as acceptor of the quantum dot donors´ excitation. The energy transfer dynamics has been investigated in detail by cw and time-resolved optical spectroscopy. Choosing different sizes of the quantum dots allows for tuning the spectral overlap between the semiconductor dot emission and dye absorption and improving the respective transfer quantum efficiency. The experimental results have been analyzed within a kinetic model which enables precisely to reveal the respective contributions of reabsorption and radiationless transfer rates. We found, that the Förster-like dipole-dipole transfer is more dominating the smaller the distance between the core of the inorganic Q-dot and the dye molecules. Recently we discussed, how this mechanism can be used to realize a multiplex-sensing approach based on dye-functionalized nanoparticles [1]. A common detection technique is fluorescence detection of analyte-sensitive fluorophores. The fluorescence emission intensity depends on the presence of a specific analyte. Multiplexed measurements can be realized by using different dyes with very different spectral emission range. In this paper we show that a distinction of spectral similar fluorescence dyes is also possible by using time resolved spectroscopy and respective modelling. By coupling different fluorophores to nanoparticles with different fluorescence lifetimes serving as donor for the excitation transfer, the effective fluorescence lifetime of the organic fluorophores as acceptor can be tuned by the radiationless resonance energy transfer. Thus, the fluorophores can be distinguished by their effective lifetimes.

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Tu-P07
Tuesday 18:30-20:30

Modification by thermal annealing of the luminescent characteristics of CdSe quantum dots in gelatin films

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Colloidal II-VI semiconductor quantum dots (QDs) embedded in polymeric matrixes have attracted much attention since they enable to create hybrid materials with improved optical and electrical properties. One of the important characteristics of composite materials is their thermal stability.

Here we present the results of our study of the influence of thermal annealing on the luminescent and optical characteristics of colloidal CdSe QDs in polymer films of gelatin. The presence of crystalline CdSe phase in the films is proved by the X-ray diffraction study. The photoluminescence (PL) spectra of the films consist of the band-edge and defect-related bands. Thermal annealing of the films between 100 and 200 ºC in air is found to result in the spectral shift of both PL bands to lower energies and a decrease of the PL intensity. In the PL excitation spectra, the maximum associated with the light absorption by the QDs also shifts to lower energies upon thermal treatment. The effects are observed for QDs of different sizes and are found to be reversible. The passivation of CdSe nanocrystals with ZnS shell reduces the effects. In the Raman spectra, the position of LO phonon peak of CdSe nanocrystals does not change upon annealing.

The effects are explained by an appearance of extra charge in the ensemble of QDs due to the break of the bonds of cadmium surface atoms with functional groups of gelatin molecules. The effect of spectral shift is supposed to be due to a quadratic Stark effect, while the change of the PL band intensity is attributed to the change of the height of potential barrier for carrier escape from the QDs.

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Tu-P08
Tuesday 18:30-20:30

X-Ray Photoelectron spectroscopy of white light emitting magic sized CdSe nanocrystals

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A large number of II-VI and III-V semiconductors nanocrystals have been studied over the years because of their size and band gap tunable optical properties, and their application in miniaturizing optoelectronic devices. Significant studies have been done in the synthesis and characterization of CdSe nanocrystals. Also, their surface has been studied using x-ray photoelectron spectroscopy (XPS). [1] Recently pyrolytically grown white light emitting magic sized CdSe nanocrystals with first absorption feature at 414 nm and exhibit broadband emission (420-710 nm) shows no band edge emission that that is typical to small nanocrystals that are less than 30Å. [2] Due to the extreme surface-to-volume ratio, the electron and hole apparently interact on the surface that produces broad emission covering the entire visible spectrum. For technological interest as white light phosphor for application in white light emitting diodes (LEDs), it is important to understand the surface coverage and oxidation of these nanocrystals. This paper reports the surface, oxidation and electronic structures of these extremely small sized white light emitting CdSe NCs using XPS. Results shows that the magic sized NCs has larger oxidized area compared to a larger sized NCs which is due to the higher coverage area with more surface ligands and their interaction with the electrons and holes on the surface.

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Tu-P09
Tuesday 18:30-20:30

Effect on the optical properties of CdS nanoparticles synthesized with different capping agents

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Semiconductor nanoparticle has emerged as an important class of material that offers great promise to a diverse range of applications ranging from energy conversion to biomedicine. The synthesis of these nanoparticles is an important aspect of the research, due their water-solubility, simple chemical modification well dispersed and stabilized nanoparticles by utilizing polymer, surfactant, ligand or capping agent.
Cadmium sulfide nanoparticles were synthesized using chemical method in aqueous solution. During synthesis three capping agents, i.e. glucose, maltodextrin and polyethylene glycol, were used and the effect of concentrations was analyzed for their effectiveness in limiting the particle growth. The optical properties of each surfactant-capped cadmium sulfide nanoparticles were investigated at room temperature photoluminescence. The observed absorption peak shift is used for evaluate the average size of cadmium sulfide nanoparticles in terms of the effective mass model for spherical particles with a Coulomb interaction. The morphology and the crystalline structure were measured by transmission electron microscopy (TEM) and x-ray diffraction (XRD), respectively. Particle size of the particles obtained from these experiments correlates well with the optical absorption spectroscopy and Scherrer´s formula from XRD patterns. Thus the presence of surfactant on the surface of cadmium sulfide plays a significant role controlling the size of the particle. XRD analysis revealed single crystal cadmium sulfide nanoparticles of size 3 nm in case of maltodextrin capping.

Tu-P10
Tuesday 18:30-20:30

Raman scattering characterization of $Zn_{1-x-y}Be_xMg_ySe$ crystalline alloys

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$Zn_{1-x-y}Be_xMg_ySe$ solid solutions are of particular interest for their potential application in photodetectors operating in the blue-violet and ultraviolet spectral range [1], in constructing blue LD and long life white LEDs [2]. Beryllium chalcogenides have strong covalent bonding that makes the material robust against defects generation and propagation. Thus, beryllium can be used to enhance the crystal lattice rigidity in II-VI alloys that will improve the performance of ZnSe-based devices [3]. Taking into account that Be-containing chalcogenides exhibit a large amount of covalent bonding, the sharp contrast between the stiffness of the covalent-like Be–Se and the other ionic-like Zn–Se and Mg–Se bonds have resulted in an additional mechanical disorder superposing on the chemical disorder in the quaternary $Zn_{1-x-y}Be_xMg_ySe$ system. Raman scattering (RS) is well suited for investigation of such mechanical disorder because it addresses directly the force constants of the bonds, which is highly sensitive to the mechanical properties of the host lattice.
The longitudinal optical (LO) and transverse optical (TO) phonons of zinc-blende $Zn_{1-x-y}Be_xMg_ySe$ solid solutions are determined by RS. The room temperature RS spectra consist of ZngSe-like, MgSe-like and BeSe-like optical (LO and TO) as well as longitudinal acoustical phonon modes. The Be–Se region exhibits a two-mode behavior, i.e. Be-rich region (h) and the soft (Zn,Mg)-rich region (s) display distinct mode characteristics. The random character of Be incorporation in $Zn_{1-x-y}Be_xMg_ySe$ is deduced from the strength balance between the h- and s-like TO modes. In addition, by analyzing the polarization-dependent character of the LO and TO RS modes the main crystal axis and planes of the investigated sample were identified.

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Tu-P11
Tuesday 18:30-20:30

Optical characterization of $Zn_{0.35}Cd_{0.44}Mg_{0.21}Se$ crystalline alloy by polarization-dependent contactless electroreflectance measurements

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$Zn_{1-x-y}Cd_xMg_ySe$ semiconductor is an interesting material for potential applications in ultraviolet to visible range emitters [1], infrared (IR) photodetectors [2], distributed Bragg reflectors [3], and mid-IR quantum cascade emitters [4]. Although a number of articles devoted to the preparation and the study of the physical properties of $Zn_{1-x-y}Cd_xMg_ySe$ thin layers have been published, only a very limited number of literature concerning the mechanisms of luminescence processes and fundamental transitions in bulk $Zn_{1-x-y}Cd_xMg_ySe$ solid solutions have been reported. The knowledge of the basic optical properties of these solid solutions is important for proper device applications.

An optical characterization of wurtzite $Zn_{0.35}Cd_{0.44}Mg_{0.21}Se$ crystalline alloy grown by the modified high-pressure Bridgman method was carried out by temperature-dependent photoluminescence (PL) and polarization-dependent contactless electroreflectance (CER) in the temperature range of 10–300 K. Low temperature PL spectra of the investigated sample consisted of the excitonic line, the "edge emission" due to radiative recombination of shallow donor-acceptor pairs and a broad band related to recombination through deep level defects. The CER experiment observed three excitonic features *A*, *B*, and *C* in the vicinity of band edge showing polarization-dependent character well known for wurtzite-type crystal lattice. The peak positions of band-edge excitonic features in the PL spectra were shifted slightly towards lower energies as compared to the lowest corresponding transition energies of *A* exciton determined from CER. In addition, the parameters that describe the temperature dependence of the transition energies and broadening parameters of the band-edge excitonic transitions were evaluated.

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Tu-P12
Tuesday 18:30-20:30

Estimation of the density of electrical carriers of n-ZnSe by photoreflectance spectroscopy*

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By means of room temperature photoreflectance spectroscopy (PR) we have studied *n*-ZnSe/GaAs heterostructures grown by molecular beam epitaxy (MBE). The *n*-type doping was produced by evaporation of $ZnCl_2$ from an effusion cell. By increasing the cell temperature a higher amount of Cl is introduced in the ZnSe films, however, not all the Cl atoms will be electrically active, beyond certain amount of Cl incorporation the electrical properties and the photoluminescence emission are degraded [1]. The films were grown on top of semi-insulating (001) substrates. Before the growth of the doped layer a thin layer (around 40 nm thickness) of non-doped ZnSe was deposited. The PR spectra were obtained employing the 405 nm line of a diode laser with a typical PR setup. The spectra of the ZnSe films exhibit features which can be directly correlated with the amount of Cl incorporated in the films, both the total and the electrically active atoms. The PR transitions were fitted employing the Aspnes model [2]. After the determination of the Cl induced carrier concentration from Ref. [1], we observe a clear correlation of the normalized amplitude of the ZnSe transition with respect to the amplitude of the GaAs transition (A_{ZnSe}/A_{GaAs}), the ZnSe/GaAs interface is the same for all samples. The larger the carrier content, the larger the ratio of amplitudes, with a maximum for around $1.2x10^{19}$ cm^{-3}, then this amplitude appears to be related only to the amount of electrically active carriers and not to the total amount of Cl in the films. With regard to the broadening parameter, the ZnSe films present a larger value for a larger total amount of Cl. Therefore, after proper calibration, the non-contact, non-destructive PR spectroscopy can be employed as a simple and reliable method for the estimation of the carrier concentration and total amount of Cl incorporated in the ZnSe epitaxial films.

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Tu-P13
Tuesday 18:30-20:30

New ultraviolet avalanche photodiodes (APDs) of organic (PEDOT:PSS) – inorganic (ZnSSe) hybrid structure

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Ultraviolet avalanche photodiodes (APDs) are attractive new optical device which plays a key-role in establishment of next-generation ultra large capacitive optical storage system, new medical X-ray technology and astronomical measurement. A development of wide bandgap semiconductor photodiodes has been made a rapid progress around the world. Up to now, we have already reported that the ZnSSe n^+-i-p structure avalanche photodiodes (APDs) with an extremely thin n^{++}-ZnSSe window layer (>10^{19}/cm^3, 300Å) revealed high sensitivity of ~5A/W at the blue region (450nm) [1]. But, the sensitivity of this APD was found to decreases markedly in ultraviolet region due to the large optical absorption loss from thin ZnSSe n^{++}-window layer.
In this study, we have developed organic-inorganic hybrid Schottky-type APDs by using UV transparent conducting polymer film as the window layer on a ZnSSe/n-GaAs wafer. The ultraviolet APD operation in new organic-inorganic hybrid structure device is demonstrated for the first time.

[Device Process and Structure]
First, the ZnSSe film structure on GaAs was grown by molecular beam epitaxy (MBE). The device structure is i-ZnSSe (active layer, 0.3μm) / n-ZnSSe (0.5μm) / n-ZnSe (200Å) / n-GaAs substrate. Then, we have formed organic polymer film (PEDOT/PSS:3,4-ethylenedioxythiophone/styrenesulfonate) by spin coating method on the i-ZnSSe epitaxial layer. The thickness of PEDOT:PSS layer is 150nm, and transmittance in ultraviolet region of 300~400nm is over 85%. The energy barrier height between i-ZnSSe and PEDOT:PSS obtained from the photo response measurement is evaluated as 1.0eV, which is sufficient value to reduce dark thermally activated current under APD high field condition (E_{APD}~6×10^5V/cm).

[UV-APD Performance]
In the dark condition, we observed a distinct avalanche breakdown characteristic in the reverse bias of 28V at 300K. This breakdown process has been confirmed as an intrinsic avalanche breakdown process from temperature dependent characteristic of the breakdown voltage. A maximum avalanche gain of G=120 was demonstrated in UV-region (325nm) under reverse bias of 28.1V at room temperature. This extremely small avalanche breakdown voltage (-28V) is one order smaller than that of commercial Si-APD, which is due to direct carrier(hole) injection into spin-orbit split-off valence band (with small hole effective mass). The low APD operation voltage of the present hybrid-APD device (about 1/10 times of Si-APD) is very important to develop the integrated UV-APD device in the future.

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Tu-P14
Tuesday 18:30-20:30

Geometry dependence of two photon absorption in CdS dots and rods

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Optical materials with high nonlinear coefficients are ideally suited to use their two photon absorption based effects, e.g. for 3D optical data storage elements. The highly localized two photon excitation and high intrinsic spatial resolution of nanopartricals makes them a candidate for storage media of Tbits/cm^3. Other applications include optical switching in communication networks, optical limiting for damage prevention in fiber networks and high resolution two photon luminescence in biology.
To understand the nonlinear effects at a nanoscale, it is necessary to study the spatial confinement and its influence on the nonlinear optical properties of CdS nanodots and rods. A Z-Scan technique and Two Photon Luminescence (TPL) were employed to investigate the influence of spatial quantization. The expected strong geometry and size dependence of the two photon absorption cross section and refractive index has been tested by series of colloidal CdS dots and rods starting from near 0D systems to longer 1D nanorods. Changes of volume normalized TPA absorption coefficient at the transition from dots to elongated rods will be discussed. Additional Two Photon Luminescence Excitation (TPLE) measurements reveal the spectral dependence of the TPA coefficients. The Influence of resonant and kontinuum excitation on the two photon absorption crossections is investigated based on a reference dye method. The two complimentary methods Z-Scan and TPL achieve a good agreement of the obtained TPA coefficients.

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Tu-P15
Tuesday 18:30-20:30

Emission of exciton and biexciton dressed states in a CdTe quantum dot

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Semiconductor quantum dots (QDs) present discrete excitonic energy levels with an atom-like light-matter interaction. This makes them attractive for nanoscale quantum optics experiments and application like single photon sources for quantum key distribution. However, as compared to atoms, QDs show a strong spectral dispersion which is a limitation for there use as sources of identical photons. A tool is needed for a fine and independent tuning of their energy to ensure a spectral overlap of the emitted photons.

Here we show that a resonant continuous wave laser field can be used to tailor the emission energy of an individual QD. The vacuum-to-exciton or the exciton-to-biexciton transitions in a CdTe/ZnTe QD are optically dressed by a strong laser field. A pump laser tuned on an excited state of a single QD is used to generate photoluminescence (PL) from the exciton and biexciton that are simultaneously dressed by the near-resonant single-mode control laser. Thanks to the large direct and exchange Coulomb interaction in these II-VI QDs, standard high resolution spectroscopy can be used to analyze the PL of the dressed QD. A power dependent Autler-Townes splitting is observed for any transition which shares a common level with the dressed transition. We demonstrate that the PL energy of any level of the exchange split exciton and biexciton can be tuned using the optical Stark effect controlled by the polarisation, intensity and detuning of the single mode laser. At the resonance, hybrid matter-field states are created. The measured Rabi splitting reaches 250 μeV and the QD levels can be well described by the dressed atom picture. This optical Stark effect could also be exploited to control the spin of an individual Mn atom in a II-VI QD [1]

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Tu-P16
Tuesday 18:30-20:30

Band bowing in $ZnSe_xTe_{1-x}$ and ZnS_xTe_{1-x} alloys

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The goal of this research is to understand the band formation in Zn(Se,Te) and Zn(S,Te) semiconductor alloys. Various measurements have shown bowing parameters up to 3 eV in these solid solutions. Such unusual large band gap bowing cannot be explained by the inevitable disorder induced bowing known for II-VI solid solutions like e.g. Zn(S,Se). For the III(N,V) semiconductor alloys it was shown that a huge band gap bowing is caused by a fundamentally different mechanism. Extremely different electronegativity or size between the substitutional ion N and the replaced ion causes a strong interaction between the localized electronic state and the conduction band edge. The Band Anticrossing Model (BAC) [1] was developed to explain such a strong bowing. It was successfully applied to various N containing III-V systems. In case of Ga(N, As) the localized N states lie above the GaAs conduction band edge. The interaction forms the new subbands, named E_-- and E_+-band.
It is the aim of the present paper to reveal whether or not the BAC model can be used to explain the strong bowing parameters even in case of the isovalent impurities S and Se in the ZnTe host.
Zn(Se,Te) and Zn(Te,S) layers have been prepared by MBE on GaAs substrates at a temperature of 340 °C. The concentration varies from a weak doping up to 15 % and 17 % of Selenium and Sulfur, respectively.
All the layers have been characterized by various optical methods at 10 K and room temperature. Photoluminescence, modulated reflectance and absorption spectroscopy measurements are used to fully determine both the emission and absorption characteristics of the system and by that help to gain further insight into the way the bands are formed.
The Se or S states are anticipated to lie above the conduction band edge of ZnTe. A remarkable difference between the III-V and the II-VI systems is that while the electronegativity of Nitrogen is almost double that of Arsenic, the respective difference is only about 20% between Te and that of Se or S. Also, the incorporation of the small N atoms in the GaAs results in strongly pronounced local strain fields, while the difference of the covalent radii of Te (135 pm) and Se (116 pm) or S (102 pm) is smaller.
Nevertheless, with increasing contents of Se and S the E_--band is strongly shifted to lower energies. When the impurity contents are high enough, the band gap energy rises again due to the bigger ZnSe and ZnS band gaps. For the Te rich side we can convincingly show that the BAC model is applicable, although we were not able so far to reveal the formation of the E_+-band.

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Tu-P17
Tuesday 18:30-20:30

A local study of the energy spectrum of electrons in CdSe/ZnSe QD structures by current DLTS and AFM

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In the last decade there has been a great interest in studying electrical and structural properties of QD heterostructures. CdSe/ZnSe QD structures are used as modeling objects, which are promising for use as an active area of green light emitters. Such structures are constantly explored; technology of their growth by molecular beam epitaxy (MBE) is improved and their optical properties are thoroughly investigated. Processes of emission and capture of charge carriers in diode-like QD structures can be studied by deep level (DL) transient spectroscopy (DLTS), but the value of an activation energy of DL is averaged along the large contact area defined by the area of the barrier contact, which greatly exceeds typical lateral extent of the quantum dots (QDs). As QDs have different sizes and therefore different values of electronic states energies, it is interesting to study the processes of electron emission from single QD or small group of QDs. This work presents the results of the study of the energy spectrum in CdSe/ZnSe structures with an array of QDs. The structures were grown on n+-GaAs(100) substrates by MBE and contained 1 or 15 layers of CdSe QD layers, separated by ZnSe barriers with thicknesses 12 – 200 nm depending on the sample. The samples were investigated by cathodoluminescence studies and electrical current DLTS with Laplace transforms (LCDLTS) in conjunction with atomic force microscopy (AFM). This method was used earlier to determine the local conduction band offset in the ZnCdS/ZnSSe structure with a single quantum well [1]. Dimensions of the study area did not exceed 70 nm, which was determined by the diameter of the AFM probe. When the density of QDs is about 10^{11} cm^{-2}, what was estimated from the AFM images and CDLTS measurements, in the active area of contact there were about 3-4 QDs. LCDLTS-spectra were measured at temperatures of 290-390 K. As a result, relaxation process was found corresponding to the emission of electrons from an energy level with activation energy ~ 620 meV. Such an emission was absent in the control sample without QDs layers. The activation energy value correlates with the results of CL measurements. This allowed us to conclude that the observed relaxation processes is due to the emission of electrons from the QDs. Thus, we have tested a new study method of temperature dependence of local current relaxation in the nanostructure because of changing the charge of a few QDs, which extends the capabilities of DLTS and AFM methods. This work was supported by Ministry of education and science of the Russian Federation.

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Tu-P18
Tuesday 18:30-20:30

Three-dimensional anisotropy studies of CdTe quantum dots

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In a standard microphotoluminescence study of quantum dots (QDs) optical axis is oriented parallel to the growth axis of the sample. Therefore a polarization of emitted photons is perpendicular to the growth axis of the sample. In this work we present the results of QDs microphotoluminescence study in a configuration with the optical axis perpendicular to the growth axis (edge emission). Using such configuration, we were able to explore both polarizations parallel and perpendicular to the growth axis.

We studied self-organized CdTe QDs in ZnTe matrix grown on GaAs and GaSb substrates using molecular beam epitaxy (MBE). Two alternative techniques were used in order to induce formation of dots from a thin CdTe layer. In the first technique the CdTe thin layer was covered by amorphous tellurium at a low temperature. Subsequently amorphous tellurium was evaporated at growth temperature before overgrowing with ZnTe. In the second technique, the CdTe thin layer was overgrown by ZnTe with high Zn content, without changing the temperature.

We present impact of the growth technique on optical properties of QDs: presence of wetting layer, dots density, spectral width and position of PL band [1]. Comparing dots grown on GaAs and GaSb substrate, enhanced emission is observed for dots grown on GaSb, which is almost lattice match to the ZnTe barrier. However, results related to the QDs anisotropy, appeared to be not dependent on growth conditions. Using the microphotoluminescence with the optical axis perpendicular to the growth axis, we found that more than 99% of QDs show the complete polarization perpendicular to the growth axis. This is in agreement with macro-photoluminescence results and with prediction done for heavy hole excitons. Surprisingly, we found also some sharp emission lines exhibiting a weak polarization degree. Moreover, the stronger polarization was parallel to the growth axis for them. Apart from polarization properties, we checked that such lines exhibit typical properties of QDs: excitation power dependence and temporal evolution such as biexciton – exciton cascade observed in photon correlation measurements.

We did magneto-optical measurements to get a deeper understanding of the observed unusual polarization anisotropy. We applied two configurations: with a magnetic field in a direction parallel or perpendicular to the growth axis. Results of the polarization resolved magnetooptical measurements are discussed in terms of multi-axis anisotropy of QDs.

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Tu-P19
Tuesday 18:30-20:30

Exciton transfer between ZnCdMnSe and ZnCdSe quantum wells

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Energy transfer of excitons between local energy minimum sites in semiconductor nanostructures such as quantum wells and quantum dots has been interested in the last two decades because of its basic aspects and its importance for next generation electronic devices. We studied tunneling transfer of spin polarized exciton in diluted magnetic semiconductor (DMS) and non-DMS (NMS) double quantum well (DQW) [1]. In this paper we report dynamics of exciton transfer between very thin DMS and NMS wells separated by a NMS barrier layer.

Asymmetric DQWs with a ZnCdMnSe DMS well 2 ML thick and a ZnCdSe NMS well 4 ML thick separated a ZnSe barrier layer 15 nm thick were grown on GaAs (001) substrates by using combination of ALE and MBE techniques. Only one electron and one heavy hole level are present both in the NMS and DMS wells. Polarization selective photoluminescence (PL), PL excitation and reflectance spectra were measured at 4 K in the Faraday geometry with magnetic field $B = 0 \sim 8$ T. Decay characteristic of PL was also measured with a streak scope and pulse laser excitation. Degree of circular polarization, $P = \{I(\sigma^+) - I(\sigma^-)\}/\{I(\sigma^+) + I(\sigma^-)\}$, of PL was measured as a function of magnetic field B for CW and pulse excitation, where $I(\sigma^{+(-)})$ is PL intensity due to down(up)-spin exciton recombination.

The DQW sample showed two PL bands at 2.745 and 2.774 eV at $B = 0$ T due to recombination of heavy hole exciton localized respectively in the NMS and DMS wells. The DMS well exciton showed a Zeeman splitting of 3 meV at 8 T, and the NMS well exciton showed no detectable splitting. The P of the NMS well PL showed a peculiar magnetic field dependence, that is, $P = 0$ at $B = 0$ T, -7.5% at 3 T, and +8.8% at 6 T under CW excitation. The PL from the NMS well after pulse excitation showed a double-exponential decay. The fast decay time τ_f was about 70 ps and independent of magnetic field. The slow decay time τ_s changed with magnetic field, from 700 ps at $B = 0$ T to 800 ps at 6 T. Ratio of the slow decay component to the fast decay component changed with magnetic field and different between for σ^+ PL decay and for σ^- PL decay. The polarization dependent PL decay caused a temporary P of 40% for $B = 6$ T. The experimental data were explained as a result of the Zeeman splitting of up- and down-spin exciton in the DMS well and exciton transfer from the DMS well to the NMS well.

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Tu-P20
Tuesday 18:30-20:30

Photoluminescence studies of CdS layers for solar cells

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Polycrystalline CdS films are used as the n-type layers in CdTe/CdS heterojunction solar cells. Different deposition methods have been studied for the preparation of efficient devices. For solar cells fabrication, chemical bath deposition (CBD) and close-spaced sublimation (CSS) techniques are mostly used. The highest efficiency small area solar cell devices have been achieved using n-type CdS layers grown by CBD and p-type CdTe grown by CBD having record conversion efficiencies of 16.5%. [1]. The CSS technique allows large area deposition. The solar cell performances are found to be greatly influenced by the CdS growth conditions and post-growth annealing. To understand in details the changes in the material, photoluminescence (PL) studies can be very useful. A better understanding of the defect formations via PL studies would lead to an optimization of the heterojunction growth. Indeed, PL probes optically active recombination centers in CdS. Some of these will contribute to losses in photocurrent of solar cell devices due to optical absorption in the CdS window layer. PL can also provide information about impurity and defect centers which act as recombination centers for charge carriers. Indeed, it is known that the CdS material is highly compensated with comparable densities of shallow donor and deep acceptor states [2]. The presence and the activation of those impurities and defects lead to a loss of the photo-generated carriers. PL studies allow an understanding of how changes are likely to occur during solar cell preparation and how to prevent the activation of recombination centers [3].

In this study, we focuse on PL measurement performed on polycrystalline CdS films grown by CSS or CBD in order to observe the evolution of PL features according to deposition technique and post-deposition treatments. CdS is naturally n-type because of the presence of sulphur vacancies (Vs^{2-}) and in most of the observed samples a DAP involving the sulfur vacancies could be identified. It seems that annealing of CBD samples in Argon atmosphere favors the occurrence of interstitial cadmium defects (I_{Cd}^{+}) and annealing in air favors interstitial oxygen defects (I_0^{-}). The comparison of the PL spectra of CBD samples as grown and annealed in oxygen atmosphere suggests the identification of the optical signature of interstitial oxygen (I_0^{-}). In the case of CSS samples, the presence of CdO could be identified in films grown under oxygen atmosphere or grown under Argon atmosphere then annealed in oxygen. Thus, it is found that the same annealing procedure have a different impact on samples grown by CBD or CSS. The studies of CBD samples annealed under $CdCl_2$ are under way.
Those studies show the interest of PL studies for a deeper understanding of defect formation processes during growth annealing procedures in the CdS layers used for solar cells fabrication. We plan to correlate the optical signatures of impurities and defects with solar cells performances

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Tu-P21
Tuesday 18:30-20:30

Spectral photoresponse of ZnSe/GaAs heterostuctures with ultra-thin CdSe quantum well insertions*

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The use of quantum wells (QWs) for photodetectors and solar cells has sometimes been a controversial subject since they are very efficient absorbing photons and trapping carriers but they are also very efficient inducing their recombination resulting in the loss of electron and holes. If carriers can be removed from the QWs before recombination, their contribution to the photocurrent can be significant. The idea of using quantum wells for this purpose has been around long time ago [1]. Previous studies have indicated that good results can be achieved when correct design parameters are employed [2, 3], recently very promising results have been obtained [4, 5].

In this work we present the results of the spectral photoresponse (SR) of ZnSe/GaAs heterostructures containing CdSe ultra-thin quantum well (UTQW) insertions grown by atomic layer epitaxy. First, we show that inserting only three CdSe UTQWs (less than 3 nm effective thickness in total) has a clear effect, increasing the SR of the heterostructure. In the case of ZnSe/GaAs heterostructures containing 30 identical UTQWs, we observe that the photocurrent is greatly increased. These insertions not only contribute to increase the photocurrent in the region that corresponds to the UTQWs, but also increment the photocurrent in the region of the GaAs substrate. The heterostructure containing 30 UTQWs of 1 ML thick CdSe presents an increased SR with clear contributions of the GaAs, the UTQWs and the ZnSe (buffer and barriers). A heterostructure containing 30 UTQWs of 3 ML CdSe presents an even greater photocurrent, around 50 times larger than that of a 3 □m epitaxial ZnSe/GaAs heterostructure, clearly showing the benefits of the UTQWs insertions. The behavior of the SR under applied polarization voltage will also be presented. We will explain the enhancement of the photoconductivity in terms of the properties of the QWs and also of the multiple reflections that induce a larger photon absorption.

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Tu-P22
Tuesday 18:30-20:30

Lattice relaxation of ZnS Grown on GaP investigated by high-resolution X-ray diffraction and transmission electron microscopy

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ZnS is a wide-band-gap semiconductor and a potential material for short-wavelength optical devices. For epitaxial growth of ZnS, GaP is often used as a substrate [1]. In this case, there is a lattice-mismatch of 0.77%, and the critical thickness for ZnS is thought to be less than 100 nm; however, it has not been investigated in detail yet. Nam et al. [2] reported the critical thickness as 35 nm on the basis of the double-crystal x-ray diffraction data; however, they did not show direct observation of lattice relaxation.

In this study, we used high-resolution x-ray diffraction (HRXRD) and transmission electron microscopy (TEM) to investigate the lattice-relaxation process of ZnS grown on GaP in detail. As a result, even in a 28-nm-thick ZnS layer, evidences of initial lattice-relaxation were found, showing the critical thickness is smaller than 28 nm.

ZnS layers with different thicknesses were grown on GaP (001) substrates by molecular beam epitaxy (MBE) in the procedure similar to that reported elsewhere [1]. The layers were characterized by HRXRD (Rigaku SmartLab) and TEM (JEOL JEM-2010) systems. In the HRXRD measurement, reciprocal space maps (RSMs), mainly around the 224 diffraction peaks of GaP and ZnS, were measured using a Ge-(400) double-crystal monochromator and a 1-dimensional semiconductor array detector (D/teX Ultra). The layers were cut and thinned by lapping and Ar-ion milling for cross section TEM observation. Lattice images of the samples were recorded by high resolution TEM (HRTEM) observation.

In the RSM of a 28-nm-thick ZnS layer on GaP, the ZnS peak is aligned with the GaP peak along *z* direction (vertical to surface). In addition, the lateral width of the peak is small and the width along *z* direction is larger because of the form of the very thin layer. If we see only these features, the ZnS layer is seemingly grown coherently onto the GaP substrate. In the ZnS peak, however, there exists a weak tail toward the peak position of relaxed ZnS layer; this seems to be due to initial lattice-relaxation. The cross section HRTEM image of the 28-nm-thick ZnS layer exhibits some stacking faults accompanied by partial dislocations. These stacking faults are likely to be due to lattice-relaxation, corresponding to the RSM observation. No evidence of lattice-relaxation is found in the RSM and HRTEM observation for a 20-nm-thick ZnS layer. Therefore, the critical thickness of ZnS on GaP is shown to be in the range between 20 nm and 28 nm.

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Tu-P23
Tuesday 18:30-20:30

Infrared radiation detection by a piezoelectric heterostructure at room temperature

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In the present work we report on our study of the HgCdTe-based IR detector operating in the middle (3–5 μm) and long wavelength (8–14 μm) infrared spectral range without cryogenic cooling to achieve useful performance. The principle of operation of the IR detector is based on the generation of the piezoelectric charge produced by mechanical stress in strained compound semiconductor heterostructure heated upon absorption of IR light.

We have carried out a systematic study of HgCdTe-based heterostructures ($Hg_{0.7}Cd_{0.3}Te$/CdTe/ZnTe/Si, $Hg_{0.74}Cd_{0.26}Te/Cd_{0.96}Zn_{0.04}Te$, $Hg_{0.78}Cd_{0.22}Te/Cd_{0.96}Zn_{0.04}Te$/GaAs) which were grown by MBE and LPE methods as well as obtained by the laser deposition method. The properties of the HgCdTe-based heterostructures have been investigated using various techniques. The charge carrier transport parameters were determined from the Hall coefficient and conductivity measurements. The photoresponse (without cryogenic cooling) and infrared transmittance spectra in the middle and long wavelength infrared spectral range (2–15 μm) were obtained. We have also evaluated a residual stress in heterostructures by X-ray diffraction and microhardness measurements techniques. With the help of mathematical modeling (the solution of finite-difference equations by sweep method) we have determined the distribution of the potential *U*, appearing in the film of a narrow-gap semiconductor, and the thermo-stimulated strain of the $Hg_{0.7}Cd_{0.3}Te$/CdTe/ZnTe/Si heterostructure at 300 K.

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Tu-P24
Tuesday 18:30-20:30

Study of the origin of weak ferromagnetism in $Zn_{1-x}Co_xO$

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The ZnO-based diluted magnetic semiconductor (DMS) is a promising candidate for realizing a ferromagnetic semiconductor with high Curie temperature. $Zn_{1-x}Co_xO$ with the Curie temperature higher than room temperature has become a model example for diluted magnetic oxides (DMOs)[1]. However, the magnetic properties of $Zn_{1-x}Co_xO$ reported so far by different research groups are quite contradictory. Some reports found that $Zn_{1-x}Co_xO$ is ferromagnetic at room temperature but the magnetic moment is much smaller than expected. On the other hand, there are also works that report on the absence of ferromagnetism in these materials.

Here we present the results of experimental study of the weak ferromagnetism in $Zn_{1-x}Co_xO$. The temperature dependencies of magnetization and thermal diffusivity have been conducted. Diluted magnetic semiconductor $Zn_{1-x}Co_xO$ (x = 0.03) thin films were deposited on Si (100) substrates by using ultrasonic spray pyrolysis. Aqueous solutions of zinc acetate (0.5 mol/l) and cobalt acetate (0.5 mol/l) were used as sources of Zn and Co, respectively. The substrate temperature was set at 400 ^{0}C, and the thickness of $Zn_{0.97}Co_{0.03}O$ films was about 200 nm. The magnetization dependencies on the magnetic field, M(H) curve, and on the temperature, M(T) curve, were measured using a superconducting quantum interference device (SQUID) magnetometer. The thermal diffusivity measurements were made using photothermal method. The structural analysis of Co doped ZnO films were carried out by using an X-ray diffractometer (XRD, Rigaku mini flex).

The XRD pattern for $Zn_{0.97}Co_{0.03}O$ films grown on Si substrates show only peaks related to the wurtzite structure without any secondary phase up to the detection limit of the instrument. Magnetization M(H) measurements show a hysteresis loop which indicates an existence of ferromagnetism in $Zn_{0.97}Co_{0.03}O$. However, the magnetic moment per Co ion is much lower than expected. A comparison of M(T) measured at zero-field-cooled (ZFC) and field-cooled (FC) conditions shows a superparamagnetic like behavior and the blocking temperature is about 130K. Temperature dependence of the thermal diffusivity of $Zn_{0.97}Co_{0.03}O$ shows a pronounced lambda-shaped minimum at 130K, which indicates an existence of a second-order phase transition at this temperature. The low value of phase transition entropy shows that only a small part of Co ions is involved in ferromagnetic ordering. The weak ferromagnetism in $Zn_{0.97}Co_{0.03}O$ with a Curie temperature of 130 K is ascribed to an uncompensated magnetic moment of CoO nanoclusters with radii of about 1 nm existing at the surface.

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Tu-P25
Tuesday 18:30-20:30

Stark effects of ZnO thin films and ZnO/ZnMgO quantum wells

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ZnO has attracted increasing interest as promising material for ultraviolet optoelectronic devices because of its wide band gap (3.37eV) and large exciton binding energy (60meV). This large exciton binding energy is an advantage in quantum confined Stark effect (QCSE) of excitonic transition, which has potential applications for optical functional devices such as high speed optical modulators and switches in the ultraviolet region. In this paper, we report on Stark effects of ZnO thin films and QCSE of ZnO/ZnMgO quantum wells (QWs).

ZnO thin bulk film and ZnO/ZnMgO QWs used in this study were grown on a-plane sapphire or c-plane ZnO (O-face) substrates by plasma-assisted MBE. Stark effects were determined by excitation-power dependent photoluminescence (PL), electroreflectance (ER) and electroabsorption (EA) experiments. We used poly(3,4-ethylenedioxythiophene):poly(styrenesulfonate) (PEDOT:PSS) as Schottky window layers formed by spin coating technique on the ZnO layers. In the ER and EA experiments, DC reverse bias (0~20V) and AC modulation (±4V) voltages were applied between the PEDOT:PSS Schotky contact and the top ZnO ohmic contact (in-plane configuration).

In order to examine Stark effect of ZnO thin films, we performed ER experiments at 18K and Electric-filed dependent excitonic transition energies of ZnO thin film were determined. As increasing DC electric fields, we observed a red-shift of excitonic transition energy. The red-shift in a low electric filed region (<100kV/cm) well agrees with a theoretical calculation, which is originated from Stark effect of ZnO bulk. On the other hand, the red-shift saturated in a high electric field region (>200kV/cm). This behavior means that Stark effect changes to Franz-Keldysh effect in the high field region.

Stark effect of ZnO/ZnMgO QWs was studied by PL and ER experiments. The QCSE in ZnO(3nm)/ $Zn_{0.7}Mg_{0.3}O$(10nm) QWs (10 periods) was investigated by excitation-power dependent PL at 77K. The PL peak shows a large blue-shift of 60meV as increasing excitation power. In the ZnO/ZnMgO quantum well structure, build-in piezo electric field induces QCSE even in a zero external electric field condition. Therefore, this blue-shift reflects that photo-excited carriers screen the build-in field and QCSE decreases as increasing excitation power. ER and EA signals from the QW exciton were observed at room RT, but Stark shift was very small in the in-plane electrode-configuration. Thus, we applied bias voltage in the vertical configuration using ZnO/$Zn_{0.95}Mg_{0.05}O$ QWs grown on conductive ZnO substrate. We performed ER experiments at RT applying DC(0~10V)+AC(±2V) voltage between the PEDOT:PSS Schottky contact and the bottom ohmic contact to the ZnO substrates. Excitonic transition energy of ZnO/ZnMgO QWs obtained from ER experiments shows blue-shift of 25meV (DC bias: 0~6V). This energy shift originates from QCSE in ZnO/ZnMgO QWs. These results show that ZnO/ZnMgO QWs can be applied to optical modulators in the new ultraviolet wavelength region.

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Tu-P26
Tuesday 18:30-20:30

Field effect transistors based on ZnO and core/shell ZnO/ZnS nanofibers

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The Field Effect Transistors (FETs) based on semiconducting electrospun nanofibers are very promising real-time sensors. We obtained ceramic one-dimensional (1D) nanostructures by electrospinning followed by the calcinations [1]. The nanofibers for FETs were calcined at air in 500º C for 4 h. Characterization was performed using XRD, TEM, AFM, SEM, EDX, PL and CL techniques. The ZnO nanofibers consisted of wurtzite crystals. The activation energy for the crystal-growth was estimated to be 12 kJ/mol. Increased ZnO crystal sizes and intensity of the band gap emission were observed at higher temperatures
(400°C - 900°C).

The nanofibers can be applied to construct a family of bio-sensors [2]. We observed resistivity decrease when the nanofibers were immersed in liquids (water and ethanol). Moreover, after applying a constant voltage between electrods, the current increased three orders of magnitude when the nanofibers were exposed to the light (325 nm). For fabrication of biosensors based on the ZnO nanofibers, a surface passivation is required. We synthesized core/shell ZnO/ZnS nanofibers and prepared a FET based on these fibers for intended biosensing applications.

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Tu-P27
Tuesday 18:30-20:30

Transparent conducting Al-doped ZnO thin films grown by Nd:YAG Pulsed-Laser Deposition

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Aluminum doped zinc oxide (ZnO:Al) thin films (210–428 nm thick) were prepared by Nd:YAG pulsed laser deposition (PLD) on glass substrates at different oxygen pressures, and the effects of oxygen pressure on the physical properties were investigated. The thin films deposited between 5 to 75 mTorr showed five diffraction peaks (100), (002), (101), (102) and (103) containing the ZnO hexagonal structure. Between 30 to 40 mTorr, the electrical resistivity decreased abruptly at minimum value of $5.5x10^{-4}$ Ω-cm, and increased reaching values of ~$3x10^{-3}$ Ω-cm. The optical transmittance of the films decreased with the increase of oxygen pressure, however high transmittance (~83 %) in VIS region was observed in the thin films prepared at 40 mTorr. The band gap of thin films was ~3.4 eV corresponding the ZnO. The carrier density increased and decreased in the range of oxygen pressure of 5 to 75 mTorr, reaching minimum values of ~$2.6x10^{20}$ cm^{-3} and maximum values of ~$9x10^{20}$ cm^{-3}, while the mobility of the free carrier decreased in the same range, reaching maximum values of ~13.6 $cm^2V^{-1}s^{-1}$.

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Tu-P28
Tuesday 18:30-20:30

Raman scattering from ZnO doped with CoO nanoparticles

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The purpose of this work was to study optical properties of nanosized powders of ZnO doped with CoO. Nanocrystaline samples were synthesized by wet chemical method. The obtained samples have CoO concentration between 5% till 95%. Samples were characterized by X-ray diffraction (XRD) to determine composition of the samples. At all concentration of CoO only two phases were register by XRD, the ZnO phase and the Co_3O_4 phase. The mean crystalline size varied from 14 nm to 156 nm for ZnO doped with CoO.

In this paper we report the experimental spectra of micro-Raman measurements, at laser power of 20 mW. In all samples raman peak at ~437 cm^{-1} is visible, also clearly visible are multiphonon peaks at ~330, ~660 and ~1153 cm^{-1}. This peaks is typical for undoped ZnO nanoparticles [1]. Raman spectrums also show bands at at ~ 691 cm^{-1}. The presence of this band is typical for Co_3O_4 [2]. We also observed bands at ~ 194, 482, 521 and 618 cm^{-1}. These bands are typical for Co_3O_4, too [2].

These results of micro-Raman spectroscopy are in good agreement with results obtained with XRD analysis. For all samples we have investigated dependence of raman peak position from grain size as well as the change of raman peak position with concentration of CoO.

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Tu-P29
Tuesday 18:30-20:30

Active-layer-thickness dependence of Rabi splitting energies in ZnO microcavities

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Semiconductor microcavities have been intensively investigated from the fundumental interests and applications because of their potentials to control exciton-photon interaction [1]. Strong coupling between excitons and photons forms quasiparticles known as cavity polaritons. Recently, a ZnO microcavity has been developed from the viewpoint of the stability of the excitons [2]. In the ZnO microcavity, three kinds of excitons labelled A, B, and C peculiar to ZnO contribute to the formation of the cavity polariton. Thus, the cavity polariton consists of four branches: the lower polariton branch (LPB), first middle polariton branch (MPB1), second middle polariton branch (MPB2), and upper polariton branch (UPB). We previously reported the first observation of the four cavity polariton branches in the ZnO microcavity [3]. However, little has been known about the active-layer-thickness dependence of the exciton-photon interaction energy, the so-called Rabi splitting energy. In the present work, we have succeeded in controlling the Rabi splitting energies in ZnO microcavities by changing the active layer thickness.

The microcavity structure grown on a (0001) Al_2O_3 substrate is composed of a ZnO active layer sandwiched by HfO_2/SiO_2 distributed Bragg reflectors (DBRs). We adopted rf magnetron sputtering for the preparation of HfO_2/SiO_2 DBRs at the bottom and top. The bottom and top DBRs consist of 9.5 and 7.5 periods, respectively. The ZnO active layer was prepared by pulsed laser deposition. The active layar thickness was changed from $\lambda/4$ to $3\lambda/2$ in order to control of the Rabi splitting energy, where λ corresponds to an effective resonant wavelength of the lowest-lying A exciton.

Angle-resolved reflectance spectra at 10K in the $\lambda/2$ ZnO microcavity clearly exhibit four cavity polariton branches: the LPB, MPB1, MPB2, and UPB. The cavity polariton dispersions are analysed by using the phenomenological Hamiltonian for the coupling between the cavity photon and the A, B and C excitons. The Rabi splitting energies of the A, B, and C exciton are evaluated to be 30 meV, 71 meV, and 84 meV, respectively. Furthermore, the formation of cavity polaritons is obsereved in all the samples with different active layer thicknesses. From the analysis, It is demonstrated that the Rabi splitting energy of the A exciton increases from 19 to 45 meV by changing the active layer thickness from $\lambda/4$ to $3\lambda/2$.

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Tu-P30
Tuesday 18:30-20:30

Luminescent properties of Ag-, Ga-doped ZnO AND ZnO–ZnS thin films

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ZnO and ZnS are interesting materials for optoelectronic applications. Optical properties of ZnO and ZnS can be controlled by the doping with Ag and Ga. In this paper, we report luminescent and structural properties of ZnO:[Ag, Ga] and ZnS–ZnO:[Ag, Ga] thin films.
ZnO:[Ag, Ga] and ZnS–ZnO:[Ag, Ga] thin films were obtained by two-stage technique as follows. At first, ZnS thin films were grown by original metal-organic chemical vapor deposition (MOCVD) under atmospheric pressure onto refractory glass substrates. Then, as-grown ZnS films were co-doped by Ag, Ga with the help of a close space sublimation method [1] and oxidized at atmospheric pressure in air at $T \geq 750°C$ for $t \geq 1$ h. Structural characteristics of the films was investigated by X-ray diffraction (XRD) and atomic force microscopy (AFM). Optical properties of the films were studied by photoluminescence spectroscopy at 77 and 300 K.
It is found that shape of photoluminescence (PL) spectra of the films depends strongly on the preparation conditions. For ZnO:[Ag, Ga] films, two kinds of PL spectra were observed: i) with emission band maxima at 400 and 450 nm; ii) with nearly equal spectral distribution in the region of 360–700 nm. For ZnS–ZnO:[Ag, Ga] films, the PL spectra are characterized by the blue-green spectral region and consist of bands with the peak maxima at 450 and 500 nm. The ratio of band intensities depended on the preparation conditions.
A detailed analysis of the PL and PL excitation spectra at various temperatures and excitation intensities allows us to obtain the data, from which an origin of emission centers is elucidated. The possible origin of radiative transitions is discussed.

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Tu-P31
Tuesday 18:30-20:30

MOVPE growth of ZnO using Zn-MOPD and Zn-TD as Zn source

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ZnO is known as a multi-functional material that can be applied to optoelectronic devices in short wave length region, transparent conductive films, phosphors, gas sensors, and so on. The current research stage of ZnO is the improvement of crystalline quality to realize active electronic devices such as LED, LD, and FET. Similar to III-V and nitride compound semiconductors, MBE and MOVPE are the key growth techniques. Especially, productivity of MOVPE is high. Two Zn sources have been used to grow ZnO; DEZn(diethyl zinc) and $Zn(acac)_2$. However, DEZn is highly active, and $Zn(acac)_2$ cannot be supplied by bubbling. These may not be the best source for ZnO growth. On the other hand, Zn-MOPD and Zn-TD have advantages; low activity in air and water, and they can be supplied by bubbler. Therefore, the new Zn sources are the candidates for MO sources. In this work, we have grown ZnO using Zn-MOPD and Zn-TD, and investigated the properties of obtained films.

Samples were grown by MOVPE on glass substrates. Zn-MOPD and Zn-TD were used as Zn source and O_2 gas was for O source. N_2 was used as carrier gas of Zn-MOPD and Zn-TD. The growth pressure was 7.5 Torr. The growth temperature was 400 - 600 ºC.

Scanning electron microscope images show that the surface of ZnO is rough and that the island size increases with the growth temperature. Hexagonal structures are seen for samples grown at higher than 550 ºC.

The main peak of XRD $\omega/2\theta$ spectra was (0002) and other diffractions were very weak. The grown ZnO films were *c*-axis oriented. However, other planes such as $(\bar{1}011)$ and $(\bar{1}012)$ were observed for samples grow at 400 and 600 ºC . The FWHM of (0002) rocking curve spectra was the smallest for ZnO grown at 500 ºC.

The PL spectra measured at 13K were dominated by near band edge emission, especially for samples grown at higher than 500 ºC. Very weak emission at lower energies were seen in these samples. However, samples grown at lower than 480 ºC showed many deep emissions. These experimental results indicate that the Zn-MOPD and Zn-TD can be used as MO sources and the optimum growth temperature is higher than 500 ºC.

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Tu-P32
Tuesday 18:30-20:30

Plasma-assisted MBE growth of ZnO on GaAs substrate with a ZnSe buffer layer

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ZnO and related compound semiconductors have drawn a great deal of attention owing to their potential applications in photonic and spintronic devices. It is widely expected that high efficiency light emitting devices may be fabricated from these material systems due to their large exciton binding energies. They are also potential candidates for instersubband devices operating at short wavelength (near infrared) and long wavelength (terahertz) ranges due, respectively, to the large conduction band offset and large optical phonon energy in ZnO-based compounds. Although 3-inch ZnO substrates are commercially available, epitaxial growth of ZnO has been performed on various substrates, such as sapphire, silicon, GaN/sapphire, and $MgAl_2O_4$ due in part to the scientific curiosity of crystal growers and in part to the high cost of ZnO substrates. Growth on GaAs substrates is of particular interest due to the potential for device integration. We report here the growth of ZnO on GaAs substrates using ZnSe as a buffer layer.

Growth of ZnO on GaAs has been reported by several groups. The reported growth was mostly performed directly on GaAs. We choose to use ZnSe as a buffer layer because the growth conditions for obtaining high quality ZnSe on GaAs substrate have been well-established. The control of the ZnO/ZnSe interface is expected to be easier than that of the ZnO/GaAs interface since ZnSe and ZnO are both II-VI semiconductors and share a common cation. The growth of ZnSe on GaAs was performed in a Riber 2300P MBE system. After the buffer layer growth, the samples were taken out of the Riber system and loaded into a modified DCA 350 MBE system for the growth of ZnO. Elemental Zn and O_2 gas, both with 6N purity, were used as source materials. Typical O_2 flow rate was 0.7 sccm during growth. A radio frequency plasma power of 350 W was used. Single crystalline ZnO thin films have been obtained on (111)A, (111)B, as well as (001) GaAs substrates. Samples were characterized by x-ray diffraction (XRD) and room-temperature photoluminescence (PL) measurements. Well defined XRD peaks and sharp PL bandedge emission were observed from these layers. Detailed characterization results will be reported.

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Tu-P33
Tuesday 18:30-20:30

Study of metal contact properties of CdZnTe-based nuclear detector by the interfacial layer-thermionic-diffusion (ITD) model

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A new approach has been adopted for studying the interfacial layer formed by metal contact deposition on CdZnTe radiation detectors. This approach involves profiling the current-voltage characteristics of the detector from very low applied biases to very high applied biases, plotting the data on a log scale with an IDL algorithm and calculating the interfacial property materials, such as the reach-through voltage (V_{RT}), the transmission coefficient through the oxide layer (I_n), the permittivity of the interface layer (E_i) and the density of states, D_s, per unit energy and area. Two CdZnTe-based detectors were fabricated in 1) as polished and 2) bromine-methanol etched surface conditions. The detectors were characterized and the metal-semiconductor interfaces were studied using the interfacial layer-thermionic-diffusion (ITD) model. The resistivity of the bulk CdZnTe was found to be 2.45×10^{-10} ohm-cm. The results are correlated with microscale X-ray response mapping of the detectors.

Thu-LNP01
Thursday 18:30-20:30

Study on the behavior of mist droplets and the mechanism in the mist Chemical Vapor Deposition

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Electronic devices, which are critical to our life, are composed of a variety of functional thin films now. In order to fabricate the thin films for devices, vacuum processes have often been used because of their high potential of producing high quality thin films. Now, an atmospheric chemical vapor deposition (CVD) or a solution-based technology is becoming the focus of attention recently because it is not necessary to hold the system under vacuum, it is possible to use a variety of safe reagent, and it can eliminate damage to the target and underlying materials. But, in a solution process, it is rather difficult to realize high uniformity controlling the influence of such as thermal convection and side reaction, which scarecely occur in a vacuum process.

Nevertheless overcoming the above disadvantages we have worked on the development of a mist chemical vapor deposition (mist CVD) method, which is an intermediate process of the atmospheric CVD and the solution-based technology, for depositing thin films. We have achieved the thin films fabrication of zinc oxide (ZnO), gallium oxide (Ga_2O_3), tin oxide (SnO_2), indium oxide (In_2O_3), ferric oxide (Fe_2O_3), and so on [1,2]. However, it is essential to elucidate the reaction process and mechanism from the mist droplets to the thin films in gas-phase and on the substrate in order for the precise control of the growth processes toward high-quality layers. Especially, we have not known whether or not the mist droplets directry attach to the substrate. We found, from the experimental results and theoretical calculation for heat processes of mist droplets, the growth processor sequence as follows; (i) the mist droplet (liquid phase) is gasified easily with heat on the substrate suface, (ii) the steam film (vapor phase) is formed surrounding the mist droplet, and (iii) the thin film is grown in the steam film.

In the conference, we will discuss the behavior of mist droplets and the mechanisum of the mist CVD in detail.

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Thu-P01
Thursday 18:30-20:30

Blanket and patterned growth of CdTe on (211) Si substrates by metalorganic vapor phase epitaxy

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(211)B CdTe is the preferred buffer layer for molecular beam epitaxy (MBE) of device-quality Hg1-xCdxTe films on Si substrates. We have previously reported on the successful metalorganic vapor phase epitaxy (MOVPE) growth of (211)B CdTe on Si substrates using Ge and ZnTe interfacial layers [1, 2]. The excellent crystal quality of the grown films was characterized by a low x-ray diffraction (XRD) (422) rocking-curve full-width–at-half-maximum (FWHM) of 85arc-s (for an 8μm thick film). This FWHM value is now comparable to the best MBE grown CdTe films. The 8μm thick MOVPE-grown CdTe film also displayed a low Everson etch pit density (EPD) of $2x10^6cm^{-2}$. One of the challenges with the MOVPE-grown films was the rough surface morphology (compared with MBE-grown films) and polycrystalline hillocks on the surface (density varying from 10^3cm^{-2} to 10^5cm^{-2} over a 2" wafer). The various MOVPE growth process parameters have been modified in order to improve the surface morphology while maintaining the excellent crystal quality. In addition, the polycrystalline hillocks previously observed on the CdTe surface have also been eliminated. Everson EPD less than $1x10^6cm^{-2}$ has also been obtained.

Here, we also report on the optimization of the growth process further using Ge and ZnTe interfacial layers, exposure of both Si and Ge to As using tertiarybutylarsine (TBAs), and modification of the reactor geometry to improve on the uniformity of film growth. Additional work using selective growth of CdTe using Si_3N_4 mask and the effect of growth conditions on the development of large growth facets were studied. Atomic force microscopy (AFM), scanning electron microscopy (SEM) and XRD are being used to study and evaluate the improvement in CdTe films. Recent results on the growth on patterned and unpatterned Si substrates will also be presented.

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Thu-P02
Thursday 18:30-20:30

Fabrication and characterization of size-controlled ZnSe nanostructures grown by selective MBE on mesa-patterned GaAs(001) substrates

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ZnSe-based II-VI compound semiconductors are promising candidates for realization of novel optoelectronic devices and their integration due to not only thier wide band gap properties but also potential for the monolithic integration of II-VI/III-V semiconductors devices on sbstrate. For such applications, it is strongly required to fabricate nanostructures with good uniformity and controllability. In this paper, we present the fabrication and characterisation of the size-controlled ZnSe nanostructures on mesa-patterned GaAs substrates grown by selective MBE technique.

The mesa-patterns oriented along the [-110] direction were prepared on GaAs(001) substrates by optical lithography and wet chemical etching with H_2SO_4:H_2O_2:H_2O or HCl:H_2O_2:H_2O solution. The etched mesa-pattern was well-difined by {111} side facets and a (001) top facet. The single ZnSe layers or ZnSe/ZnCdSe/ZnSe quantum well (QW) layers were grown on the mesa-patterned substrates at growth temperatures from 280^{o}C to 350^{o}C by using a conventional solid-source MBE system. The growth rate of the ZnSe layer on the planar GaAs(001) substrate was 430 - 480 nm/hr. After the MBE growth proceedure, the formed structures were carefully characterized by scanning electron microscopy (SEM) and photoluminescence (PL) measurements.

From cross-sectional SEM observations after the growth of single ZnSe layers on the GaAs mesa-patterns, the formed ZnSe ridge structure was found to be characterized by the {111} side facets, the {112} corner facets and a (001) top facet. The width of the (001) top facet of the ZnSe ridge structure was linear to the top width of the GaAs mesa-pattern. The growth rate ratio of the ZnSe layers on between the {111} and (001) facets, $R_{\{111\}}/R_{(001)}$, was also investigated. With the growth temperature increase, $R_{\{111\}}/R_{(001)}$ was gradually decreased. At the higher temperature of 350^{o}C, $R_{\{111\}}/R_{(001)}$ was obtained to be 0.5, which indicates that a selective MBE growth mode occurs on the mesa-patterned substrate.

From PL measurements of the ZnSe/ZnCdSe/ZnSe planer and ridge quantum well (QW) structures, the strong peaks due to the localized excitons in the ZnCdSe QW layers were observed. Compaerd to the ZnCdSe planar QW, blue shifts of PL peaks were observed from the ZnCdSe ridge QW structures. The observed peak positions shift systematically to the higher energy side with decreasing of the top width of the ZnSe ridge structures. This probably originates from lateral confinement effects in ZnCdSe ridge QWs on the mesa-patterns.

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Thu-P03
Thursday 18:30-20:30

Influence of source transport rate upon phosphorus doping in ZnTe layer grown by MOVPE

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Since ZnTe light emitting diodes (LEDs) prepared by a thermal diffusion of Al into phosphorus (P)-doped ZnTe with a high carrier concentration of the order of 10^{18} cm^{-3} shows efficiency comparable to GaP LED [1], P is considered to be a suitable p-type dopant in ZnTe. According to the previous studies [2-5], P doping of ZnTe is attainable using tris-dimethylaminophosphorus by metalorganic vapor phase epitaxy (MOVPE), and a post-growth annealing in nitrogen ambient [2,3] and/or a use of relatively higher substrate temperature such as 500 ºC [4] may be effective for P acceptor activation. Recently, we have shown that a high carrier concentration of the order of 10^{18} cm^{-3} is obtainable at a substrate temperature of 500 ºC even without the annealing treatment [5]. In order to understand the P doping in ZnTe, it is necessary to investigate the effects of the growth conditions upon the electrical and photoluminescence properties of ZnTe for such a substrate temperature. In this study, we have investigated the influence of source transport rate under a fixed VI/II ratio upon P doping in ZnTe layer on (100) ZnTe substrate by varying both source transport rates simultaneously until high ones close to the surface-kinetics regime. With increasing the transport rate, the growth rate increases and the growth mode approaches the surface-kinetics regime. Also, the relative intensity of P acceptor related free-to-bound emission increases and the emission peak of exciton bound to P acceptor shifts toward longer wavelength in as-grown ZnTe layer. Furthermore, the carrier concentration increases with source transport rate in agreement with the above behavior, not with standing that the ratio of dopant concentration in the gas phase does not vary. After the post annealing, the carrier concentration of the layer increases to similar value independent of source transport rate. These results indicate an increase of the as-grown activation efficiency of P with getting closer to the surface-kinetics regime, which is consistent with the result that ZnTe layer of high quality is attainable when the growth mode approaches the surface-kinetics regime. The temperature dependence of carrier concentration and information on the other substrate orientation will be reported.

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Thu-P04
Thursday 18:30-20:30

Influence of Te/Zn flux ratio on doping in ZnTe grown by MBE on GASB substrates

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Both electronic and optoelectronic devices need n- and p-type doped semiconductors. Nearly all large-band-gap II-VI semiconductors exhibit a preference for one type of doping, and in the case of ZnTe it is hard to achieve n-type doping. The highest reported electron concentration is $4x10^{18}cm^{-3}$ for aluminum doped ZnTe grown on ZnTe substrates by MBE [1]. However, there are few reports of n-type doping in ZnTe on less expensive and lattice-matched 6.1 Å GaSb substrates, and n-type doping in ZnTe remains a key hurdle for device-level application.

Although the fundamental cause of the doping problem for ZnTe is not completely understood, most research suggests that acceptor-like Zn vacancies play a major role as compensating defects. A Zn rich condition may suppress the formation of Zn vacancies and may provide a solution to overcome the doping hurdle [2]. To study the influence of the Te/Zn flux ratio on the donor compensation, the flux ratio is varied in the range of 0.5 to 2 for aluminum doped ZnTe epitaxial films grown on GaSb substrates by MBE. A 10 nm thick aluminum doped ZnSe contact layer is deposited on top of the aluminum doped ZnTe films to lower the contact resistance. The epitaxial growth is carried out using a dual chamber MBE system, following a procedure reported previously [3].

Structural and material qualities of ZnTe films with varying Te/Zn flux ratio are characterized using XRD, TEM, and PL measurements. Hall effect samples are prepared using indium contacts that are annealed in forming gas ($5\%H_2$+95%Ar). More details will be presented at the conference. This study could enhance our understanding of n-type doping of ZnTe and enable the realization of devices based on ZnTe, such as LEDs, photodetectors and ultrahigh-efficiency multijunction solar cells [4].

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Thu-P05
Thursday 18:30-20:30

Influence of the composition profile in the excitonic emission of thin graded ZnCdSe quantum wells

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The energy levels in quantum wells (QWs) can be tuned by the appropriate selection of the band gaps of the QW and barrier materials and QW layer thickness. This is the typical approach for the case of rectangular QWs. It has been shown previously, in the case of thin and ultra-thin ZnCdSe QWs, that the submonolayer pulsed beam epitaxy (SPBE) growth technique is an excellent tool to control those QW parameters [1, 2]. Another approach to tune the energy levels is engineering the QW potential shape, i.e. its composition profile. This would be very complicated (even more in the case of thin QWs) using conventional growth techniques such as molecular beam epitaxy (MBE) or the elaboration of digital alloys by atomic layer epitaxy (ALE). In this work we employed SPBE to grow thin graded ZnCdSe QWs in layer-by-layer mode. The Cd content, controlled at the monolayer (ML) scale, was gradually increased towards the center of the QW in order to produce a symmetric potential. Three samples, each one containing 15 ML thick graded ZnCdSe QW, were grown. The only difference between the QWs was the composition of central three MLs. The samples were characterized by means of photoluminescence (PL) spectroscopy. Each one presented a single excitonic peak, however, large differences between the samples were observed, even though the QWs composition profiles were quite similar. Each QW presented a characteristic behavior in regard of PL peak energy, width, intensity and temperature quenching. The excitonic spectra of these samples were also compared with those of a 16 ML thick ZnCdSe QW and a 3 ML CdSe ultra-thin QW with emissions around the same energy. Two of the graded QWs presented intensities comparables to the rectangular QWs, and furthermore, one of the graded QWs exhibited a relatively low quenching of the emission with increasing temperature, which appears very convenient for optoelectronic applications.

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Thu-P07
Thursday 18:30-20:30

Cathodoluminescence of ZnSe-based II-VI green laser heterostructures

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Green lasers emitting at 510–550 nm are extremely important for many applications. Wide-gap II-VI semiconductor compounds remain the most suitable materials for green lasers with electron beam pumping. The study considered cathodoluminescence of laser heterostructures with multilayer ZnCdSe/ZnSe QW grown pseudomorphically by MBE on a GaAs substrate. The heterostructure contains lower and upper ZnMgSSe cladding layers of 1 μm and 20 nm thickness respectively and a 0.3 μm Zn(Mg)SSe/ZnSe superlattice waveguide. The active region consists of 7 nm ZnCdSe QW or CdSe QD sheets symmetrically embedded in ZnSe QW.

An electron probe microanalysis procedure has been employed for the determination of both the composition and depth position of ZnCdSe layer in the heterostructures. The composition as $Zn_{0.74}Cd_{0.26}Se$ and the layer depth position of 150 nm were determined with a relative error of 10%.

The cathodoluminescence (CL) at different electron beam excitation power was used for the study of the layers composition, the QW (QD) luminescence intensity and the time dependence. The CL spectra consist of QW (QD) luminescence at 2.4 eV, the Zn(Mg)SSe/ZnSe superlattice band at 2.75 eV and the ZnMgSSe band at 2.9 eV. The cathodoluminescence was applied for the diagnostics of the confinement and carrier transport properties of heterostructures. The CL intensity of the bands was measured at different electron beam energies in the range of 2.5 – 20 keV. The experimental results were fitted by the calculation of the amount of the electron-hole pairs producing the observed QW luminescence. In the calculation the electron energy loss distribution at the region across the structure are used in assumption that all generated electron hole pairs diffuse to QW and recombined. This way we evaluate the region in the structure with the transport of the charge carriers to the QW layer. This approach allows one to estimate the size of the transport region and the diffusion length of the charge carriers across the structure and in the ZnMgSSe cladding layer, it varies from 200 – 400 nm for different samples.

In addition the cathodoluminescence has been applied to study the defects in 1-μm-thick ZnMgSSe bottom cladding layer. The observed CL spectra show the exciton band of ZnMgSSe at 2.9 eV and a wide defect luminescence band at 2.2 eV. The analysis of the band intensities at different electron-beam current densities shows different saturation behaviour of the defect band intensities for the samples. The saturation intensity and the luminescence lifetime correlate with the defect luminescence intensity and the concentration. These results were applied to the evaluation of the luminescent defect density.

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Thu-P08
Thursday 18:30-20:30

Degradation mechanism and current-pulse-width control in II-VI and III-N compound blue-UV - white LEDs

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This paper presents degradation mechanism of II-VI (ZnSe-) and III-N(AlGaInN-) light emitting diodes, and its drastic life-time improvement by means of "current-pulse-width control" technique. We have studied two different type LEDs; (a) ZnSe-based white LEDs, composed by all solid-state (phosphor-free), MBE grown on ZnSe substrates, and (b)AlGaInN-Ultraviolet and Blue LEDs, grown on sapphire substrataes by MOVPE. Here, first we examined device degradation mechanism from view point of micrtoscopic point defect reactions (defect generation /enhancement during LED operation) using Double-Carrier pulse DLTS technique, coupled with systematic LED aging experiment. In case of ZnSe white LEDs, H0 hole trap center (E_v+0.7 eV) in p-type ZnMgSSe cladding layer is an important deep center by which rapid-degradation is caused [1]. Concerning III-N UV LEDs, two different defects (H1 hole trap center and unknown deep defect-band (D-B) in bandgap) are responsible for the degradation. In III-N LEDs, we have focused on controlling deep defect band (D-B) which is responsible defect for early-stage UV-LED operation.

[Current Pulse-Width Control and Its Remarkable Effect on LED Life-Time]

This technique is essentially different from usual pulse current-drive where pulse duty-ratio is important to suppress thermal heating damage. The point of the present method (**current pulse-width control**) is to adjust current pulse-width (ΔW: msec - μsec) as to meet condition that ΔW is equal or smaller than electron-hole non-radiative recombination time ($\tau_{e\text{-}h}$) of each deep center which are responsible for the LED degradation. Optimum current pulse-width (ΔW^*) can be determined from experimental values of $\tau_{e\text{-}h}$ for ZnSe-LED and for GaInAlN – UV and Blue LEDs .

Case of ZnSe White LEDs: LED aging test using the current pulse-width control has proved drastic improvement in its life-time . With current pulse-width (pulse height 50mA, ΔW<0.8 msec, duty-ratio = 50-80%) we have observed marked improvement where the life-time is 15-20 times longer than the case in dc-current operation (25mA). Here average LED brightness was the same in both DC- and Pulse current operation conditon.

Case of AlInGaN-UV and Blue LEDs: LED aging tests on GaInAlN UV-and Blue LEDs have shown considerable improvement in LED life-time under large current drive condition (bright LED :50-70mA: 300K). The life-times of the UV-LEDs are found to increase 10-15 times larger than DC-current drive condition. This improvement is found to reflect the suppression of the deep defect-band (D-B) generation (in quantum active layer of UV-LED). Also noted is that the current pulse width control is effective in GaN-Blue LEDs in case of very high current drive condition (>100 mA), and then efficient and low cost white LEDs illumination can be realized.

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Thu-P09
Thursday 18:30-20:30

Synthesis of CdSe nanoparticles immersed in an organic matrix of amylopectin by means of r.f. sputtering

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CdSe nanoparticles immersed in an organic matrix of amylopectin have been synthesized by means of the r.f. magnetron-sputtering growth technique. The target was elaborated employing a mixture of CdSe and Amylopectin high purity powders. X-ray diffraction (XRD) shows that the amylopectin thin films have an amorphous structure, and the Raman spectrum reveals that the crystalline structure of this molecular organic material is not affected by the sputtering-process. CdSe nanoparticles immersed in grow with the cubic zincblende structure. The average radius of the grains, calculated by using the Sherrer's formula radius in XRD peaks, is of the order of 8 nm. The band gap of CdSe nanoparticles measured from optical absorption measurements is 1.875 eV. Synthesis of semiconducting nanoparticles in organic biocompatible matrices is a hot topic of research due to its important applications as labels in biomolecular detection in place of conventional molecular flurophores.

Thu-P10
Thursday 18:30-20:30

Time-resolved spectroscopy of carrier dynamics in graded $ZnCd_xO$ multilayer structures

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Steady interest in ZnO-based electronics in recent years is to a large extent due to new promising applications offered by alloying and nanostructuring. The bandgap-engineered ZnCdO compounds, e.g. in the role of advanced absorbers of solar radiation in photoelectrochemical and photovoltaic applications, are among such novelties. Indeed, the efficiency of light absorption can be increased by stacking several ZnCdO layers with graded Cd content into a multilayer (ML) structure, which readily provides broader coverage of the solar spectrum and more efficient charge separation due to the built-in field. However, the interface regions between the stacked layers are potential sites for enhanced recombination of the photogenerated carriers. Hence, a general understanding of the charge carrier dynamics in multilayered ZnCdO structures is both of fundamental interest and also imperative for device implementations.
In the present work, steady-state and time-resolved photoluminescence (TRPL) spectroscopy have been employed to study charge carrier dynamics and the origin of luminescence bands in ZnCdO MLs grown by MOCVD [1]. The investigated MLs comprised 5-layer stacks with total thicknesses of 50nm, 125nm and 250nm. The photoelectrical activity of the individual layers was verified by employing optical transmittance and diffuse-reflectance techniques. Structural and composition properties were analyzed by XRD, RBS and SEM. For comparison, a set of single layers with similarly variable Cd-content up to 60% was analyzed to shed more light on the role of interface recombination. Systematic studies of the spectral peak position and intensity under different excitation intensities and temperatures suggested excitonic origin of the multiple components forming a characteristic plateau in the region from 3.3 to 2.5eV. The analysis of dynamic processes of the excitonic transitions revealed several characteristic time constants spread throughout the subnanosecond to microsecond time domains. The temperature dependencies of the radiative and non-radiative recombination lifetime parameters in ML structures have been extracted providing further evidence for the assignment of excitonic origin of the transitions. We discuss the observed multi-exponential behavior of the PL decays in terms of instantaneous lifetime evolution and also simplified recombination model involving fast and slow time components attributed to nonradiative recombination, exciton annihilation and recombination involving deep traps.

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Thu-P11
Thursday 18:30-20:30

Profiling unusual diffusion by scanning photoluminescence

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Radiotracer experiments have shown that the diffusion of the group I elements ^{67}Cu, ^{111}Ag, or ^{193}Au in CdTe and ZnTe can, under certain conditions, exhibit uphill diffusion profiles, i.e. the diffusion against the concentration gradient of the dopant [1]. After implantation into one side of a Te-rich CdTe-crystal and subsequent annealing under Cd vapour pressure at 800 K, peak-shaped concentration profiles located at the center of typically 800 µm thick crystals are observed. In order to get additional information about the underlying mechanisms scanning photoluminescence (PL) experiments have been performed.

The experiments were performed on Te-rich CdTe crystals, which were cleaved after annealing in order to get a surface containing the information about the depth-correlated distribution of the defects. Across the cleaved surface a laser spot, focused to a diameter of about 5 µm, is scanned and the luminescence is detected every 20 µm by a grating monochromator along with a CCD camera. The cleaving and subsequent PL-scanning can be repeated several times on the same crystal enabling the investigation of changes in defect distribution caused by different annealing procedures. The PL spectra of nominally undoped CdTe-crystals show different recombination channels, like free excitons (F, X), donor bound excitons (D^0, X), acceptor bound excitons (A^0, X) and donor-acceptor-pairs (DAP). Initially the intensities of all PL-signals are almost constant across the crystal. After annealing in Cd-atmosphere intensity profiles symmetrical to the center of the crystal are observed, similar to the results of previous investigations performed by Horodyský et al [2]. At a depth of about 100 µm a drastic drop of the (D^0, X) and (F, X) recombination is observed, accompanied by a rise of the (A^0, X) and the DAP recombination. The profiles of the PL spectra indicate that intrinsic defects and residual impurities are driven towards the center of the crystal.

In a second experiment Au was implanted with an energy of 300 keV into one side of a CdTe crystal. After annealing at 800 K under Cd pressure excitons bound to Au-acceptors (Au^0, X) are observed. The intensity profile is comparable to the profile of the (A^0, X) recombination. The shape of the (Au^0, X) profile agrees well with the concentration profile measured by tracer diffusion using the isotope ^{193}Au [1]. Compared to radiotracer diffusion experiments two advantages of scanning PL should be noted: Firstly, different defects can be investigated simultaneously and, secondly, an annealing sequence can be investigated on the same crystal.

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Thu-P12
Thursday 18:30-20:30

Structural and optical characters of ZnTeO alloys grown by MBE

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O atom in ZnTe forms localized states in the band gap state. Increasing the O concentration up to alloy of ZnTe and ZnO, it is expected that the localized states can be tailored to intermediate band. By using intermediate band of ZnTeO alloy, the photon that has lower energy than the band gap energy can be absorbed. This helps the effective use of solar spectrum and improves the efficiency of semiconductor solar cell. The theoretical efficiency of ZnTeO solar cell is 58 % when O concentration is 2 %. In this work, we grown ZnTeO alloys on ZnTe substrates and investigated the structural and optical properties.

ZnTeO alloys were grown on ZnTe (001) substrates by MBE equipped with a RF radical cell. Growth temperature was 300 ºC. O composition was controlled by O_2 flow rate. Thickness of ZnTeO layers were 600 nm. The structural properties were investigated by X-ray diffraction(XRD). The optical properties were investigated by photoluminescence(PL) and photo-reflectance(PR) spectroscopies.

The main peak of XRD $\omega/2\theta$ spectra showed only one peak from epitaxial ZnTeO layers. The peak angle shifted to higher angle with increasing O_2 flow rate, indicating the increase of O concentration. From (224) reciprocal lattice mapping of XRD, it was found that ZnTeO epitaxial layer is coherently grown on ZnTe substrates. O concentration was 0.34% for the sample grown with O_2 flow rate 0.005ccm.

PR signal from ZnTeO layer shifted to higher energies with increasing O concentration. This shift indicates the band-anti crossing model[1] can be applied to ZnTeO.

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Thu-P13
Thursday 18:30-20:30

Exploring the dielectric functions of MBE-grown GaMnAs using temperature-dependent spectroscopic ellipsometry

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Using temperature-dependent spectroscopic ellipsometry, we have measured the dielectric functions of a series of molecular beam epitaxy-grown $Ga_{1-x}Mn_xAs$ thin films. Initially, x-ray diffraction experiments were employed to determine the alloy concentrations of these samples which were grown on GaAs (100) substrates. A rotating analyzer spectroscopic ellipsometer was used to measure the complex reflection ratio for each of the specimens in the energy range between 0.7-6.0 eV at room temperature. Subsequently, by incorporating a cryostat, we obtained ellipsometric data for all samples from 300 K to 20 K, a range that covers their ferromagnetic transition temperatures. By modeling the ellipsometric data pertaining to the transparent region, we were able to determine the film thickness and the index of refraction of $Ga_{1-x}Mn_xAs$ precisely. Extending the analysis into the absorption region, we were able to determine the dielectric function for each sample. Evaluating the entire set of data, the dielectric functions of $Ga_{1-x}Mn_xAs$ were obtained for ten temperatures between 20 K and 300 K. All of the dielectric functions displayed critical points corresponding to electronic transitions in the Brillouin zone. This work allows us to predict how the critical points vary as a function of temperature, and particularly, to obtain insights into the band structure dynamics of $Ga_{1-x}Mn_xAs$ alloys near their Curie temperature.

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Thu-P14
Thursday 18:30-20:30

Synthesis and characterization of novel organically linked II-VI semiconductor nanoparticles

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We report on the wet-chemical synthesis and characterization of three-dimensional networks of ZnO nanoparticles where the formation of structures is achieved by covalently linking the nanocrystals with various bi-functional organic molecules. The resulting n-type scaffolds are supposed to act as electron acceptors in solar cells in combination with commonly used donor polymers. Currently, most of the solution processed organic solar cells consist of fullerene-polymer blends, and small molecules like fullerene tend to diffuse through the polymer matrix thus causing morphological degradation and shortening of solar cell life time. This disadvantage can be avoided by using structures with evenly distributed nanoparticles resulting in a well retained percolation pathway, and this can be realized by hybrid organically crosslinked ZnO networks.

The newly developed wet-chemical synthesis is a facile and low-temperature method which provides considerable amounts of product. The colloidal synthesis will be presented with application of two ligands that vary in size and binding sites. Furthermore we report on structural characterization of dried powders and thin films by means of X-ray diffraction and electron microscopy in order to examine the regularity of the structures.

We also present first investigations of the electrical behaviour in lateral direction for both hybrid ZnO networks. The measurement setup is a four-point probe and additional current-voltage measurements were carried out to assure good electrical contact of the samples. These measurements were further used to verify the specific current characteristic of the different structures. We will demonstrate that both materials show ohmic behaviour as well as a promising lateral conductivity with different values for the two samples.

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Thu-P15
Thursday 18:30-20:30

Optical stark effect and dressed excitonic states in Mn-doped CdTe quantum dots

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Growing interest is given to the possible control of individual spins in solid states because such systems can be seen as ultimate units for data storage and processing. On the road towards the interconnection of multiple spins, electrically or optically, much has still to be understood at the single spin level.

Here we report on recent results concerning the optical probing and control of a single Mn spin embedded in a CdTe/ZnTe quantum dot (QD). It is demonstrated that the Mn states and exciton-Mn complexes can be dressed by a strong laser and that their energies can be tuned thanks to the optical Stark effect.

The Photoluminescence (PL) spectrum of an exciton (X) and biexciton exchanged coupled to a Mn are well established [1]. In the simplest case (no coupling to dark excitons and no electrical doping) the PL spectrum is composed of six lines that correspond to the six possible projections of the S=5/2 spin of the Mn. Here we report on the possibility to mix the Mn or X-Mn complexes with photon states. While addressing a transition with an intense continuous wave laser, the strong light-matter coupling exhibits itself by the appearance of a splitting of the corresponding states by the so called Rabi energy. One convenient way to measure this energy in a Mn doped QD is to probe the PL of the biexciton when the strong laser is tuned on a Mn to XMn transition. The splitting of the PL line (for a given polarization of the detected photon) is then a direct measure of the Rabi energy that can be as large as 250 eV. A clear and expected dependence of the Rabi splitting versus the polarization, intensity and the detuning of the laser to resonance is observed. It is worth mentioning that this strong coupling does also appear for mixed dark-bright excitons coupled to Mn. Our experiment demonstrates that any spin state of an individual Mn atom can be independently tuned using the optical Stark effect. This approach opens then a way to control the Mn spin without any external applied magnetic field.
While these results gave some hope to coherently control the Mn spin, we improved the quality of the samples in order to conveniently probe the details of the strong light-matter interaction in this system. For example, the PL line width of single dots could be decreased, by about a factor 2, for appropriate growth conditions of the ZnTe capping layer.

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Thu-P16
Thursday 18:30-20:30

Electron-nuclear spin dynamics in CdTe quantum dots

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Individual electron spins in quantum dots (QDs) are a promising system to store quantum information due to there expected long coherence time. However, in the commonly studied III-V semiconductor QDs, the hyperfine interaction of the electron with the fluctuating nuclear spins governs the time scale on which an electron spin can be stored in the absence of external magnetic field. Continuous pumping of electrons can generate a dynamical nuclear polarization through hyperfine mediated spin flip-flop. It has been proposed that a full polarization of the nuclei could cancel the decoherence induced by the fluctuating hyperfine field. Alternatively, nuclear spins could be suppressed completely by using QDs based on isotopically purified II-VI materials since Zn, Cd, Mg, Se and Te all have dominant isotopes without nuclear spins.

We report on the dynamics of optically induced nuclear spin polarization in individual CdTe/ZnTe QDs. Individual QDs containing a single electron obtained by modulation doping have been studied. The triplet state of the excited charged exciton is identified in photoluminescence excitation spectra. Negative photoluminescence polarization, optical pumping of the resident electron and nuclear spin polarization built-up is directly observed in time-resolved optical pumping experiments when the QD is excited at higher energy than the charged exciton triplet. In the optical pumping regime, the formation of a dynamical nuclear polarization is probed in the magnetic field dependence of the polarization rate of the negatively charged exciton. The build up of nuclear spin polarization reaches the microsecond range at high excitation intensity. Relaxation time of the nuclear polarization in a range of 50 microseconds is observed at zero magnetic field and significantly increases under an external magnetic field of a few milli-Tesla. We will discuss mechanisms responsible for the fast initialization and relaxation of the diluted nuclear spins in these II-VI semiconductor QDs.

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Thu-P17
Thursday 18:30-20:30

Magnetic polarons in (Cd,Mn)Te/(Zn,Mg)Te single magnetic quantum dots

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0D diluted magnetic semiconductor (DMS) nanostructures have recently renewed the interest for magnetic polarons, *ie* a local ferromagnetic order induced by the coupling between localized spins and confined carriers [1, 2]. In parallel to top down methods based on the lithography of ferromagnetic epilayers, 0D nanostructures open up new ways to make semiconductor heterostructures incorporating DMS ferromagnetic domains. II-VI telluride and selenide materials are particularly interesting for fundamental studies because: (i) isoelectronic Mn atoms can be used to introduce localized spins in well controlled 0D nanostructures, (ii) 0D carrier can be independently injected optically or by doping and (iii) single object can be studied by micro-photoluminescence.

Self organized (Cd,Mn)Te/(Zn,Mg)Te magnetic quantum dots (QDs) with nominal Mn concentrations comprised between 4% and 10% have been grown by molecular beam epitaxy. By contrast to previous works [2], we studied highly concentrated QDs with Mn atoms incorporated only in the dots. A Mg concentration of 20% was also added in the barrier in order to keep a large valence band offset up to x_{Mn}=10%. We investigated the magnetic polaron formation during the lifetime of an electron hole pair optically injected in the dot. Micro-photoluminescence spectra of single QD have been recorded under magnetic field between 5K and 100K using a micro-photoluminescence set-up [3].

In the samples with Mn concentrations larger than 6%, the formation of magnetic polarons is revealed by a characteristic non monotonic variation of the PL line with the temperature. We analyzed consistently all the experimental data using the adiabatic approximation and by taking into account gaussian spin fluctuations. All the experimental parameters associated with the magnetic polarons can be reproduced by the model assuming a reduced Mn concentration in the dots (typically by a factor 2 in comparison to the nominal concentrations). This result suggests a small diffusion of Mn atoms during the QD formation obtained by depositing and desorbing in situ amorphous Te [4]. Mn profiles calculated by taking into account the Mn segregation and its small diffusion are qualitatively in agreement with the optical results. TEM analyses will be performed in order to confirm the presence of non uniform Mn profiles in the samples.

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Thu-P18
Thursday 18:30-20:30

Study of thermal stability of CdSe/ZnSe quantum dot heterostructures

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The processes of Cd/Zn interdiffusion are known to influence considerably the formation of CdZnSe/ZnSe nanostructures and device performance. The peculiarities of Cd/Zn interdiffusion in CdZnSe/ZnSe quantum well (QW) heterostructures had been studied in details. However, much less information is available for CdSe/ZnSe quantum dot (QD) heterostructures which are supposed to be to be more stable against degradation.

Here we report on the photoluminescence (PL) study of Cd(Zn)Se/ZnSe QD and multi-QW structures grown by molecular beam epitaxy and subjected to post-growth thermal annealing for 15 min between 200 and 440 ºC. The PL spectra of as-grown structures are dominated by the band caused by exciton recombination in the QDs (QWs) and the band connected with the defect complex including a column II vacancy. Spectral position and excitation spectrum of defect-related band indicate the presence of column II vacancies in the wetting layers of QD structure as well as in the QW layers of QW structure.

After heat treatment at temperatures up to 270 ºC, the PL intensity in the structures studied increases presumably due to annealing of as-grown nonradiative defects, while at temperatures above 270-340 ºC it drops. A blue shift of the excitonic band position caused by Cd out-diffusion from the QDs (QWs) is observed starting at temperatures of 320 ºC. A blue shift magnitude in the structures treated at 440 ºC amounts to 100 meV for QD excitonic band and 20 meV for QW excitonic band. It is found that the energy of excitonic transitions in the wetting layer does not change upon annealing. Lower thermal stability of the QDs as compared to that of the wetting layer and the QW is explained by lateral Cd/Zn interdiffusion in the wetting layers via column II vacancies.

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Thu-P19
Thursday 18:30-20:30

The structural characterization of the CdSe/ZnSe quantum dots using x-ray spectroscopic methods

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CdSe nano-objects draw interest due to wide possibility of application such as light emitting devices in the yellow, blue, and the green spectral region, biosensors, solar cells, and as single-photon emission relevant for quantum cryptography and, in the future, quantum computing. The high lattice mismatch of about 7% CdSe/ZnSe allows the self-assembled formation of quantum dots during epitaxial growth. Nevertheless, the QDs growth mode differs significantly from the well-known Stranski-Krastanov one. A segregation driven process based on a Cd-Zn exchange is responsible for the CdSe dot formation [1, 2]. Although the CdSe system is widely investigated, only little is known about their local structure, atomic ordering and strain distribution. These parameters in a crucial manner influence the optical and electrical properties. Therefore, it is important to use non-destructive structural sensitive methods suitable for the determination of these parameters. In the presented paper the extended x-ray absorption fine structure (EXAFS) and diffraction anomalous fine structure (DAFS) analysis are used as a spectroscopic method for the investigation of the CdZnSe quantum dots grown by molecular beam (MBE) and migration-enhanced epitaxy (MEE). The EXAFS can yield the structural parameters averaged over the sample volume, while the DAFS signal is local; therefore, both methods give a complementary insight to the local structure of the system under examination. The experimental data were supported by a model calculation based on the full valence-force-field (VFF) method and a simplified random-cluster model. The intermixing between Cd and Zn atoms is investigated. The Cd content in the volume of the quantum dots varies from ~25% on the bottom to ~50% on the top. The EXAFS and DAFS analysis provided that the anion-cation Cd-Se bond lengths correspond to a fully relaxed $Cd_xZn_{1-x}Se$ alloy with x between 0.25 and 0.5. A good correspondence of the measured and calculated data has been achieved.

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Thu-P20
Thursday 18:30-20:30

Photoluminescence study of the peak splitting of the excitonic emission of CdSe fractional monolayer quantum dots.

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We have deposited fractional monolayer quantum dots (FMQDs) of CdSe with coverages of 0.25 and 0.5 ML in a ZnSe matrix. The low temperature photoluminescence (PL) spectra of these samples presents a remarkable narrow and intense peak with a clear splitting whose origin is not well established. The FMQDs were grown by means of atomic layer epitaxy (ALE) on top of a ZnSe buffer layer previously grown by molecular beam epitaxy on a GaAs(001) semi-insulating substrate, the FMQDs were grown at a fixed temperature in the range of 260 to 290 ºC. The excitonic peaks are located around 2.75 eV for the 0.5 ML FMQD, and around 2.78 for the 0.25 ML samples. The energy splitting depends on Cd coverage and growth temperature and are in the 6.4 to 7.7 meV range. Quantum dots grown by other epitaxial methods with a similar CdSe coverage do not exhibit a visible splitting [1, 2]. The PL spectra were measured with a HeCd laser (325 and 442 nm lines); the intensity of the peaks changes with power and wavelength of the excitation. To explain this splitting several mechanisms may be considered: free and impurity bound excitons, localized excitons, biexcitons, heavy and light hole excitons, ionized excitons, etc. By means of PL measurements as a function of temperature, excitation intensity and wavelength, and strain analysis [3, 4] and considering the evolution of the peaks with increasing Cd coverage, we infer that the components of the peak are originated by heavy- and light-hole free excitons.

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Thu-P21
Thursday 18:30-20:30

Investigation of exchange interactions between excitons and magnetic ions as a function of translational wavevector in $Cd_{1-x}Mn_xTe$ quantum wells

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The exchange interactions between the charge carriers and the magnetic ions in dilute magnetic semiconductors have a profound effect on the magneto-optical properties. In particular, the Zeeman splittings of the electron, hole and exciton states can be enhanced by up to two orders of magnitude and such behaviour has been studied extensively, both for bulk material and for low-dimensional structures. In the latter case, the question arises of the extent to which quantum confinement might affect the magnitudes of the exchange interactions. Such confinement-associated changes could for example be caused by a wavevector dependence of the kinetic components of the exchange interactions or by motion-induced mixing of the quantum states. Some limited data on such changes have been obtained by magneto-optical studies of carriers in quantum wells [1] and the purpose of the present study was to extend the range of such investigations.

The essence of our investigation is the use of wide $Cd_{1-x}Mn_xTe$ quantum wells (width L greater than five times the exciton Bohr radius) with non-magnetic $Cd_{1-y}Mg_yTe$ barriers ($y \approx 0.36$). In such wells, the excitons can be described by the centre of mass approximation, in which they are considered as composite particles moving with a translational wavevector $\boldsymbol{K}$. The component K_z of the wavevector normal to the plane of the well is to a first approximation quantized according to $K_z = N\pi/L$, where N is an integer ($N \geq 1$), and the exciton recombination energies contain a term $h^2N^2/8ML^2$, where M is the translational mass of the exciton. Transitions from states of different N (and hence of different values of K_z) can be resolved in optical spectra and their splittings in magnetic fields studied. The approach has been used successfully to study wavevector-dependent changes in the magnetic properties of excitons in *non*-magnetic wells and to account for these changes in terms of motion-induced mixing between the exciton states [2]. In the present study of magnetic wells we have used Mn concentrations x ranging between 0.0003 and 0.016 and we shall report studies of the exchange interaction for values of K_z in the range up to 4×10^6 cm^{-1}.

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Thu-P22
Thursday 18:30-20:30

Towards spin-charge texture in magnetic semiconductors

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There has been much interest recently in the possible interactions between a two-dimensional electron gas (2DEG) confined within a dilute magnetic semiconductor (DMS) quantum well and micro- or nano-magnetic structures that may be fabricated on the top barrier and in close proximity to the 2DEG [1,2]. In particular, it is hoped that `spin-charge textures' in the 2DEG arising from the inhomogeneous magnetic fields (whose effects are amplified by the giant Zeeman splitting of the DMS heterostructure) may lead to new forms of behaviour in the 2DEG itself. Such behaviour may be probed either optically or in charge transport experiments. Of the optical techniques, photoluminescence and spin-flip Raman scattering (SFRS) give probably the most direct probes of the exciton and 2DEG spin splittings respectively.

However, preparatory magneto-optical studies of nanomagnet/DMS/2DEG hybrid structures reveal a range of effects that must be thoroughly understood and taken into account before any signatures of nanomagnetic structures can definitively be identified. Some of these are quite predictable; for instance, optical heating and optical carrier generation processes are modified by the presence of partial metallization on the sample surface. Whilst heating effects are well-known, the influence of the optical excitation (and any possible secondary, above-barrier excitation) in modifying the carrier density is less simple to predict. As has recently been shown, optical modulation of the exciton oscillator strength through effects such as modification of the 2DEG density furthermore leads to super-linear changes in the spin-flip Raman cross-section. We shall show experimental results aiming to quantify the detection limits of SFRS for genuine effects of the nanomagnet structures in view of these effects. In particular, we shall shown one highly unexpected phenomenon which is that, even in the absence of nanomagnet metallization, the electron SFRS in some samples shows a dependence on the orientation of the crystal axes with respect to the in-plane magnetic field. It is usually assumed that the conduction band Zeeman splitting is isotropic in-plane and varies only weakly as the magnetic field rotates to the normal to the quantum well We consider possible explanations for this surprising result, which poses a significant challenge for the use of SFRS in probing patterned samples, for which the obvious first step is to attempt to induce an anisotropy in the magneto-optics via the built-in magnetic field of the nanomagnets.

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Thu-P23
Thursday 18:30-20:30

Neutron diffraction research of crystal lattice local nanodistortions in diluted magnetic semiconductors $Zn_{1-x}Co_xS$ and $Zn_{1-x}Co_xSe$

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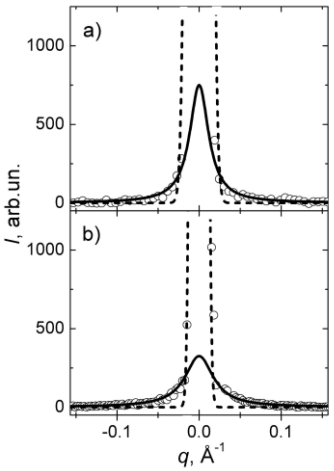
II-VI semiconductors doped with magnetic ions are attractive for using in optoelectronic and spintronic devices. In this work we present results of neutron diffraction measured on $Zn_{1-x}Co_xS$ and $Zn_{1-x}Co_xSe$ (x = 0.01) single crystals having sphalerite structure. X-ray emission spectra Lα Co of $Zn_{1-x}Co_xS$ crystals show the presence of distortions in the crystal lattice [1]. The neutron experiment has been performed to study unhomogeneties of the crystal structure. Neutron diffraction scans have been measured in different planes of reciprocal lattice. In vicinity of strong Bragg peaks a visible neutron diffuse scattering shows existence of local nanodistortions of the crystal lattice (see figure). These distortions may be induced by doping Co^{2+} ions. Profile analyses of peaks point out on near-spherical form of distorted lattice regions for both consistencies. One can suppose from temperature dependencies of the neutron diffuse scattering that the distortions induced by Co^{2+} ions are suppressed by the host crystal lattice with the temperature decrease. Structural state topology at these compounds is opposite to the experimental results obtained for $Zn_{1-x}M_xSe$ (M = Cr, Ni, V; x~0.001) single crystals [2] where the same structure distortions grow in their size with a temperature decrease and can be classified by their types. The possible nature of this effect is under discussion.



Neutron diffraction scans obtained on single crystals $Zn_{0.99}Co_{0.01}S$ (a) and $Zn_{0.99}Co_{0.01}Se$ (b) near Bragg reflection (220) in <001> direction at T = 300 K. Points – experimental results, instrumental curve is drawn by dash, the diffuse scattering is shown by solid line.

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Thu-P24
Thursday 18:30-20:30

X-ray pole figure analysis of ZnTe layers grown on lattice mismatched substrates

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The electro-optical effect of ZnTe is recently highlighted, and various device structures utilizing ZnTe are explored. In order to take advantages of the characteristic feature of ZnTe, the layer thickness and orientation should be carefully controlled. ZnTe substrates are recently commercially available, and high quality homoepitaxial layers can be grown. On the other hand, the cost of the substrate could be a serious concern for the practical device application. In this study, Si and sapphire substrates were used since they are widely used for many kinds of device applications. The lattice mismatch between those substrate materials and ZnTe is above 10 % and those mismatches should be carefully considered. Layers were grown by MBE, and the X-ray pole figure analyses were performed to study the domain formation during the film growth. (110), (211) oriented Si substrates and c, a, m plane sapphire substrates were used. ZnTe layers were grown at around 300 ^{o}C on a thin buffer layer of ZnTe that was nucleated on the substrate surface at around 100 ^{o}C. Judging from the conventional theta-2theta scans, (111) oriented ZnTe layers were observed for many samples. By taking the pole figure data, and studying the crystal symmetry of the domain structures, detail information associated with the crystal quality were obtained. The pole figure analysis revealed that several kinds of (110) oriented ZnTe domains rotated 60 degrees each other were formed on the (110) oriented Si surface, and the growth parameter affected the domain structures in the film. On the other hand, preferentially oriented single domain of (111) was confirmed for the layer grown on the c-plane of Al_2O_3. Dominant domains formed on the a-plane Al_2O_3 exhibited (111) orientation with two different alignments. Those results would be used to grow single domain structure ZnTe layers on Al_2O_3 substrates. ZnTe layers grown on m-plane sapphire exhibited a unique domain formation. The pole figure data combined with the conventional theta-2theta measurement indicated that (112) oriented plane of ZnTe was a dominant domain formed on the m-plane sapphire; weak features associated with the formation of (100) oriented plane were also confirmed. These crystallographic features would be related to the interface valency as well as the interfacial bond structure. X-ray pole figure method was a useful and powerful method to study the domain formation of the severely lattice mismatched structures.

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Thu-P25
Thursday 18:30-20:30

Local-strain induced structural-instability of Nitrogen acceptor and its influence on p-type conduction-control in homo-epitaxially grown ZnO by MBE

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Despite active research and development on ZnO based new electrical and optical devices, we still have technical difficulty in perfect p-type conduction control for a level of its practical application. To overcome this problem we have continued a systematic study on p-type conduction control using Nitrogen (N) acceptor doping in homo-epitaxial MBE growth. Previously[1], we reported unique structural-instability on N-acceptor, and by which marked PPC (Persistent-Photoconductivity) and abnormal TSC (Thermally Stimulated Current) curves under low-temperature photo-excitation condition ($h\nu_{ex} < E_g$) have taken place. Such abnormal property of N-acceptor has appeared as a structure-transition between shallow (effective-mass) acceptor and deep acceptor with large lattice distortion. Also this may cause imperfect conduction control like a p-/n-type mixed island. Here we present new direct evidence on N-acceptor instability in ZnO homo-epitaxial films, which is obtained by low-temperature PL spectrum focusing onto D-A (Donor-Acceptor) pair-emission under simultaneous two laser excitations (325 nm He-Cd laser ($> E_g$) and 514.5 nm Ar-ion laser ($< E_g$)). D-A pair emission signals have revealed repeatable change (reduction / recovery) by simultaneous side-excitation and by subsequent heat treatment. This effect has proved direct evidence on N-acceptor instability (AX-center behavior). Also presented is a first detection of local-strain distribution profile (induced by N-doping) on c-axis in N-doped ZnO films by precise X-ray diffraction analysis.

N-acceptor doped MBE growth are performed on c-ZnO substrates with Zn-polar face at 450-500˚C. Radical NO* through RF-plasma source (300 W: 1-2 sccm) was used. Pure Zinc (6-nine) was supplied by means of K-cell with typical partial pressure of $1\text{-}3\times10^{-7}$ Torr. N-doping densities ranged from 5×10^{18} /cm^3 to 1×10^{19} /cm^3, measured by SIMS. All most of all as-grown samples were n^--type ($1\text{-}10\times10^{16}$ /cm^3) , and we performed rapid post anneal (600˚C: 1-12 min) in O_2 flow crucible. After post anneal N-doped ZnO films have changed from n-type to p^--type conduction (with extremely high resistivity > 10^2-10^3 Ωcm). Evaluation of conduction-type change is made not by Hall-measurement but by thermal activation energy of carrier density (ΔE: 20 meV → 103 meV). High resistive ZnO films are studied by SSRM and SCM experiments, exhibiting p-/n- type mixed small island structure. Such island structure is also examined from view point of local-strain distribution using X-ray diffraction analysis. This experiment has revealed considerable local-strain distribution for both as-grown and post annealed samples, and thus the remarkable local-strain is induced by N-doping itself. It is, therefore, important to control such local strain and the related N-acceptor instability in order to realize complete p-type conduction for practical device levels.

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Thu-P26
Thursday 18:30-20:30

The observation of strong coupling between exciton and photon in ZnO whispering gallery cavity at high temperature and its tuning

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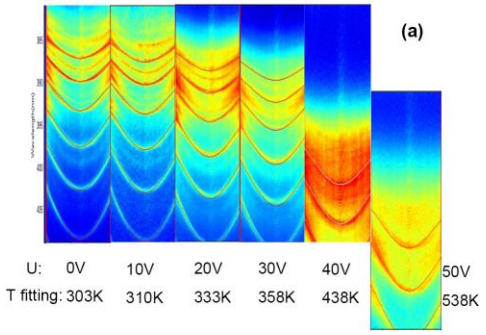
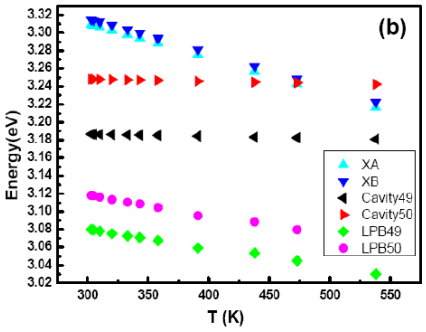
The strong coupling of exciton-photon (i. e. exciton polariton) has been observed in various semiconductor optical cavities [1-2] and has attracted tremendous attention in the past decades due to its potential in nano-photonics and polaritonics application. Here we report the tuning of strong coupling between exciton and photon by current induced thermal effect in a ZnO whispering gallery (WG) microcavity. A red shift of the lower polariton branch (LPB) was observed with increasing the voltage [Fig. 1 (a)]. When the voltage is 50 V, the redshift can reach up to 40~50 meV. With a simple heat conduction model, it is found that the thermal equilibrium can be established in a very short time (~ 10 μs). The relationship of voltage versus temperature can be obtained by comparing the redshift to that of the thermal experiment heated by a hot plate. As a result, one can get the temperature dependence of LPB [Fig. 1 (b)]. It is also found that the strong coupling is preserved up to a very high temperature (~ 500 K), much higher than the reported one (~ 410 K) and close to the predicted maximum value of 610 K [2-3]. Our results show opportunity for its optoelectrical application like wavelength-tunable polariton light emitting devices at or above room temperature.





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Thu-P27
Thursday 18:30-20:30

Study of stoichiometry of ZnO films grown at low temperature

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Over 5,000 articles devoted to ZnO in 2011 makes zinc oxide the most studied semiconductor among II-VI and III-V materials. This booming interest is related to a wide range of applications that cover such different fields as photovoltaics, optoelectronics, sensing, transparent organic electronics and many more. All these applications require perfect control of electrical parameters, including the repeatable n- and p-type doping. Therefore, understanding the source of high n-type conductivity, which occurs commonly in ZnO layers grown by various methods is of great importance.

We present the results of extensive studies performed by X-ray Photoelectron Spectroscopy (XPS), Rutherford Backscattering Spectroscopy (RBS), Secondary Ion Mass Spectroscopy (SIMS) and Electron Dispersive X-ray Spectroscopy (EDX) on ZnO films obtained at low temperatures (100^{o}C-300^{o}C) by Atomic Layer Deposition (ALD). The investigations have been targeted to determine the relation between electrical properties and chemical composition of the ZnO layers grown at low temperature regime. Hall effect measurements demonstrate that the free carriers concentration in these ZnO films scales with temperature [1]. SIMS and XPS studies show that the observed concentration differences are not caused neither by hydrogen nor by carbon, which are considered to be the main n-type impurities in ZnO films grown at higher temperature limits. Careful XPS and RBS studies lead to the conclusion that the cause of the low n-type conductivity in ZnO layers obtained at low-temperature regime is higher oxygen content which means that the stoichiometry of the films is closer to 1:1 than for films grown at higher temperature.

The research was partially supported by the European Union within the European Regional Development Fund, through grant Innovative Economy (POIG.01.01.02-00-008/08). The RBS measurements have been supported by the European Community as an Integrating Activity 'Support of Public and Industrial Research Using Ion Beam Technology (SPIRIT)' under EC contract no. 227012.

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Thu-P28
Thursday 18:30-20:30

Optical properties of the inorganic-organic hybrid: pentacene on ZnO

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The electronic coupling and level alignment are fundamental questions concerning organic-inorganic hybrid systems. In comparison to other organic semiconductors pentacene has a rather high carrier mobility and is therefore a promising candidate for electronic devices using organic semiconductors. Like many other organic semiconductors pentacene is p-type. Recently, p-pentacene/n-ZnO hybrids has been introduced as p-n junction diodes [1] or bilayer transistors [2]. Although the electron mobility and the device characteristics have been studied already, very little is known about the interaction of these two materials and the energy level alignment. We prepared p-pentacene films with thicknesses of 10 nm, 20 nm and 100 nm on the n-ZnO-O(000-1) surface by molecular beam deposition under ultra high vacuum conditions. The films were grown at room-temperature. All of them are in the so called thin film phase. To characterize the films AFM and X-ray diffraction measurements have been done. The pentacene molecules stand almost upright on the ZnO surface with a deviation of 9^0 to the normal axis and form single crystalline islands with extensions of several µm. Optical spectroscopy was used to study the electronic properties of these hybrid systems. The samples have been characterized by means of absorption and photoluminescence. The HOMO-LUMO transition as well as the excitonic states of the pentacene have been measured in the temperature range between 10 K and room temperature. At low temperatures a thickness dependent shift was observed for the two Davydov components of the pentacene exciton, the exciton binding energy and the HOMO-LUMO transition. The layers exhibit a blue shift of the HOMO-LUMO transition with decreasing temperature. Amorphous pentacene layers on ZnO exhibit however a red shift. The blue-shift is stronger the thinner the layer and was found to be about 50meV for the 10nm sample. A reason for this unique behaviour is the strong binding of the first pentacene layer onto the ZnO substrate. The two materials have very different thermal expansion coefficients resulting in a strong in-plane tensional strain. This in-plane strain component rapidly declines with increasing film thickness due to relaxation of the subsequent pentacene monolayers. Due to the anisotropic in-plane expansion coefficient of pentacene not only the lattice constants, but also the angle between the molecules changes, while cooling them down. For electronic applications it is important to realize that the level alignment between pentacen and ZnO is influenced by a strong bowing of the electronic levels close to the interface on a nm scale. Besides the HOMO-LUMO transitions new interface states have been observed. Possible reasons will be discussed in detail.

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Thu-P29
Thursday 18:30-20:30

Nitrogen doping on ZnO films grown by plasma-assisted MBE and its effects to the transport properties of TFTs

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The ZnO thin film transistor (TFT) has become a key device for transparent electronic circuits due to low cost, non-toxicity, high electron mobility and wide band gap. Compared to other wide band gap materials, ZnO can be formed on glass and plastic substrates at lower temperature with simple and excellent process flexibility. We have demonstrated highly transparent ZnO films on glass, polyethylene terephthalate and polycarbonate substrates by using plasma-assisted molecular beam epitaxy (PAMBE) [1]. In this paper, we present the fabrication and characterization of the ZnO TFTs grown by PAMBE. An attempt to investigate the effects of nitrogen doping on ZnO films was made in order to control the transport properties of the TFTs.

The undoped and N-doped ZnO films were grown on SiO_2/Si substrates. Zn vapor was supplied by heating of metallic Zn. Oxygen and nitrogen were supplied at flow rates between 0.7 and 1.4 sccm into a RF plasma cell. After MBE growth of the ZnO films, the TFTs with different channel width/length ratios, *W*/*L*, were fabricaed. Source and drain electrodes were deposited on top of the ZnO films by vacuum evaporation using Al. Back gate electrodes were also prepared for applying bias voltages. A post-annealing process was performed at 400°C for 1h in oder to improve the TFT performance.

Undoped ZnO TFTs show n-channel enhancement mode behavior and good current saturation. The saturation current of 0.2 mA and the saturation mobility of 6 cm^2/Vs were obtained, respectively, under a gate bias of 20 V. The off current on the order of 10^{-10} A and the on-to-off current ratio of 6×10^5 were obtained when the *W*/*L* ratio was 470/20. The threshold voltages were changed from 7 to 9 V with the *W*/*L* ratio increase.

N-doped ZnO TFTs also show n-channel enhancement mode behavior and good current saturation, but drastic reductions of the saturation current and the mobility were observed. The saturation current of 0.02 mA and the saturation mobility of 2 cm^2/Vs were obtained, respectively, under a gate bias of 20 V. On the other hand, the threshold voltages of N-doped ZnO TFTs were independent to the *W*/*L* ratio and stable at 13 V higher than those of undoped ZnO TFTs.

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Thu-P30
Thursday 18:30-20:30

Influence of crystal orientation on nitrogen incorporation in high quality ZnO films

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In spite of many studies, *p*-type doping of ZnO and its related alloys is still a blocking point for the development of ZnO based optoelectronic devices. Among many candidates (As, P, N, C …) studied to achieve *p* type doping of ZnO, the more promising results have been obtained using nitrogen by Tsukasaki et al.[1] In this case the free hole concentration at room temperature is limited to 10^{16} cm^{-3}.

However high p type doping level could not be achieve possibly because most of these studies were based on ZnO grown on foreign substrates (Sapphire, Si, SCAM, $LiAlO_{3...}$). Indeed, the heteroepitaxy of ZnO generates a high density of impurities and structural defects leading to local inhomogeneities of the dopants and parallel conduction channels. Therefore, reliable electrical characterizations are not straightforward on heteroepitaxial layers. The use of ZnO bulk substrates can circumvent these limitations, providing very high quality ZnO films [2]. In addition, it has already been shown that the orientation of the substrate plays an important role in the incorporation of dopants, including nitrogen [3].

In this presentation we report on the interplays between growth parameters, structural, optical and electrical properties in nitrogen doped ZnO thin films grown on both non polar (*m* plane and *a* plane), semi-polar (r plane) and polar (O-face and Zn-face) oriented ZnO substrates by molecular beam epitaxy.

Nitrogen was activated in an *rf*-plasma cell. Secondary Ion Mass Spectroscopy (SIMS) measurements show that the nitrogen concentration strongly depends on the growth temperature (T_{Gr}) and film orientation. Low temperature photoluminescence spectra taken from ZnO:N layers show different features which can be assigned with respect of the literature. Two series of broad donor acceptor pair (DAP) emission are systematically observed around 3.20 and 3.24 eV for nitrogen doped films, which is an unambiguous optical signature of shallow acceptor levels. The ratio between the intensity of these two bands, which depends on the film orientation and annealing treatment, will be discussed regarding the impurity concentration in the layers.

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Thu-P31
Thursday 18:30-20:30

Circular polariscopic analysis of a ZnO wafer for highly sensitive and speedy evaluation of residual strains: Its relation with x-ray diffraction pattern and topography

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ZnO has been attracting much attention as applications to, for example, optical devices alternative to III-Nitrides-based devices owing to its wide-band gap energy [1]. The optical and/or electronic properties of the ZnO-based epitaxial layer structures have been main targets in the research field of ZnO, whereas the characterization of the single crystal wafer has hardly been paid attention. We emphasize, from the view point of the above-mentioned device application, that the ZnO wafers with a large diameter are essential; however, the large ZnO wafers are less available because, comparing with the growth of GaAs wafers, the growth techniques, e.g., the hydrothermal synthesis, are quite different. Accordingly, the appropriate evaluation is required in order to promote the development of the ZnO wafer. We also note that the information obtained from single crystal wafers is the most fundamental in semiconductor physics.

In the present paper, we explore the conventional method for the analysis of the ZnO wafers. We focus our attention on the circular polariscopic measurement, which is sensitive to the strains through the photoelastic effect [2]. We demonstrate its high sensitivity to the residual strains in the ZnO wafer.

The present sample was a (0001)-oriented ZnO wafer with a diameter of 2 inches. The present wafer has an optically uniform transparency in the whole area, whereas the measured x-ray topograph shows that the contrast of the image is remarkably inhomogeneous. In order to clarify the origin of the above-mentioned inhomogeneousity, we performed the circular polariscopic measurement in the cross-Nicol configuration. Here, we describe the advantage that the circular polariscopic measurement, which uses the right circular polarizer and left analyzer, eliminates the ghost image regardless of the strain, the so-called isogyre [2]. This advantage enables to evaluate the whole wafer region by simply taking a snapshot with use of a digital still camera. The measured circular polariscopic wafer map clearly reflects the condition of the whole area of the sample as the brightness corresponding to the magnitude of the strain. The distribution of the strain coincides with the inhomogeneous contrast of the x-ray topograph. The crystal-plane modification caused by the stain is confirmed from the fact that, in the x-ray diffraction pattern, the forbidden reflection line is observed in the relatively bright area of the circular polariscopic wafer map. Thus, we conclude that the circular polariscopic analysis has the high potential both to complement the information from the x-ray topography and to evaluate the strain distribution in the ZnO wafer.

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Thu-P32
Thursday 18:30-20:30

The influence of annealing on structural and luminescence characteristics of ZnS:Cu

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ZnS activated by Cu is an efficient phosphor emitting light in blue-green spectral range. Doping of ZnS by Cu results in appearance of two bands (blue and green) in this range. However the contribution of each of them to luminescence spectra depends on conditions of synthesis and following technological treatment.

In this work the influence of annealing at 800°C on spectra of photoluminescence (PL), electron paramagnetic resonance and X-ray diffraction (XRD) of power-like ZnS:Cu is investigated. ZnS:Cu was grown by the method of self-propagating high temperature synthesis with adding of CuCl. It is shown that variation of the rate of heating to annealing temperature results in non-monotone change of spectral position and full width at half maximum (FWHM) of PL band as well as of Mn^{2+} paramagnetic centers concentration. The change of spectral characteristics of photoluminescence band is explained by the change of the ratio of intensities of blue and green Cu-related bands. With the increase of heating time the contribution of blue band at first decreases and then increases. At the same time the concentration of Mn^{2+} centers changes in opposite manner. It is found that after synthesis the powder of ZnS:Cu is mixed cubic and hexagonal phases and contains also ZnO and CuZn phases. It is shown that annealing at 800°C give rise to flow of three processes: i) transformation of hexagonal phase of ZnS in cubic one, ii) ZnS and CuZn oxidation, iii) Cu diffusion to ZnS microcrystal from alloy CuZn. The model that explains the changes of photoluminescence and EPR spectra by diffusion of impurities to bulk of microcrystals, in particular from CuZn alloy, and their accumulation at extended defects is proposed.

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