Division of Solid State Physics
Institute of Experimental Physics
Faculty of Physics, Warsaw University
Ul. Hoza 69, 00-681 Warszawa, POLAND

FINAL REPORT

Date of issue of this report : 22nd February 2006

CONTRACT N° : G5MA-CT-2002-04062

PROJECT START DATE : 1/1/2003 DURATION : 36 months

EU funding: 220 000 EURO

PROJECT TITLE :

Physics and Technology of Semiconductor Materials and Structures for Optoelectronics and Spintronics

ACRONYM : CEMOS

Keywords: optoelectronics, spintronics

PROJECT CO-ORDINATOR :

Prof. Marian Grynberg
Faculty of Physics, Warsaw University
Ul Hoza 69, 00-681 Warszawa, POLAND
ph. +48225532134
fax +48226219712
e-mail:Marian.Grynberg@fuw.edu.pl

Project funded by the European Community under the 'Competitive and Sustainable Growth' Programme (1998-2002)

Table of contents

2. Executive Summary

The Centre of Excellence CEMOS (G5MA-CT-2002-04062) consisted of measures aimed at enhancing quality of research and training provided in the Solid State Division, Faculty of Physics, Warsaw University in the area of Physics and Technology of Semiconductor Materials and Structures for Optoelectronics and Spintronics. The measures supported research work on nitride-based materials for optoelectronics as well as on novel materials of potential significance for emerging spintronic technologies. The output of the project can be seen as an important support of the integration of Poland in the European Research. Significant research potential of the Division was used more effectively due to tightening connections with other European research centres. This helped to focus scientific efforts on targets, which are important for European society. A series of workshops and several visits of scientists from and to the Centre were organized. The twinning arrangement with Universite Joseph Fourier in Grenoble, France has been reached and collaboration with the institution has become more close. Scientific collaboration with the Grenoble High Magnetic Laboratory, Grenoble, France has strengthen. Research activities supported by the accompanying measures have been confirmed by numerous publications in international journals.

Another important mission of the Centre which was supported by the project was a **preparation of Polish society to a new knowledge-oriented environment**. Competitive and sustainable growth is not possible without **human resources** ready to cope with demands of high-technology market. Training of such resources cannot be done without high-level research. The Centre of Excellence combined those two missions. Although its main activities, which are teaching at professional, graduate and PhD levels and research on semiconductor systems and structures is financed by Polish government and international collaboration-resources, the potential of the Centre has increased due to accompanying measures supported by the project. It is believed that this resulted in new opportunities, otherwise not available.

Activities of the Centre have been organized in a series of workpackages listed below:

WP1	Semiconductors in optoelectronics and spintronics – a special session during the Jaszowiec summer shool	Dr hab. A.Golnik, Prof. J.M.Baranowski, Prof. A.Twardowski
WP2	Workshop on Optical Properties of 2D systems with interacting carriers	
WP3	Workshop on Semimagnetic Semiconductors – Materials for Spintronics	prof. M. Nawrocki
WP4.	Enhancement of the PhD studies quality	prof. M. Kamińska
WP5	Research feedback for development of spintronics materials	prof. A. Twardowski, prof. M. Kamińska
WP6	Research on optoelectronic application of nitride semiconductors/	prof. J. Baranowski
WP7	Strengthening of the Research Collaboration with Grenoble High Magnetic Field Laboratory	prof. Marian Grynberg, prof. R.Stępniewski
WP8	Twinning of the CEMOS with Laboratoire de Spectrometrie Physique in education and research concerning semiconductor materials and structures for optoelectronics and spintronics	prof. J.Gaj
WP9	Co-ordination of the Centre (CEMOS) activities	prof. Marian Grynberg,

The detailed description of activities of the Centre are given in next sections of this report.

3.Activity report

The Centre of Excellence CEMOS (G5MA-CT-2002-04062) supported measures aimed at enhancing quality of research and training provided in the Solid State Division, Faculty of Physics, Warsaw University in the area of Physics and Technology of Semiconductor Materials and Structures for Optoelectronics and Spintronics. The accompanying measures were mainly supporting transfer of knowledge through a number of seminars/ workshops/conferences organized both in the host and in the collaboration institutions as well as a number of visits to and from the Centre.

Conferences and workshops

Special sessions during the Jaszowiec summer schools organised in years 2003, 2004, and 2005.

- The XXXII International School on the Physics of Semiconducting Compounds was held in Jaszowiec, 30.05-6.06.2003. There were 193 participants from 18 countries, among them: 20 from EU countries, 147 from Poland, and 12 from new accessing EU members (for a book of abstracts see Annex A). Among 6 invited speakers of a tutorial session and 15 of a regular conference part there were 10 speakers from EU countries. The special session day - "**Semiconductors in spintronics and optoelectronics**" was organized on 3.06.2003. The day involved 3 invited lectures, a panel discussion, 6 oral contributions and a poster session with 36 accepted posters. The panel discussion entitled "Ferromagnetic Semiconductors" was moderated by prof. J.K. Furdyna (NotreDame, USA) and has 8 introducing speakers: J.Sadowski (Copenhagen), W. Walukiewicz (Berkeley), J. Masek (Prague), P. Kacman (Warsaw), M. Kamińska (Warsaw), M. Sawicki (Warsaw), H. Munekata (Tokyo), M. Tanaka (Tokyo). The lively discussion after invited talks and within the panel session pointed out the technological problems and scientific challenges on the way to synthesize the semiconductor compounds that can be ferromagnetic at the room temperature. The Proceedings (28 selected contributions and 6 invited talks) have been published in Acta Physica Polonica -see Annex B.

- XXXIII International School on the Physics of Semiconducting Compounds was held in Ustroń-Jaszowiec at 28.05-4.06.2004. There were over 200 participants from 15 countries (for a book of abstracts see Annex C). Among 6 invited speakers of a tutorial session and 15 of a regular conference part there have been 14 speakers from EU countries. Two special session days have been organized during the conference. The first "**Semiconductors in**

optoelectronics" was held on 31.05.2004. The session involved 3 invited lectures, 6 oral contributions and a poster session with 34 accepted posters. The second special session "**Semiconductors in spintronics**" took place on 1.06.2004 and included also 3 invited lectures, 6 oral contributions and a poster session with 34 accepted posters. The Proceedings (33 selected contributions and 4 invited talks) have been published in Acta Physica Polonica A -see Annex D.

- The XXXIV International School on the Physics of Semiconducting Compounds, "*Jaszowiec 2005*" was held on June 4 - 10, 2005 in Ustroń-Jaszowiec, Poland. A two-day Tutorial Session that traditionally precedes *Jaszowiec* Schools was also organized. Over 130 colleagues from 18 countries participated in the Preschool and over 220 in the actual School. There were 21 invited talks presented during the School and Pre-School and over 150 contributed, oral or poster, presentations (for a Book of Abstracts see Annex E). Among 4 invited speakers of a tutorial session and 17 of a regular conference part there have been 17 speakers from EU countries. Two special sessions have been organized during the conference. The first "**Semiconductors in optoelectronics: photonics**" was held on 06.06.2005. The day involved 4 invited lectures, 6 oral contributions and a poster session with 45 accepted posters. The second special session "**Semiconductors in spintronics**" took place at 09.6.2005 and included also 4 invited lectures, 6 oral contributions and a poster session with 46 accepted posters. The conference Proceedings (41 selected oral and poster contributions and 7 invited talks) have been published in Acta Physica Polonica A - see Annex F.

The Workshop on Optical Properties of 2D Systems with Interacting Carriers

- The workshop was held in June 10-13, 2004 in Warsaw. There have been 44 researchers taking part, coming from Poland, Germany, France, Russia, Spain, USA, UK and Canada. Three days of sessions involved 19 invited lectures and a poster session with 6 posters. The schedule of the workshop can be found on http://www.fuw.edu.pl/~op2ds. 14 invited speakers were invited from abroad with support of the project, 3 came from Poland and 2 (from USA and Canada) were financed by the US Navy ARL-ERO grant. The size of the meeting allowed for an in-depth discussions during the presentations and later, in an informal atmosphere. The scope of the presented papers showed that the physics of charged excitons in quantum wells, initiated by Kuntheak Kheng et al. in 1993, is alive and well a decade later. It showed nevertheless that the community developing that field feels a need for exploring new paths, turning its attention to the physics of quantum dots, to subtle aspects of many-body interactions etc. The proceedings containing papers by keynote speakers have

been published in a special issue of Acta Physica Polonica A: vol. 106, No3, p 281-450 (2004) – see Annex G

Workshops devoted to research on nitrides

- One day workshop **Nitride Growth and Applications** was held in Warsaw on 18/9/2003 for about 30 participants. There were seven invited talks, four devoted to a progress in nitride technology and three to devices. Talks on the technology had been given by M. Heuken from Aixtron AG (Recent progress in GaN Technology"), by A. Strittmatter from Technische Universitat Berlin ("Benfits of optical in-situ measurements for the MOCVD of III-Nitrides"), E.Dumiszewska from Institute of Electronic Materials Technology ('Growth of AlGaN on sapphire substrates") and K.Pakula from Institute of Experimental Physics Warsaw University ("Growth of nitrides with reduced dislocation density using SiN interlayer"). Talks about devices had been given by P. Prystawko from High Pressure Research Center Unipress Polish Academy of Sciences ("Violet laser diode on bulk substrate"), K.Kopczyński from Military University of Technology ("Application of UV detectors") and L.Dobrzański from Institute of Electronic Materials Technology ("UV Solar blind detectors").

- The Fall Meeting of European Materials Society (E-MRS) was held in Warsaw between 6/9/2004 to 10/9/2004. Its Symposium C was organized as a workshop being a part of: the CEMOS: **"Science and Technology of Nitrides and Related Materials"**. The workshop was devoted to growth, device technology, characterization techniques and characteristic physical phenomena of III-nitrides and similar wide-bandgap materials. Its objective was to bring together a wide range of specialists from universities, research institutes and industrial laboratories, as well as post-graduate students, and young scientists actively working on wide-bandgap materials. During four days of the workshop (September 7-10), more than 50 participants listened to 11 invited talks and 19 oral presentations. Moreover, 16 posters were presented. The proceedings are published in physica status solidi (c) **2**, 847-1238 (2005) – see Annex H.

Workshops on spintronic materials

- The First workshop was focused on possibilities of fabrication nano-composites based on classical semiconductors as silicon and GaAs using high pressure infiltration technique. The workshop was organized by Warsaw University, with participants from France, Lithuania and Sweden. **Prof. B. Pałosz** (Poland) presented current possibilities offered by high pressure

infiltration technique, **prof. J-L.Coutaz (France)** discussed possible use of semiconductor nano-composites in high frequency (THz) applications, **prof. A.Krotkus (Lithuania)** considered solar cells applications and **Dr. J.Sadowski (Sweden)** presented recent advances in fabrication of magnetic nano-composites by MBE technique. Broad discussion showed that semiconductor nano-composites should be regarded as prospective materials for high-tech applications. It was also suggested that the considered materials deserve a separate research project, possible conducted as a part of EC Framework Programs.

- The Second Workshop was focused on magnetic (ferromagnetic) composites based on GaAs and GaN as matrices with nano-dots of MnAs or MnN embedded in the nonmagnetic matrix. The meeting was organized by Warsaw University and Institute of Physics PAS. Possible applications in spin electronics were discussed. Prof. V.Holy (Czech Republic) presented possibilities of structural characterization of the considered composites, which is crucial for understanding these materials and can provide the necessary feedback for their fabrication.

- The Third Workshop **"Spin in nanostructures"** in Pułtusk, 13-14 November 2004. The workshop involved 14 participants: 12 from Warsaw University, 1 from Polish Academy of Sciences and 1 from CNRS Marcoussis, France (Dr Olivier Krebs). Twelve talks and on round table discussion took place. The themes ranged from physical mechanisms of spin-dependent phenomena in quantum dots, MBE growth of self-organized quantum dot systems to various experimental techniques useful in the studies of spin-dependent properties of nanostructures.

Workshops on Semimagnetic Semiconductors

Three Workshops on Semimagnetic (Diluted Magnetic) Semiconductors were organized on 28 February 2004, 18 December 2004, and 17 December 2005 for 3 x 60 researchers from Poland with participation of four physicist from France and Germany in each of Workshops. The workshop is organized in the response to rapid development in the area of semimagnetic semiconductors based low-dimensional systems and important increasing number of young researchers and PhD students from Warsaw University, Polish Academy of Sciences, Warsaw Technical University involved in the experimental and theoretical studies of semimagnetic semiconductor low-dimensional structures.

The half of the participants were the young researchers, working on their PhD thesis, the second half – recognised experts in the subject. Thirteen 15 to 20 min. (Feb. 2004), eleven 15 to 30 min (Dec. 2004), and fifteen 20 minutes papers were presented by young persons and

after any paper the free discussion was opened. In February at the end of Workshop the round table discussion with participation of French and German physicists was organized. The booklets with abstracts for participants have been prepared, see Annexes I,J, and K.

Meeting of the Members of the International Advisory Board

- In order to present activities of our Center of Excellence and to discuss the possibilities of the further cooperation, on June 2-3 we have organized the Meeting of the Members of our International Advisory Board. We have hosted the following persons: Prof. G. Bauer from Johannes Kepler Univesität, Linz, Austria, Prof. J. Cibert from Universite Joseph Fourier, Grenoble, France, Prof. C. T. Foxon from Nottingham, United Kingdom, Prof. B. Monemar from Linköping University, Linköping, Sweden Prof. L. Vina from Autonoma Universidad de Madrid, Spain. Other members of the Board: prof. J. Furdyna from Notre Dame University, USA and prof. P. Vogl from Technische Universität, München, Germany, could not participate in the meeting. Prof. J. Furdyna had visited our Center earlier in March 2005. During the seminar on 2nd June 2005 the main subjects of our scientific activities have been presented to our guests. Schedule of this meeting is given below. The presentations have been included to the report in electronic format as Annex L

Visitors and Visits

A number of visits to/and from the Centre have been paid. These were both short and long term and devoted to transfer of knowledge, joint experiments and discussions on prospects of collaboration. Most significant visits are listed below.

Short term

Dr D. Maude of GHMFL: 3/12/2003 – 6/12/2003, a seminar "Resistively Detected Nuclear Magnetic Resonance in the Quantum Hall Regime: Possible Evidence for A Skyrme Crystal Near Filling Factor v=1" given on 5/12/2003.

Dr G. Martinez of GHMFL: 19/5/2004 – 20/5/2004 The visit of Dr. Gerard Martinez, the director of GHMFL to the Centre was devoted to the preparation of the regular partnership of the Poland in GHMFL. During his visit these problems have been discussed during the visit of Dr Martinez and representatives of the Centre (Prof. M. Grynberg and Prof. Roman Stępniewski) in the Department of International Co-operation in Ministry of Scientific Research and Information Technology.

Dr M. Horvatic of the GHMFL: 9/12/2005-14/12/2005, seminar "Spin superstructure in the 1/8 magnetization plateau of the 2D quantum antiferromagnet $SrCu_2(BO_3)_2$" given on 9/1/2004 at the Centre.

Dr J.L.Tholence of the GHMFL: 6/12/2005-14/12/2005 The visit of Dr. Tholence, the director of GHMFL from the 1st January 2006 was devoted to preparation of the future partnership of Poland in GHMFL.

Dr A. Babiński to the GHMFL: 23/8/2004 - 28/8/2004, bridging activities in preparation for the Polish part of the project (ICA1-CT-2002-70010), which was a continuation of the project "Semiconductor Quantum dots in High Magnetic Field" (ICA1-CT-2002-70009) in which Dr A. Babinski was involved in GHMFL until the end of July 2004. Beside of that, during this visit single-dot spectroscopy measurements have been performed and methods of further cooperation have been discussed. In particular the effect of excitation energy on photoluminescence spectra from single dots has been investigated, 28/1/2005-7/2/2005: experiments in high magnetic field, 31/5/2005-7/6/2005: experiments in high magnetic field, seminar, "Single Quantum Dots in High Magnetic Field" on 6th June 2005. 18/11/2005-27/11/2005: experiments in high magnetic field, seminar "The Fock-Darwin spectrum of a single quantum dot on 25th November 2005.

Dr A. Witowski to the GHMFL**:** 23/1/2004 - 8/2/2004: measurements of the far infrared magnetotransmission of GaN free standing and ZnO samples. In the case of GaN the observed line, suspected to originate from intra acceptor transitions, did not change position with the magnetic field, thus excluding the hypothesis. The as grown ZnO samples show a very strong absorption unaffected by the magnetic field in the region above 160 cm^{-1}. The annealed sample is transparent up to 300 cm^{-1}. In this region (around 300 cm^{-1}) small changes of transmission with magnetic field were observed, suggesting an electronic origin of at least part of the absorption.

Mr M. Szot to the GHMFL: 23/3/2004 - 5/4/2004: magnetophotoconductivity measurements on CdTe/CdMgTe quantum wells deposited on semi-insulating GaAs in a wide range of magnetic fields and for far-infrared excitation energies.

Ms B.Chwalisz to the GHMFL: 17/8/2003 – 13/9/2003: A number of magneto-optical experiments in high magnetic field on GaN/AlGaN structures grown on GaN buffer layer with SiN spacer, covered by metallic mask with 3-10μm mesas. It is expected that in such structure nano-objects, quantum dots (QDs) like, are formed. Photoluminescence spectra from such structures show interesting emission in the shape of sharp lines, similar to the luminescence that is expected for single QD. The purpose of the work of Barbara Chwalisz was to find the evolution in magnetic field of the single luminescence line, what would give information about the electronic states involved in the recombination process. The work with the structures covered with mask has a disadvantage that is difficult to illuminate with the exciting laser beam in several micrometer mesa. The experiment performed by Barbara Chwalisz let to determine the problems that appeared during the experiment and allowed for the development of new experimental techniques that would solve them in the future. The new experimental tools were built, but still more trials are needed. 31/3/2004-15/02/2004; 4/7/2004-28/7/2004: Investigation of optical properties of type II GaAs/AlAs low dimensional structures.

Dr M. Potemski of GHMFL: 5/11/2003 – 9/11/2003: seminar “Microwave induced oscillations in the longitudinal and transverse resistance of a 2DEG” given on 7/11/2003 at the Centre, 31/5/2004 – 4/6/2004: invited lecture “Microwave induced oscillations in the longitudinal & transverse resistance of a 2DEG” during the XXXIII International School on the Physics of Semiconducting Compounds "Jaszowiec 2004”;, 8/9/2005-12/9/2005 – transfer of knowledge.

Dr A.Wysmołek: 24/9/2004-10/10/2004, 31/1/2005-10/2/2005: photoluminescence studies of the sample consisting of two identical GaAs 60Å quantum wells separated by 50Å

barrier. Dr Andrzej Wysmołek was also involved in the experiments performed by Ms. B. Chwalisz.

Prof. R. Stępniewski, to the Humboldt-University of Berlin to attend a German-Polish Workshop on Physics and Technology on Nitride Semiconductors (March 1-3, 2004). The scope of the workshop was to bring together Polish and German scientists from university, academy and industry, working in the field of nitride semiconductor research. Objective of the workshop was to present an overview on the activities in nitride semiconductor research in both countries and to initiate and enhance scientific collaboration between Polish and German scientists. Two days were dedicated to scientific presentations given by invited experts in the field. In addition selected contributed papers were presented in the combination of posters and short oral presentations. Prof Roman Stępniewski contributed to the lecture program of the workshop with an invited lecture entitled: "*Electronic structure of shallow impurities in GaN studied via bound exciton magnetooptics*".

prof. A. Krtschil, from Otto-von-Guericke-University Magdeburg (Germany) gave a seminar entitled "Electrical microcharacterization of wide-gap semiconductors by scanning probe microscopy" (March, 5) and participated in discussion with group of prof. J. Baranowski.

Prof. Jean-Philippe Poizat of UJF: 16.01.2003 - 22.01.2003 a seminar "Single photon quantum cryptography" given at the Centre

Dr O. Krebs of LNN two visits in 2004, a seminar "Investigation of spin relaxation of electrons and holes in single charge-tunable InAs/GaAs quantum dots" on 19/11/2004 at the Centre.

Prof. M. Grynberg, to Montpellier (France) and to Bremen (Germany). The coordinator of the Centre visited Institute of Solid State Physics (University of Bremen) and Universite Montpellier II. These two visits have been devoted to the establishing the possibilities of further cooperation and, especially, of exchange of interesting samples. The current technological achievements and experimental facilities/possibilities in the field of semiconductor physics and technology has been discussed. In both places prof. M.Grynber gave a seminar entitled *Shallow impurities magnetospectroscopy in II-VI two-dimensional structures*.

Prof. D. Hommel of Bremen University, (Germany) gave a seminar "Nitride-based optoelectronics:where we are and what has to be solved " on 14/11/2003 at the Centre.

Prof. S. Jursenas of Vilnius University, Lithuania gave a seminar "Carrier Recombination in highly photoexcited GaN" on 21/1/2005 at the Centre.

Prof. M. Dyakonov of Universite Montpellier II, France gave a seminar "Plasma instability and terahertz emission in small field-effect transitors " on 20/5/2005 at the Centre.

Prof. J. Gaj to UJF 21.06.2003 -05.07.2003 worked with the UJF student C. Couteau on optical properties of CdTe/ZnTe and CdSe/ZnSe self assembled quantum dot systems. J. Gaj participated also in the jury of the doctoral thesis of H. Boukari.

Dr P. Kossacki to UJF 12.05.2003 - 24.05.2003

Prof. David Ferrand of UJF 26.04.2003 - 03.05.2003

Prof. Jean-Louis Coutaz (University of Savoie, Chambery, France) 26.09.2003 - 30.09.2003

Prof. A. Krotkus (Semiconductor Physics Institute, Vilnius, Lithuania) 26.09.2003 - 30.09.2003 consultations concerning new semiconductor composite materials, which could be used for applications in modern electronics. Discussions with groups of Professor M.Kaminska and Professor A.Twardowski were focused on systems exhibiting broad, ramp-like absorption edge, suitable for solar cells and systems with very short carrier lifetime, which could be used in fast electronic devices. Possible collaborative actions were discussed and planned.

Long term visits (1 month and more)

Prof. R. Stępniewski to GHMFL: 1/3/2003-30/9/2003: During his stay he was involved in the spectroscopic studies of the semiconductors in high magnetic fields. He was in permanent contact with dr. M. Sadowski, dr. A. Babinski and M. Byszewski discussing their actual experimental results. This experience allows for better examination of the experimental possibilities that can be realised within common projects. Results of his activities have been presented in an invited talk entitled: "Electronic structure of shallow impurities in GaN studied via bound exciton magnetooptics" during the European Materials Research Society Fall Meeting 2003, that had place in Poland, in Warsaw at 14-19 September 2003. A seminar "Electronic structure of shallow impurities in GaN studied via bound exciton magnetooptics" has also been given on 17.06.2003 at the GHMFL

Mr J. Suffczyński, to UJF 4/2/2003-7/05/2003: The goal of experimental activities was observation of temporal and polarization correlation (antibunching, entanglement)

between single photons coming from single quantum dot (QD). Microluminescence experiment on CdSe/ZnSe QD was performed at low (5K) temperature in order to find strong and spectrally separated emission from a single QD. Preparation of single photon correlation experiment was done with use of typical Hanbury-Brown and Twiss setup. It involved choice of optimal experimental conditions (voltage on photomultipliers (PM), parameters of the Single Photon Counting Card), selection of two most reliable PM from disposable ones and coupling of the Ti:SAP laser beam with optical fiber. The obtained results were presented in a poster form on the meeting Horizons'03 in Toulouse in September 2003 (Title: Boite Quantique Comme Source de Photons Uniques, Christophe COUTEAU, Sebastian MOEHL, Frank TINJOD, Jan SUFFCZYNSKI, Robert ROMESTAIN, Jean-Claude VIAL, Kuntheak KHENGet Jean-Philippe POIZAT).

Ms P. Płochocka, to the University of Madrid (Spain) 12.04.03-18.05.03. investigation of dynamics of optical processes in semiconductors. The experimental work was focused on measurements of time resolved photoluminescence of modulation doped (Cd,Mn)Te quantum well. The experiments were performed for different hole gas concentrations, for different excitation energies and excitation powers. The aim of this work was to determine the temperature of the photo-created plasma and also to investigate the interaction between preexisting and photo-created carriers. The main result was the observation that presence of carriers significantly affects the shape of the exciton transition line.

Ms. M.Gryglas, to the Laboratoire de Photonique et Nanostructures (CNRS) in Marcoussis (France) 30.11.03-23.12.03 **:** measurements for her PhD thesis. She investigated the tunnelling process via single impurities in GaAs/AlAs/GaAs hetersotructure *d*-doped with silicon in the centre. The main aim was to examine the properties of a new wafer that was recently processed and was expected to have a small number of impurities inside the junctions. The other aim was to discuss the results already obtained. Marta performed I-V characteristics at very low, 30mK temperatures and in magnetic field. She observed features related to resonant tunnelling via donors in I-V curves and resolved Landau quantisation in the magnetic field. She had also an opportunity to discuss her results with dr G.Faini, dr B.Jouault, prof. M. Dyakonov, known specialists in the field

Ms B.Chwalisz to GHMFL: 11/6/2005-31/10/2005 experiments on optical properties of "natural quantum dots" formed at the GaAs/AlGaAs interface. Seminar: Intriguing Properties of Single Natural Quantum Dot-like Objects Formed in Type II GaAs/AlAs QWs on 18th October 2005

Dr. P. Kossacki to UJF: 01.09.2003-30.09.2003 experimental work with the UJF student H. Boukari on the interpretation of the experimental results of spin-dependent effects in photoluminescence measured on p-doped CdMnTe quantum wells.

Dr A.Kudelski to UJF **:** 30.09.2003-29.10.2003 to profit from the specialized traning by UJF experts: Jean Philippe Poizat, Joel Cibert and David Ferrand. The training covered the field of photon emission from self organized quantum dots (J-P. Poizat) and optical studies of new spintronics materials (D. Ferrand) as well as of spin-dependent properties of doped semiconductor quantum wells (J. Cibert).

4. Consolidated report

Objectives

The objectives of the projects were:

(1) to intensify research on new materials of recognised importance for advanced applications for optoelectronics and spintronics.

(2) to enhance quality of education provided by the Centre and to improve quality of training of human resources (PhD) in skills connected with emerging optoelectronic and spintronic applications.

(3) to strengthen collaboration with other educational, scientific and industrial institutions in Poland, in the area of nitride semiconductors.

(4) to improve and intensify links with chosen European research Centres.

(5) to maintain and attempt to increase the linkage to high-technology industry

Results and achievements

Accompanying measures supported by the project substantially influenced the research activities of the Centre in 2003-2005. Therefore the whole research output of the Division related to "**Physics and Technology of Semiconductor Materials and Structures for Optoelectronics and Spintronics"** profited to lesser or larger extent from the project. For the sake of clarity only the main conclusions of the work are given here, followed by references to the papers by staff and students of the Division published in 2003-2006.

An advancement of technology of nitride-based materials by J. Baranowski et al

The main problem connected with growth of nitrides are treading dislocations. Due to a large lattice mismatch between sapphire substrates and nitride epilayer the density of treading dislocations is usually of the order $10^9 – 10^{10}$ cm^{-2}. Our technological work has been focused on improving quality of AlGaN and GaN layers via reduction density of treading dislocations. It was found that growth interruption of GaN layer connected with introduction of silane to the MOCVD reactor leads etching and roughening of the surface of GaN layer. Successive growth of GaN starts in 3D mode and that leads to bending of several dislocations. The resulting GaN layer has reduced density of treading dislocations to $10^7 – 10^8$ cm^{-2}.

The reaction of silane with nitride surface allowed to develop method of growth of low density quantum dots of GaN on AlGaN surface. The resulting rough AlGaN surface reduced number of nucleation sites for successive growth of GaN. By this method it was possible to grow a low density of GaN quantum dots on AlGaN surface. [1-4]

The far infrared magnetotransmission of GaN free standing and ZnO by A. Witowski et al

The far infrared magnetotransmission of GaN free standing and ZnO has been investigated. In the case of GaN the observed line, suspected to originate from intra acceptor transitions, did not change position with the magnetic field, thus excluding the hypothesis. The as grown ZnO samples show a very strong absorption unaffected by the magnetic field in the region above 160 cm^{-1}. The annealed sample is transparent up to 300 cm^{-1}. In this region (around 300 cm^{-1}) small changes of transmission with magnetic field were observed, suggesting an electronic origin of at least part of the absorption. [5-6]

The far infrared magnetophotoconductivity of a uniformly doped with Iodine CdTe/CdMgTe quantum well

The main goal of the project was to perform magnetophotoconductivity measurements of uniformly doped with Iodine CdTe/CdMgTe quantum well in the Far Infra Red using FIR laser. In particularity, project assumed the following: repeating and widening (for FIR wavelengths of 570.6 μm) the results obtained for mentioned samples earlier at another experimental set-up. In spectra two lines (at 0.5 and 2 T) were observed. Surprisingly, the position of mentioned lines in magnetic field does not depend on energy of FIR light. In proposed interpretation, the presence of these lines is attributed to the quasi-continuum of shallow donor transitions accessible for observation in the structure and with localization of

electrons on potential fluctuations, realization of measurements for samples with donor concentration of Iodine higher than 10^{16} cm^{-3}. The main objectives of the project have been fully realized. For two samples magneto-photoconductivity measurements were carried out for several FIR laser wavelengths from range 96.5÷570.6 μm - the results are qualitatively the same as these obtained earlier. But for one of samples new line (at 5T) was observed. Probably, this line is connected with potential fluctuations with smaller characteristic spatial size – with a diameter of approximately 20 nm. [7-8]

Spectroscopy of (Zn,Co)O in magnetic field

The existence of carrier-ion exchange coupling typical for diluted magnetic semiconductors has been to proven. The coupling constant alpha-beta was determined based on a subtle analysis of intra-ion and excitonic magnetoabsorption. An important influence of electron-hole exchange interaction on excitonic Zeeman splittings was established, in contrast to all previously studied diluted magnetic semiconductors. [9]

Main contributors: J. Cibert, D. Ferrand, H. Mariette, W. Pacuski, P. Kossacki.

Systematic spectroscopic studies of p-doped CdTe-based ferromagnetic quantum wells

Control of the ferromagnetic phase transition by doping, light, lattice mismatch strain, and electric field was evidenced. A new type of doping from surface states was introduced, helping to extend the range of Curie temperatures. Simple Zener model was found to describe well the properties of the ferromagnetic phase. Joint effort allowed us to construct in both laboratories unique experimental set-ups with micro-coils producing fast (nanosecond) pulses of magnetic field. This was used for optical studies of dynamics of the ferromagnetic phase. [10-14]

Main contributors: J. Cibert, H. Boukari, D. Ferrand, S. Tatarenko, W. Maslana, M. Goryca, W. Pacuski, P. Kossacki.

Spectroscopic studies of CdTe-based quantum dots were performed by Kossacki et al. Single quantum dot spectroscopy was developed. Photoluminesce lines of neutral and charged excitons and biexcitons were identified. Anisotropic exchange splittins was measured in the range of tens of microelectronvolts for exciton and biexciton lines. Two types of correlation spectroscopy was developed: single photon correlated detection in a Hanbury-Brown and Twiss

setup, and femtosecond excitattion correlation spectroscopy. Polarization resolved measurements evidenced correlated single photon emission from individual quantum dots. No entangled photon pairs were detected because of the QD anisotropy. [15-18]

Main contributors: C. Couteau, J-Ph. Poizat, L. Besombes, J. Suffczyński, B. Piechal, K. Kowalik, A. Golnik, P. Kossacki, M. Nawrocki, J. A. Gaj

Photoluminescence of *p*-doped quantum wells with strong spin splitting

The spectroscopic properties of a spin-polarized two-dimensional hole gas have been studied in modulation doped $Cd_{1-x}Mn_xTe$ quantum wells with variable carrier density up to 5×10^{11} cm^{-2}. The giant Zeeman effect, which is characteristic of diluted magnetic semiconductors, induces a significant spin splitting even at very small values of the applied field. Several methods of measuring the carrier density (Hall effect, filling factors of the Landau levels at high field, various manifestations of Moss-Burstein shifts) are described and calibrated. The value of the spin splitting needed to fully polarize the hole gas shows a strong enhancement of the spin susceptibility of the hole gas due to the carrier-carrier interaction. At small values of the spin splitting, whatever the carrier density (nonzero) is, photoluminescence lines are due to the formation of charged excitons in the singlet state. Spectral shifts in photoluminescence and in transmission (including an "excitonic Moss-Bustein shift") are observed and discussed in terms of excitations of the partially or fully polarized hole gas. At large spin splitting, and without changing the carrier density, the singlet state of the charged exciton is destabilized in favour of a triplet state configuration of holes. The binding energy of the singlet state is thus measured and found to be independent of the carrier density (in contrast to the splitting between the charged exciton and the neutral exciton lines). The state stable at large spin splitting is close to the neutral exciton at low carrier density, and close to an uncorrelated electron-hole pair at the largest values of the carrier density achieved. The triplet state gives rise to a characteristic double-line structure with an indirect transition to the ground state (with a strong phonon replica) and a direct transition to an excited state of the hole gas. [19]

Main contributors: J. Cibert, S. Tatarenko, P. Płochocka, W. Maslana, B. Piechal, P. Kossacki, J. A. Gaj, A. Golnik.

Exciton-exciton interaction and biexcitons in the presence of spin-polarized carriers by P.Kossacki et al.

An absorption study of the neutral exciton, biexciton and positively charged exciton (trion) in a (Cd,Mn)Te quantum well under the influence of a femtosecond, circularly polarized, resonant pump pulse has been performed (see Fig. 1) . By using spin-dependent selection rules in a quantum well containing a strongly diluted magnetic semiconductor, we could unambiguously separate the biexcitonic transitions from the charged exciton ones, and we report on their simultaneous observation for a well chosen configuration of the pump and probe polarization. The influence of the hole gas on the biexciton line is described. In a polarization such as the charged exciton line is not present in the transmission spectrum, the sum of the neutral exciton and biexciton intensities is conserved, whatever the density of preexisting holes. However, when both the charged exciton and the biexciton coexist, we observed some intensity stealing from the biexciton by the charged exciton. [20]

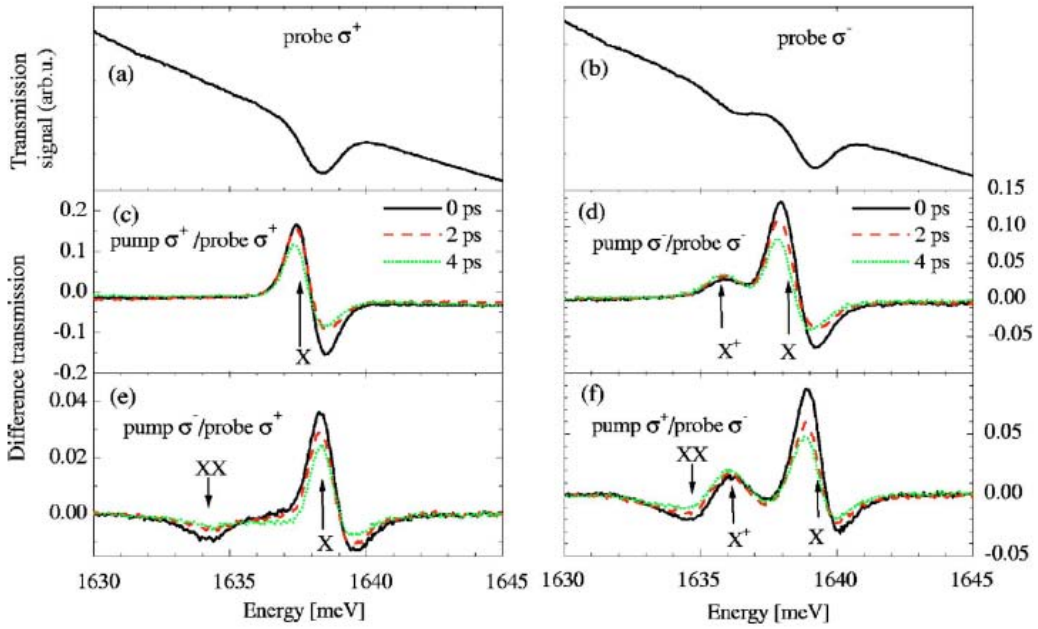

FIG. 1 (a), (b) Transmission of the σ+ (a) and σ − (b) polarized probe pulse 10 ns after the cross-polarized pump pulse ("negative delay"), (c)-(f) Difference transmission spectra for zero delay (black solid lines), 2 ps positive delay (red dashed lines), and 4 ps, positive delay (green dotted lines). The magnetic field was B=0.5 T, the hole density p=0.5x10^{10} cm^{-2}. from [20]

Femtosecond Study of the Interplay between Excitons, Trions, and Carriers in (Cd,Mn)Te QuantumWells by P.Plochocka et al.

The absorption by neutral excitons and positively charged excitons (trions) following a

femtosecond, circularly polarized, resonant pump pulse has been investigated. Three populations are involved: free holes, excitons, and trions, all exhibiting transient spin polarization. In particular, a polarization of the gas of free holes is created by the formation of trions. The evolution of these populations is described, including spin flip and trion formation.We evaluate the contributions of phase space filling and spin-dependent screening. A new explanation of the oscillator strength stealing phenomena, which is observed in doped quantum wells has been proposed. The explanation is based on the screening of neutral excitons by charge carriers. It has also been found that binding holes into charged excitons excludes them from the interaction with the rest of the system, so that oscillator strength stealing is partially blocked.

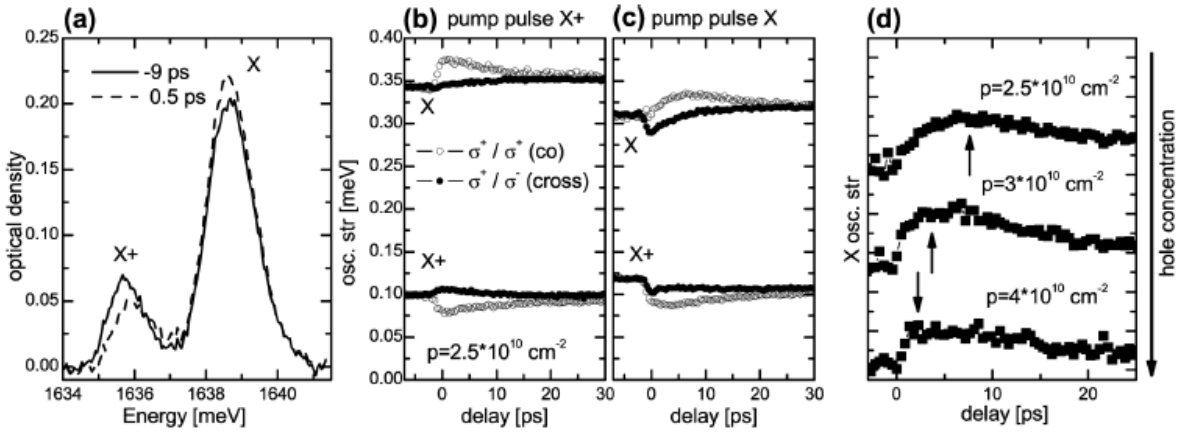

Fig. 2 (a) Optical density for a QW with hole density p (2:5 $\times 10^{10}$ cm^{-2}, at negative delay (-9 ps, solid line) and short positive delays (0:5 ps, dashed line), for a copolarized pump pulse tuned to $X+$. (b) Evolution of the X and $X\_$ oscillator strength with pump pulse tuned to $X\_$. (c) Evolution of X and $X\_$ with pump pulse tuned to X. (d) Evolution of the X oscillator strength for different hole densities, with the pump beam tuned to the $X+$ line [from 21]

Carrier dynamics of GaN/AlGaN structures containing quantum dots, by K. Korona et al

Optical properties of GaN/AlGaN structures containing quantum dots, which were obtained in a low-pressure MOVPE reactor on a SiH4-treated surface have been investigated. Photoluminescence (PL) shows two bright PL bands (P1, P2) and one weak PL band (P3) at energies of 3.48 eV, 3.44 eV and 3.35 eV, respectively. Time-resolved PL shows that the P1, P2 and P3 bands have lifetimes of about 0.05 ns, 0.4 ns and 1.3 ns, respectively.

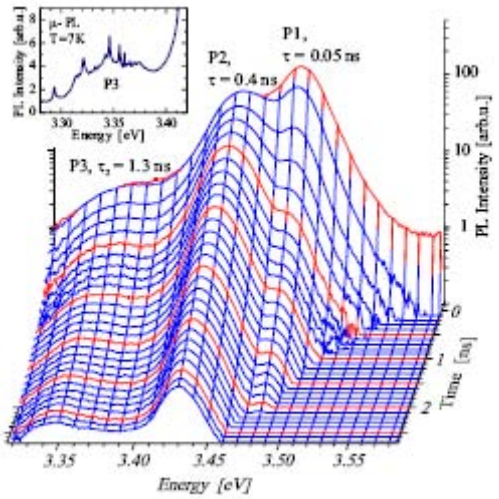

Fig. 3 Quasi-3-dimensional time-resolved PL spectrum (main) and micro-PL spectrum (inset). The sharp peaks in the micro-PL come from individual QDs. The TRPL spectrum shows a significant shift of the QD luminescence (P2 and P3 bands). For example, maximum of the P2 band shifts from 3.445 eV to 3.430 eV.

Micro-photoluminescence measurements reveal that these bands consist in fact of many sharp lines coming from small spots on the sample. Such behaviour is characteristic for quantum dots or islands. The P2 shows significant spectral shift with time. As confirmed by power dependent measurements, the spectral shift is due to excitation of high-energy quantum dots followed by diffusion of excitons between QDs to lower energies. Excitation distribution parameters found at low temperature allow explaining of the behaviour of the PL at higher temperatures. [22]

Carrier dynamics of GaN/AlGaN quantum wells, by B.Chwalisz et al

Temperature and excitation power dependencies of photoluminescence from GaN/AlGaN quantum well structures have been studied. It has been shown that depending on the well width, the increase of the excitation power results in the blue or red shift of the emission energy.

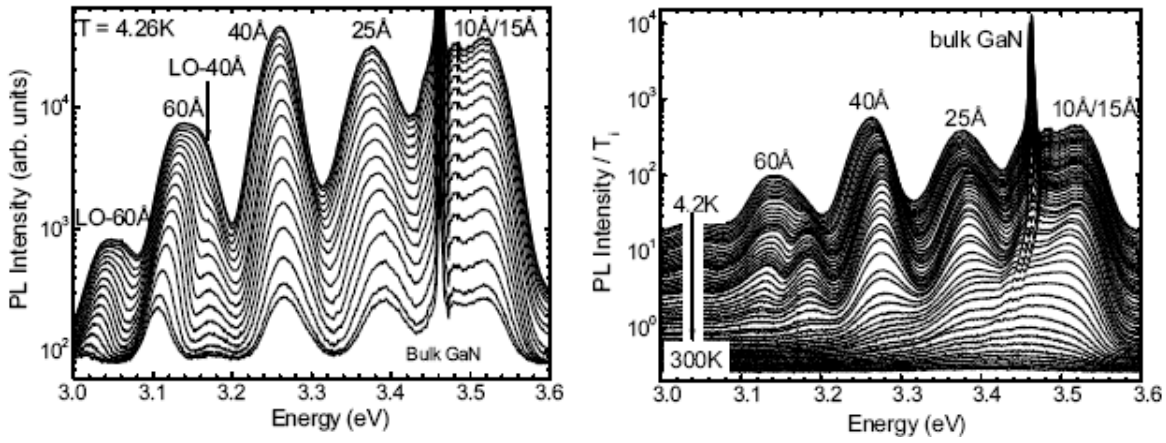

Fig. 4 PL spectra taken at 4.2 K for various excitation power (left panel) and a temperature dependent PL spectra (right panel)

Temperature affects the observed emission energy shifts in a way which is entirely different from that for unstrained GaN bulk. Surprisingly, the observed differences are larger for wider wells. These results can be understood assuming that not only potential fluctuations but also built-in electric field and strain effects must be taken into account. The role of the particular mechanisms is discussed on the basis of performed calculations. [23]

Optical properties of "natural dots" formed at the GaAs/AlAs interface by B. Chwalisz at al

It has been previously found that broad, indirect macro-photoluminescence (macro-PL) of such structure can be dominated by sharp emission lines spreading up to 200 meV below the direct Γ-Γ transition (see Annex L2). These lines become clearly resolved when a high magnetic field is applied in the direction perpendicular to the quantum well plane. The appearance of sharp emission lines in the macro-PL spectrum was not well understood, although they have been tentatively attributed to laterally type-II quantum-dot-like objects. The PL spectra with built-in type-II interfaces exhibit a number of intriguing properties which have been interpreted as the observation of a precursor of the Bose condensate of excitons or alternatively are assigned to effects of trapping of photoexcited carriers in naturally built-in quantum-dot-like objects formed out of potential fluctuations caused by the interface roughness.

It was found that the micro –PL spectra from such structures, below the main quantum well transition, under low excitation power is composed of sharp lines similar to previously observed from quantum dots (see Fig.5)

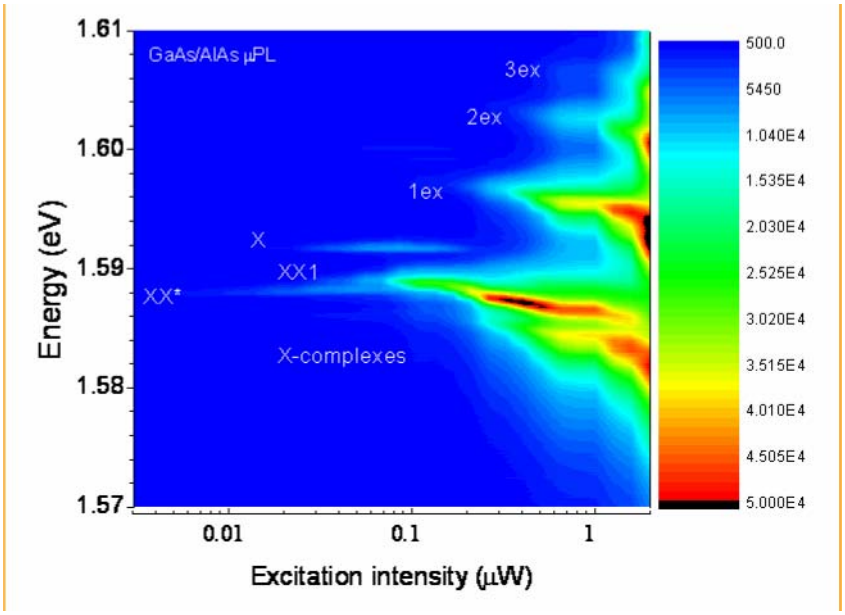

Fig.5 Power dependence of the emission from a single "natural" dot formed at the GaAs/AlAs interface

The energetic position and the excitation power behavior allow for the identification of these lines as coming from the recombination of exciton, biexciton and higher order excitonic complexes. Moreover, it was found that it is possible to observe the luminescence from the excited states of the illuminating quantum dot like object. Its magnetic field behavior allowed for the discussion of the symmetry and orbital origin of the states and its modification by the excitation power. It has been discovered that the properties of the system at high excitation regime are of specific character with strong diffusion and probably super-linear properties. Furthermore, under particular excitation power condition for several emission lines the specific oscillations, similar to Aharonov – Bohm oscillations, of the emission energy and luminescence intensity have been observed. These results make a strong basis for the discussion the shape, confining potential and high carrier density properties of the system. [24-25]

Electroreflectance investigations of AlGaN/GaN heterostructurewith a QW placed inside AlGaN layer by A. Drabińska et al

Electroreflectance technique, which has been developed at the Centre has been proved to be a very efficient tool for studying the properties of low dimensional structures (see in Annex L1). The technique has recently been applied to nitride-based systems.

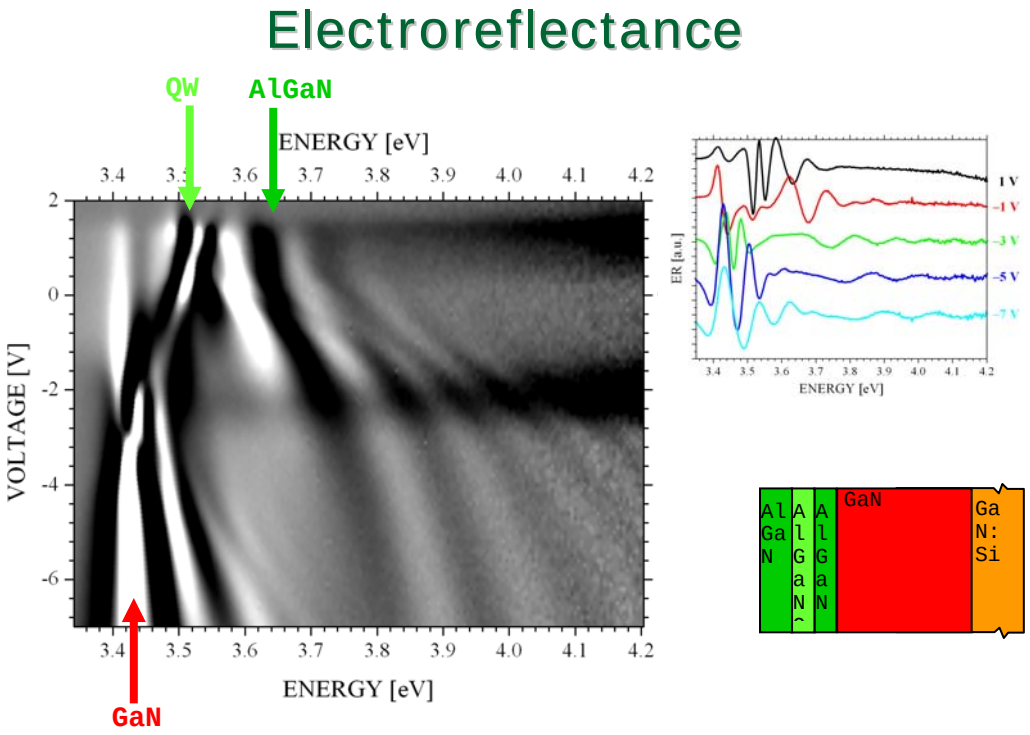

Fig. 6 Electroreflectance measurement of the AlGaN/GaN heterostructure

Typical result of electroreflectance measurement is shown in Fig. 6. The surface plot consists of a series of electroreflectance spectra taken at different bias. Oscillatory structures clearly seen in the plot are due to Franz-Keldysh oscialltions in the AlGaN barrier, AlGaN quantum well and GaN layer. Analysis of Franz-Keldysh oscillations from GaN layer and AlGaN barrier allowed to calculate the electric field in the structure. Analysis of electric field dependence on bias allowed to obtain the occupancy of QW and difference of total polarization between GaN and AlGaN layers. It was also possible to obtain the position of AlGaN/GaN interface and the total width of AlGaN/GaN heterostructure. [26]

Kelvin Probe Microscopy *principle* & *applications by* R.Bożek

The Atomic Force Microscope previously existing at the Division has recently been upgraded and now a Kelvin Probe Microscopy (KPM) can be performed (see Annex L4). Such sub-micron photovoltage spectroscopy allows for semi-quantitative measurements of spatial (lateral) resolution of 100 nm. Using the technique electric charges, precipitations (composition, phase), roughness of buried interfaces other factors influencing work function can be detected

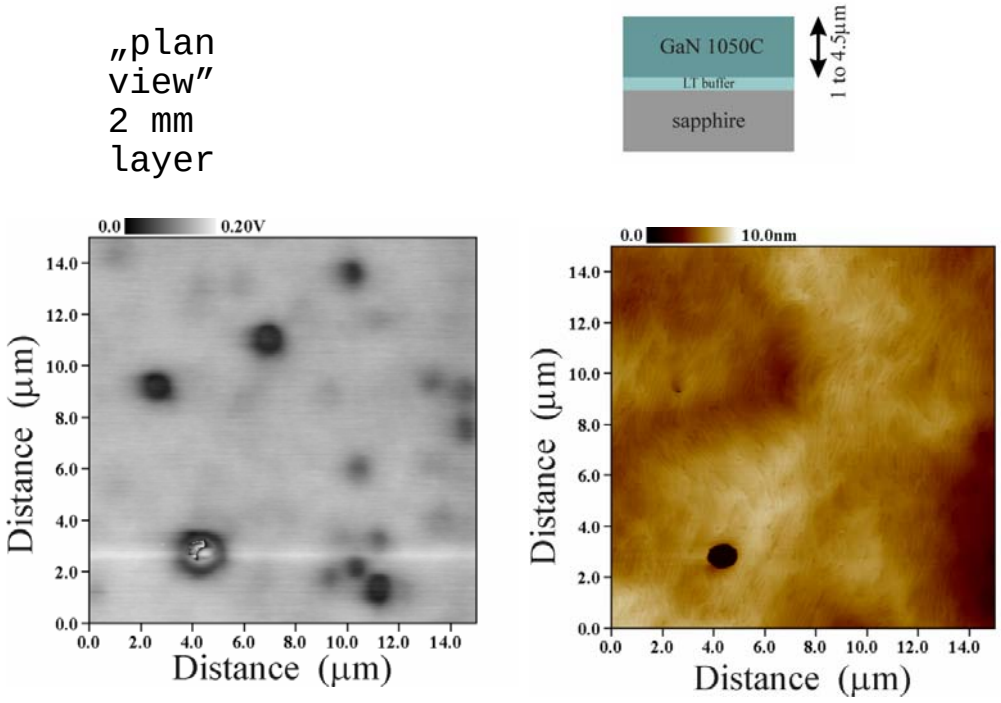

Fig.7. KPM (left panel) and AFM (right panel) images of the same area of GaN sample

The information, which can be obtained using the KPM is summarized in Fig.7. The topography of a GaN sample obtained using the FPM (left-hand side) is compared to the surface topography resulting from a usual AFM measurement. Both pictures present the same part of the sample. It can be seen that more details of a structure buried below the surface are visible on the FPM image. [27-29]

Luminescence from a modulation-doped GaAs/InGaAs/GaAlAs quantum well in magnetic field by A. Babiński et al

Optical emission from a modulation-doped pseudomorphic GaAs/InGaAs/GaAlAs quantum well (QW) has been investigated. Oscillations of the photoluminescence (PL) intensity in magnetic field are investigated. Recombination processes giving rise to the PL are identified and their effect on the PL is established. It has been shown that measurements of the oscillations in the low-energy tail of the PL can provide information on the density of

the quasi-two-dimensional electron gas confined in the quantum well. It has been proposed that the mechanism responsible for the oscillations is analogous to the effect previously observed in quantum wells purposely doped with acceptors. [30]

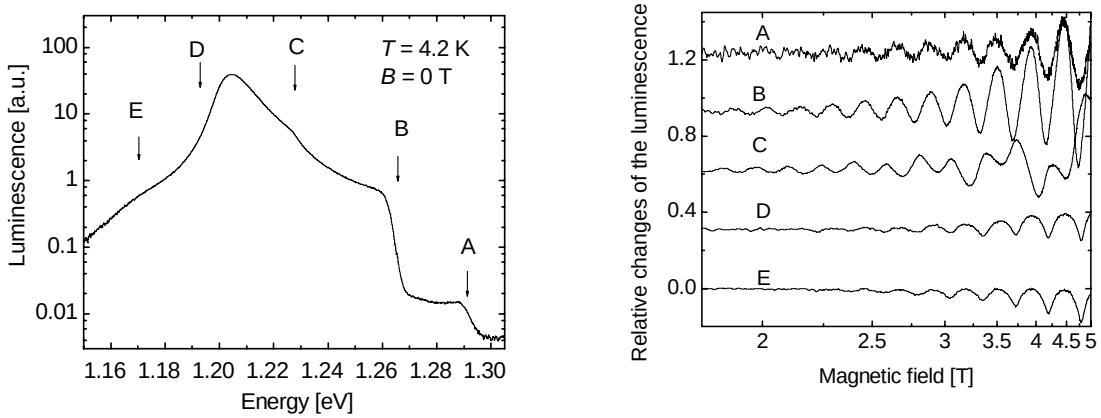

Figure 7. Characteristic energies of the luminescence spectrum from a modulation-doped GaAs/InGaAs/GaAlAs quantum well (left panel) and oscillations of the intensity recorded at those energies (right panel).

Far-infrared absorption of GaN by D.Wasik

GaN doped with Be, Mn, or Mg have been studied in far infrared. Characteristic vibronic line connected to local vibrations of a complex Be-V_N has been observed. This suggests a new compensation mechanism important for GaN samples grown by "Unipress". The undoped samples are strongly *n*-type. It is believed that electrons come from nitrogen vacancies. Samples must be compensated with acceptors. Our results suggests two possible mechanisms of compensation involving beryllium (1) – electron capture by the acceptor atom, (2)-neutralisation of nitrogen vacancies.

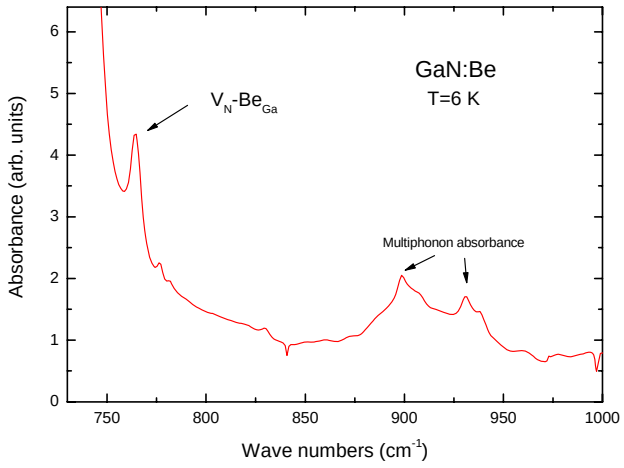

Fig. 8. The infrared absorption spectrum of GaN:Be. Sharp line at 764 cm^{-1} is due to local vibrations of a complex V_N-Be_{Ga}. Features At higher energies are due to multiphonon absorption.

Twinning of the CEMOS with Laboratoire de Spectrometrie Physique in education and research concerning semiconductor materials and structures for optoelectronics and spintronics

The existing collaboration of both partner laboratories in the field of semiconductor materials and structures for optoelectronics and spintronics has strengthen as a result of the activities.[9-17, 31-50] This has been achieved i.e. by:

(a) Widening the offer of specialised education for the students. Several PhD students have been sent to the Laboratoire de Spectrometrie Physique (LSP) as e.g: Mr. A. Kudelski, Mr W. Pacuski, Mr. W. Maślana, Ms. P. Płochocka, Ms K.Kowalik, Mr. B. Piechal, and Mr. M. Goryca. They were able to profit from the specialized training by LSP experts on photon emission from self-organised quantum dots (J-P. Poizat), optical studies of new spintronics materials (D. Ferrand) and of spin dependent properties of doped semiconductor quantum wells (J. Cibert). The LSP student profited from visits of Warsaw experts in Grenoble. Dr P. Kossacki and Prof. J. Gaj worked with Grenoble students C. Couteau and S. Moehl on optical properties of CdTe/ZnTe and CdSe/ZnSe self assembled quantum dot systems.

(b) Visits of P. Kossacki and J. Gaj in Grenoble helped to transfer the experience in single photon correlation measurements of the LSP team to Warsaw laboratory, where a new experimental setup has been constructed. Measurements of time-resolved photoluminescence and of photoluminescence anisotropy on quantum dot samples fabricated in Grenoble have been started, preliminary results are analysed and a scheme of distributing experimental tasks between the two laboratories is developed. Seminars presenting the results of collaboration were given at the Centre:

- by Dr P. Kossacki on 16/12/2005 “Spectroscopy of ferromagnetic (Cd,Mn)Te quantum dots” (in Polish)
- by Dr P. Kossacki. on 23/3/2004 “Photoluminescence from quantum wells with spin-polarized hole gas” (in Polish)
- by Prof. J.Gaj on 20/4/2004 “Photon emission from a quantum dot” (in Polish)

(c) Visits of staff and students from the LSP to the Centre gave opportunity to exchange information e.g. through seminars:

(d) Several presentations of joint work have been given at international conferences: e.g. 11th Conference on Modulated Semiconductor Structures, Nara, Japan 2003, 27th International Conference on Physics of Semiconductors, Flagstaff, USA 2004; 12th Conference on

Modulated Semiconductor Structures, Albuquerque, USA 2005, at Nara, Japan, and Jaszowiec 2003, 2004, and 2005

Strengthening of the Research Collaboration with Grenoble High Magnetic Field Laboratory

Intense exchange of personnel and students confirms a close collaboration with the High Magnetic Field Laboratory, CNRS in Grenoble. Topics covered by the workpackage were :

1. Examining possibilities of using semiconductor growth technologies available at the Centre for the preparation of samples for new common investigations in high field facility equipment not available at the Centre and available at GHMFL
2. Selection of the projects for future experiments, exchange of information and co-ordination of common projects
3. Forming new research groups for research in the high magnetic fields.
4. Determination of the required samples parameters and samples preparation.
5. Performing preliminary measurements, selection of samples for experiments in high magnetic fields.
6. Performing measurements with use of high magnetic fields in GHMFL.
7. Discussing results of measurements, determination of the future experiments, preparation of the publications
8. Determination of the Centre role within the Polish contribution to the European High Magnetic Field Laboratory in Grenoble.

Several visits to and from the Laboratory have been paid (listed in previous Section of this report) The research scope of the Centre and the number of papers published by the staff of the Centre has increased. Scientific topics covered by joint projects are listed in Annual Reports of the GHMFL:

- (2005) http://ghmfl.grenoble.cnrs.fr/ar2005.pdf,
- (2004) http://ghmfl.grenoble.cnrs.fr/AR2004.pdf,
- (2003) http://ghmfl.grenoble.cnrs.fr/ar03.htm,

Young researchers have been attracted to work at the Centre. Several presentations of their work done in collaboration with the GHMFL have been given at the Centre [25, 51, 52], e.g.:

- "Investigation of a neutral Mn impurity in GaN in high magnetic fields" (in Polish) given on 4/5/2004 by Ms A. Wołoś
- "The 2-dimensional electron gas at the GaN/AlGaN heterostructure" (in Polish) on 14/12/2003 by Ms B. Chwalisz.

- "The exciton complexes in natural dots at the GaAs/AlGaAs interface" (in Polish) on 12/4/2004 by Ms B. Chwalisz.
- "The effect of magnetic field on tunneling in a system of GaAs/GaAlAs quantum wells" (in Polish) on 22/11/2005 by Ms K. Surowiecka.

The knowledge by the Centre employees on newest achievements in the Grenoble High Magnetic Field Laboratory increased through presentations given in Warsaw and in Grenoble [53-55] e.g.

- seminar "Magnetospectroscopy of donor states in GaN – from bound excitons to intra-donor transitions" (in Polish) given on 9/1/2004 at the Centre by Dr A. Wysmolek,
- seminar "Electronic structure of shallow impurities in GaN studied via bound exciton magnetooptics" given on 17/6/2003 by Prof. R.Stepniewski: at the GHMFL
- presentation "Basic properties of GaN - wide-gap semiconductor deduced from high magnetic field optical studies given during the Colloquium "Science in High Magnetic Fields" in Grenoble 13-14/6/2005
- seminar "InAs/GaAs quantum dots in high magnetic fields" (in Polish) given on 26/11/2004 at the Centre by Dr A.Babiński
- seminar "Spin superstructure in the 1/8 magnetization plateau of the 2D quantum antiferromagnet $SrCu_2(BO_3)_2$" given on 9/1/2004 at the Centre by Dr M.Horvatic of the GHMFL

Conclusions

Activities of CEMOS improved significantly the quality of research and teaching provided by the Division of Solid State Physics, Faculty of Physics, Warsaw University.

The quality of research improved as the CEMOS provided means to effectively exchange staff for joint experiments. The obtained results have been published in a number of articles in international journals by researchers from the Division. Stronger collaboration of the host with other institutions resulted from the project. Technical means of transfer of knowledge were provided through numerous workshops and special sessions during conferences. Very high quality of teaching provided has been maintained by relatively easy contact with best specialists in the field, who have been invited to give talks and presentations during the lifetime of the project. The contact of PhD students with those experienced scientists helped them to be immersed in the academic network at the European level. Hopefully this has positively affected their readiness to look for permanent positions outside Poland, which would ascertain a scientific collaboration at a European level on a long run.

Involvement of students in projects dealing with cutting-edge topics of semiconductor physics supported by the project will hopefully attract a greater number of young people to careers in research. At the local level, the gender and age structure of the Division has already improved when compared to the situation before 2003, which may have been due to the CEMOS. In 2006 there is 25 scientific staff in the Division (vs 20 in 2003) and three among them are below age of 35. There are 3 female scientist working in 2006 vs 1 in 2003. It is believed that this is a trend rather than a fluctuation.

Concluding it must be stressed that The Centre of Excellence CEMOS financed by the EC under the contract has been proved a very effective tool of support for the Division of Solid State Physics, Faculty of Physics, Warsaw University in 2003-2005 in its way to become an active player on the European Research Area stage. It is the general feeling of the staff involved, supported by actual deliverables of the project that this particular instrument of financing has very large potential. Its inclusion into the 7^{th} Framework Programme would be very important not only for prospective recipients but also for Europe as a whole. There must be no doubt that the activity is one of the most effective ways of achieving the goals of the Lisbon Strategy.

References

1. K.Pakuła, R.Bożek, J. Baranowski, J. Jasiński, Z Liliental-Weber, Reduction of dislocation density in heteroepitaxial GaAlN; role of SiH(4) treatment JOURNAL OF CRYSTAL GROWTH **267** (2004) 1.

2. B.Chwalisz, A. Wysmołek, R.Bożek, R. Stępniewski, K.Pakuła, P. Kossacki, A.Golnik, J. Baranowski, Spatially resolved micro-luminescence from GaN / AlGaN quantum dots ACTA PHYSICA POLONICA A **105** (2004) 517.

3. K. Korona, B.Chwalisz, A.Wysmołek, R.Stępniewski, K. Pakuła, J. Baranowski, J Kuhl, Recombination dynamics in GaN / AlGaN low dimensional structures obtained by SiH_4 treatment PHYSICA STATUS SOLIDI C-CONFERENCES **2** (2005) 1069.

4. K. Surowiecka, A. Wysmołek, R.Stępniewski, R. Bożek, K.Pakuła, J. Baranowski, Temporal Evolution of Multi-Carrier Complexes in Single GaN ĄlGaN Quantum Dots ACTA PHYSICA POLONICA A **108** (2005), 879

5. A Mycielski, L Kowalczyk, A Szadkowski, B. Chwalisz, A.Wysmołek, R.Stępniewski, Jacek Baranowski, M Potemski, A.Witowski, R Jakieła, A Barcz, B Witkowska, W Kaliszek, A Jędrzejczak, A Suchocki, E Łusakowska, E Kamińska The chemical vapour transport growth of ZnO single crystals JOURNAL OF ALLOYS AND COMPOUNDS 371 (2004), p.150

6. A.Mycielski, A Szadkowski, L Kowalczyk, B.Witkowska, W Kaliszek, B.Chwalisz, A.Wysmołek, R.Stępniewski, J.Baranowski, M.Potemski, A.Witowski, R Jakieła, A Barcz, P Aleshkevych, M Jouanne, W.Szuszkiewicz, A Suchocki, E.Łusakowska, E Kamińska, W Dobrowolski , ZnO and ZnO:Mn crystals obtained with the chemical vapour transport method PHYSICA STATUS SOLIDI C-CONFERENCES 1 Nr 4 (2004), p.884-887

7. M.Szot, K.Karpierz, J.Kossut, M. Grynberg, FIR photon energy independent intra-impurity transitions in uniformly iodine-doped CdTeCd(1-x)Mg(x)Te quantum well PHYSICA STATUS SOLIDI C-CONFERENCES **2** (2003) 609

8. M.Szot, K.Karpierz, J Kossut, M. Grynberg, Intra-impurity transitions in uniformly Iodine doped MBE CdTe/CdMgTe quantum well-with no energetic scaling w: Proc.Conf. Physics of Semiconductors ICPS-27: 27th Intern. Conf. Phys. Semicond., Flagstaff, Arizona 16-30 July 2004, 1129, AIP (American Institute of Physics) Publishing, r. 2005

9. D Ferrand, S Marcet, W.Pacuski, E Gheeraert, P.Kossacki, J.Gaj, J Cibert, C Deparis, H Mariette, C Morhain, Spin Carrier Exchange Interactions in (Ga,Mn)N and (Zn,Co)O Wide Band Gap Diluted Magnetic Semiconductor Epilayers JOURNAL OF SUPERCONDUCTIVITY 18 Nr 1 (2005), 15-21

10. W. Maślana, P.Kossacki, M Bertolini, H Boukari, D Ferrand, S Tatarenko, J.Cibert, J.Gaj, p-type doping of II-VI heterostructures from surface states: Application to ferromagnetic Cd(1-x)Mn(x)Te quantum wells APPLIED PHYSICS LETTERS **82** (2003), 1875-1877

11. H Boukari, M Bertolini, D Ferrand, J Cibert, S Tatarenko, P.Kossacki, J.Gaj, Magneto-optical spectroscopy of gated p-doped CdMnTe quantum wells PHYSICA STATUS SOLIDI B-BASIC RESEARCH 241 Nr 3 (2004), 718-721

12. J.Gaj, P.Kossacki, P.Płochocka, W. Maślana, J Cibert, S Tatarenko, C.Radzewicz Neutral and charged excitons in a CdTe-based quantum well LOW TEMPERATURE PHYSICS 30 Nr 11 (2004), 1133-1138

13. H Boukari, P.Kossacki, M Bertolini, D Ferrand, J Cibert, S Tatarenko, J.Gaj, B Deveaud, V Ciulin, Photoluminescence of p-Doped Quantum Wells with Strong Spin Splitting ACTA PHYSICA POLONICA A 106 Nr 3 (2004), 299-310

14. H.Boukari, P.Kossacki, D Ferrand, J Cibert, M Bertolini, S Tatarenko, J.Gaj, Spectroscopy and Characteristic Energies of a Spin-Polarized Hole Gas w: Proc.Conf. Physics of Semiconductors ICPS-27: 27th Intern. Conf. Phys. Semicond., Flagstaff, Arizona 16-30 July 2004, 1311-1312, AIP (American Institute of Physics) Publishing, (2005)

15. K.Kowalik, A.Kudelski, A. Golnik, J.Gaj, G.Karczewski, J. Kossut, Characterization of self-assembled CdTe / ZnTe quantum dots ACTA PHYSICA POLONICA A 103 Nr 6 (2003), 539-544,

16. C Couteau, S Moehl, Jan Suffczyński, J.Gaj, F Tinjod, J Gerard, K Kheng, H Mariette, R Romestain, J Poizat, Photon Correlations and Cross-Correlations from a Single CdTe / ZnTe Quantum Dot ACTA PHYSICA POLONICA A 106 Nr 2 (2004), 169-176

17. C Couteau, S Moehl, F Tinjod, J Gerard, K Kheng, H Mariette, J.Gaj, R Romestain, J Poizat, Correlated photon emission from a single II-VI quantum dot APPLIED PHYSICS LETTERS 85 Nr 25 (2004), 6251-6253

18. K. Korona, P Wojnar, J.Gaj, G Karczewski, J Kossut, J Kuhl, Influence of quantum dot density on excitonic transport and recombination in CdZnTe/ZnTe QD structures SOLID STATE COMMUNICATIONS 133 (2005), 369-373

19. P.Kossacki, H Boukari, M Bertolini, D Ferrand, J Cibert, S Tatarenko, J.Gaj, D Deveaud, V Ciulin, M Potemski, Photoluminescence of p-doped quantum wells with strong splitting PHYSICAL REVIEW B 70 (2004), 195337

20. P.Kossacki, P.Płochocka, Bernard Piechal, W. Maślana, Andrzej Golnik, J Cibert, S Tatarenko, J.Gaj, Exciton-exciton interaction and biexcitons in the presence of spin-polarized carriers PHYSICAL REVIEW B **72** (2005), 035340

21. P. Plochocka P, Kossacki P, Maslana W, Cibert J, Tatarenko S, Radzewicz C, Gaj JA. Femtosecond study ofthe interplay between excitons, trions, and carriers in (Cd,Mn)Te quantum wells. Physical Review Letters, **92**, 177402 (2004)

22. K. P. Korona, B. Chwalisz, A. Wysmołek, R. Stępniewski, K. Pakuła, J. M. Baranowski, J. Kuhl, "Recombination dynamics in GaN/AlGaN low dimensional structures obtained by SiH_4 treatment"**,** phys. stat. sol. (c) **2**, pp. 1069-1072 (2005) (proceedings of EMRS2004)

23. B. Chwalisz, A. Wysmolek, K. P. Korona, R. Stępniewski, C. Skierbiszewski, I. Grzegory, S. Porowski, "Anomalous behaviour of the photoluminescence from GaN/AlGaN quantum wells"**,** phys. stat. sol. (c) **2**, pp. 1010-1013 (2005)

24. A. Wysmolek, B. Chwalisz, M. Potemski, R. Stępniewski, A. Babinski, S. Raymond, and V. Thierry-Mieg "Emission from mesoscopic-size islands formed in a GaAs/AlAs double layer structure", Acta Phys. Polonica A 106, 367 (2004)

25. B. Chwalisz, A. Wysmolek, M. Potemski, R. Stępniewski, A. Babinski, and V. Thierry-Mieg "Magneto-luminescence of a single lateral island formed in the type – II GaAs/AlAs QW" International Journal of Modern Physics, **18**, 3807 (2004)

26. A. Drabińska, K. Pakuła, J. M. Baranowski, I. Frymark, "Electoreflectance and photoreflectance studies of AlGaN/GaN heterostructure with a QW placed inside AlGaN layer" PHYSICA STATUS SOLIDI A-APPLIED RESEARCH **202** (2005) 1308-1312

27. R. Bożek, K.Pakuła, J.Baranowski Light induced contrast in Kelvin Force Microscopy of GaN epilayers PHYSICA STATUS SOLIDI C-CONFERENCES **1** (2004), p.364-367

28. R.Bożek, K.Pakuła, Jacek Baranowski Light induced contrast in Kelvin Force Microscopy of GaN epilayers EUROPEAN PHYSICAL JOURNAL-APPLIED PHYSICS **27** (2004), p.97-100

29. R.Bożek, Application of Kelvin Probe Microscopy for Nitride Heterostructures ACTA PHYSICA POLONICA A **108** (2005) p. 541-554.

30. A. Babinski, M. Potemski, H. Shtrikman, "Quantum oscillations of the luminescence from a modulation-doped GaAs/InGaAs/GaAlAs quantum well", Appl. Phys. Lett. **88**, 051909 (2006)

31. S Tatarenko, M Bertolini, W. Maślana, H Boukari, B Gilles, J Cibert, D Ferrand, P.Kossacki, J.Gaj, Control of ferromagnetism in Cd(1-x)Mn(x)Te quantum wells OPTO-ELECTRONICS REVIEW **11** (2003), 133-138,

32. H Boukari, M Bertolini, D Ferrand, J Cibert, S Tatarenko, J Wróbel, M Sawicki, P.Kossacki, A Wasiela, J.Gaj, T. Dietl, Control of magnetic properties in (Cd,Mn)Te quantum wells inserted in pin diodes JOURNAL OF SUPERCONDUCTIVITY **16** (2003), 163-166

33. K.Kowalik, A.Kudelski, J.Gaj, T.Wojtowicz, Olivier Krebs, Paul Voisin, In-plane optical anisotropy of parabolic and half-parabolic Cd1xMnxTe quantum wells SOLID STATE COMMUNICATIONS 126 (2003), 467-471

34. Michael Bertolini, W. Maślana, H Boukari, B Gilles, J Cibert, David Ferrand, S Tatarenko, P.Kossacki, J.Gaj, New structures for carrier-controlled ferromagnetism in Cd1-xMnxTe quantum wells JOURNAL OF CRYSTAL GROWTH **251** (2003), 342-346

35. Dynamics of neutral and charged exciton line intensities SEMICONDUCTOR SCIENCE AND TECHNOLOGY **19** (2004), 296-298 P.Płochocka, P.Kossacki, W. Maślana, J Cibert, S Tatarenko, A.Golnik, C.Radzewicz, J.Gaj

36. J Cibert, H Boukari, M Bertolini, Wojciech Pacuski, D Ferrand, S Tatarenko, P.Kossacki, J.Gaj Ferromagnetic phase in II-VI semiconductors controlled by carriers PHYSICA STATUS SOLIDI B-BASIC RESEARCH 241 (2004), 692-699

37. K.Kowalik, O Krebs, A.Kudelski, Andrzej Golnik, A Lemaitre, P Senellart, G Karczewski, J Kossut, J.Gaj, P Voisin Influence of an Electric Field on Fine Properties of III-V and II-VI Quantum Dots Systems ACTA PHYSICA POLONICA A 106 (2004), 177-184

38. J.Gaj, A.Golnik, P.Kossacki, K.Kowalik, W. Maślana, M Kutrowski, T Wojtowicz Localization of neutral and charged excitons in (Cd,Mn)Te quantum well: a

microphotoluminescence study PHYSICA STATUS SOLIDI C-CONFERENCES 1 (2004), 831-834

39. A.Kudelski, K.Kowalik, J.Kasprzak, A.Golnik, J.Gaj, T Wojtowicz, G Cywiński, Magnetic field controlled in-plane optical anisotropy in parabolic (Cd,Mn,Mg)Te quantum wells PHYSICA STATUS SOLIDI C-CONFERENCES 1 Nr 4 (2004), 965-968

40. P.Płochocka, P.Kossacki, B.Piechal, W. Maślana, A.Golnik, J Cibert, S Tatarenko, J.Gaj, Many-Body Interactions in the CdTe-Based Quantum Well under Strong Optical Excitation ACTA PHYSICA POLONICA A 106 Nr 3 (2004), 413-422

41. A.Golnik, P.Kossacki, K.Kowalik, W. Maślana, J.Gaj, M Kutrowski, T Wojtowicz, Microphotoluminescence study of local temperature fluctuations in n-type (Cd, Mn)Te quantum well SOLID STATE COMMUNICATIONS 131 (2004), 283-288

42. P.Kossacki, W.Pacuski, W. Maślana, J.Gaj, M Bertolini, D Ferrand, S Tatarenko, J Cibert, Spin engineering of carrier-induced magnetic ordering in (Cd, Mn) Te quantum wells PHYSICA E 21 (2004), 943-946

43. K.Kowalik, O Krebs, A Lemaitre, S Laurent, P Senellart, P Voisin, J.Gaj, Influence of an in-plane electric field on exciton fine structure in InAs-GaAs self-assembled quantum dots APPLIED PHYSICS LETTERS 86 (2005), 041907 / 1-3

44. B.Piechal, Jan Suffczyński, A.Trajnerowicz, M Goryca, P.Kossacki, A.Golnik, J.Gaj Long Decays of Excitonic Photoluminescence from CdTe / ZnTe Individual Quantum Dots ACTA PHYSICA POLONICA A 108 Nr 5 (2005), 831-836

45. A.Kudelski, K.Kowalik, Andrzej Golnik, G Karczewski, J Kossut, J.Gaj, Spatially correlated 0D exciton states in CdTe / ZnTe semiconductor system JOURNAL OF LUMINESCENCE 112 (2005), 127-130

46. S Tatarenko, M.Bertolini, H Boukari, D.Ferrand, J Cibert, B Gilles, W. Maślana, P.Kossacki, J.Gaj New structures for carrier-controlled ferromagnetism in Cd1-xMnxTe quantum wells w: Proc. 2002 International Conference on Molecular Beam Epitaxy, 11-12, IEEE, (2003)

47. K.Kowalik, O Krebs, A Lemaitre, P Senellart, J.Gaj, P Voisin, Control of the Anisotropic Exchange Splitting of Individual InAs/GaAs Quantum Dots with an In-Plane Electric Field in Physics of Semiconductors ICPS-27: 27th Intern. Conf. Phys. Semicond., Flagstaff, Arizona 16-30 July 2004, 717-718, AIP (American Institute of Physics) Publishing, (2005)

48. P.Kossacki, P.Płochocka, W. Maślana, Bernard Piechal, Andrzej Golnik, J Cibert, S Tatarenko, J.Gaj, Femtosecond study of interplay between excitons, trions, and carriers in (Cd,Mn)Te quantum wells w: Proceedings SPIE, San Jose, California 24-27 January 2005, 275-284, SPIE The International Society for Optical Engineering, (2005)

49. P.Płochocka, P.Kossacki, W. Maślana, C. Radzewicz, J Cibert, S Tatarenko, J.Gaj, Interplay of excitons, biexcitons, and charged excitons in pump-probe absorption experiments on a (Cd, Mn)Te quantum well in Physics of Semiconductors ICPS-27: 27th Intern. Conf. Phys. Semicond., Flagstaff, Arizona 16-30 July 2004 1168-1169, AIP (American Institute of Physics) Publishing, (2005)

50. W. Maślana, P.Kossacki, P.Płochocka, A. Golnik, J.Gaj, D Ferrand, M Bertolini, S Tatarenko, J Cibert, Microphotoluminescence study of disorder in a ferromagnetic (Cd,

Mn)Te quantum well in Physics of Semiconductors ICPS-27: 27th Intern. Conf. Phys. Semicond., Flagstaff, Arizona 16-30 July 2004, 1299-1300, AIP (American Institute of Physics) Publishing, (2005)

51. A. Wołoś, A. Wysmolek, M. Kaminska, A. Twardowski, M. Bockowski, I. Grzegory, S. Porowski, and M. Potemski "Neutral Mn acceptor in bulk GaN in high magnetic fields" PHYSICAL REVIEW B **70**, 245202 (2004)

52. B. Chwalisz, A. Wysmołek, R. Stępniewski, M.Potemski, W. Knap, J.M. Baranowski, N. Grandjean, J. Massies, P. Prystawko, I. Gregory „Optical detection of 2DEG in GaN/AlGaN Structures – High Magnetic Field Studies" phys. stat. sol. (c) 1, 193-197 (2004)

53. R. Stępniewski, A. Wysmołek, M. Potemski „Electronic structure of shallow impurities in GaN studied via bound exciton magnetooptics", phys. stat. sol. (a), **201**, 181–189 (2004)

54. A. Babiński, S. Awirothananon, J. Lapointe, Z.Wasilewski, S. Raymond, and M. Potemski, "Single-Dot Spectroscopy in High Magnetic Fields", Physica E, **26**, 1-4, 190 (2005)

55. R. Stępniewski, A. Wysmołek, M. Potemski „Electronic structure of shallow impurities in GaN studied via bound exciton magnetooptics" phys. stat. sol. (a), **201**, 181–189 (2004)

56. R.Stępniewski, A.Wysmołek, M.Potemski, K.Pakuła, J.Baranowski, I Grzegory, S Porowski, G Martinez, P Wyder, Fine Structure of Effective Mass Acceptors in Gallium Nitride PHYSICAL REVIEW LETTERS **91** (2003), 226404 / 1-4

57. A.Wysmołek, K. Korona, R.Stępniewski, J.Baranowski, J Błoniarz, M Potemski, R Jones, D Look, J Kuhl, S Park, S Lee, Reply to ''Comment on "Recombination of excitons bound to oxygen and silicon donors in freestanding GaN" PHYSICAL REVIEW B 69 (2004), p.157302 / 1-3

58. A.Wysmołek, M.Potemski, R.Stępniewski, J.Baranowski, D Look, S Lee, J Han Resonant interaction of LO phonons with excited donor states in GaN PHYSICA STATUS SOLIDI B-BASIC RESEARCH 235 (2003), p.36-39

59. Ł.Kłopotowski, J.Suffczyński, M.Nawrocki, E.Janik, Hanle Effect of Charged and Neutral Excitons in Quantum Wells JOURNAL OF SUPERCONDUCTIVITY 16 Nr 2 (2003), p.435-437

60. F Teppe, M Vladimirova, D Scalbert, Michał Nawrocki, J Cibert Imaging electron spin vector in semiconductors SOLID STATE COMMUNICATIONS 128 (2003), p.403-406

61. M.Nawrocki, Ł.Kłopotowski, J.Suffczyński Optical spin injection and tunneling in asymmetric coupled II-VI quantum wells PHYSICA STATUS SOLIDI B-BASIC RESEARCH **241** (2004), p.680-687

62. D Scalbert, F Teppe, M Vladimirova, S Tatarenko, J Cibert, M.Nawrocki, Softening of spin resonance at low temperature in p-doped Cd(1-x)Mn(x)Te quantum wells PHYSICAL REVIEW B 70 (2004), p.245304 / 1-7

63. Ł.Kłopotowski, M.Nawrocki, J-D Ganiere, B Deveaud, E Janik, Tunneling of spin-polarized holes in asymmetric double quantum well structures SEMICONDUCTOR SCIENCE AND TECHNOLOGY 19 Nr 4 (2004), p.380-382

64. M Vladimorova, D Scalbert, M.Nawrocki, Exciton quantum beats in CdMnTe quantum wells PHYSICA STATUS SOLIDI C-CONFERENCES 2 Nr 2 (2005), p.910-913

65. Ł.Kłopotowski, J.Suffczyński, M.Nawrocki, E Janik, Exciton Spin Manipulation in Asymmetric Double Quantum Well Structures w: Proc. 26th Conf. Phys. Semicond., Edinburgh 2002, p.P931-P937, IOP Publishing, (2003)

66. F Teppe, D Scalbert, Y Semenov, M.Nawrocki, J Cibert, S Tatarenko, T Wojtowicz New Spin Resonance Detected by Time-Resolved Faraday and Kerr Effect in II-VI Diluted Magnetic Semiconductor Quantum Wells w: Proc. 26th Conf. Phys. Semicond., Edinburgh 2002, p.H2431-H2438, IOP Publishing, (2003)

67. F Teppe, D Scalbert, Michał Nawrocki, J Cibert, S Tatarenko, Softening of the Magnetic Resonance Near the Ferromagnetic Transition in a p-doped CdMnTe Quantum Well w: Proc. 26th Conf. Phys. Semicond., Edinburgh 2002, p.H2441-H2448, IOP Publishing, (2003)

68. K. Korona, et al.Dynamics of Trapping on Donors and Relaxation of the B-Exciton in GaN PHYSICA STATUS SOLIDI B-BASIC RESEARCH 235 (2003), p.31-35

69. P.Trautman, K.Pakuła, R.Bożek, J.M.Baranowski, Light-induced narrowing of excitonic absorption lines in GaN APPLIED PHYSICS LETTERS **83** (2003), p.3510-3512

70. B.Chwalisz, A.Wysmołek, R.Bożek, K. Korona, R.Stępniewski, Wojciech Knap, Krzysztof Pakuła, J.Baranowski, N Grandjean, J Massies, P Prystawko, I Grzegory, Localization effects in GaN / AlGaN quantum well - photoluminescence studies ACTA PHYSICA POLONICA A 103 Nr 6 (2003), p.573-578

71. M.Wojdak, M Klik, M Forcales, T Gregorkiewicz, J Wells, K.Pakuła, J.Baranowski, S.Porowski, Photoluminescence of GaN layers studied with two-color spectroscopy SOLID-STATE ELECTRONICS 47 (2003), p.579-581

72. Tuning of Spectral Sensitivity of AlGaN / GaN UV Detector ACTA PHYSICA POLONICA A 103 Nr 6 (2003), p.675-681 K. Korona, A.Drabińska, A Trajnerowicz, R.Bożek, K.Pakuła, Jacek Baranowski

73. B.Chwalisz, A.Wysmołek, R.Stępniewski, M.Potemski, W.Knap, J.Baranowski, N Grandjean, M Massies, P Prystawko, I Grzegory, Optical detection of 2DEG in GaN / AlGaN structures - High magnetic field studies PHYSICA STATUS SOLIDI C-CONFERENCES 1 Nr 2 (2004), p.193-197

74. K.Pakuła, R.Bożek, J.Baranowski, J.Jasiński, Z Liliental-Weber Reduction of dislocation density in heteroepitaxial GaN; role of SiH_4 treatment JOURNAL OF CRYSTAL GROWTH **267** (2004), p.1-7

75. Spatially resolved micro-luminescence from GaN / AlGaN quantum dots ACTA PHYSICA POLONICA A 105 (2004), 517-522 B.Chwalisz, A.Wysmołek, R.Bożek, R.Stępniewski, K.Pakuła, P.Kossacki, A.Golnik, J.Baranowski

76. An Estimate of the Energy Gap of InN from Measurements of the Fundamental Absorption Edge ACTA PHYSICA POLONICA A 108 (2005), p.903-908 P.Trautman, K.Pakuła, A.Witowski, J.Baranowski

77. Electoreflectance and photoreflectance studies of AlGaN/GaN heterostructure with a QW placed inside AlGaN layer PHYSICA STATUS SOLIDI A-APPLIED

RESEARCH 202 (2005), p.1308-1312 A.Drabińska, K.Pakuła, J.Baranowski, I.Frymark

78. Potential and Carrier Distribution in AlGaN Superlattice ACTA PHYSICA POLONICA A 108 Nr 4 (2005), p.723-729 K. Korona, K.Pakuła, R.Bożek, A.Drabińska, K.Surowiecka, R.Stępniewski, E.Rohozińska, J.Baranowski

79. Recombination dynamics in GaN / AlGaN low dimensional structures obtained by SiH4 treatment PHYSICA STATUS SOLIDI C-CONFERENCES **2** (2005), p.1069-1072 K. Korona, B.Chwalisz, A.Wysmołek, R.Stępniewski, Krzysztof Pakuła, J.Baranowski, J Kuhl

80. Spontaneous superlattice formation in MOVPE growth of AlGaN PHYSICA STATUS SOLIDI C-CONFERENCES 2 Nr 3 (2005), p.1073-1076 Krzysztof Pakuła, Rafał Bożek, Jacek Baranowski, J Jasiński

81. Temporal Evolution of Multi-Carrier Complexes in Single GaN ĄlGaN Quantum Dots ACTA PHYSICA POLONICA A 108 Nr 5 (2005), p.879-884 Katarzyna Surowiecka, A.Wysmołek, R.Stępniewski, R.Bożek, Krzysztof Pakuła, Jacek Baranowski

82. The fundamental absorption edge of high crystalline quality GaN and that of amorphous GaN grown at low temperature PHYSICA STATUS SOLIDI C-CONFERENCES 2 Nr 3 (2005), p.1027-1030 Jacek Baranowski, Krzysztof Pakuła, Paweł Trautman

83. Formation of Mn-Related Defect Band in InP ACTA PHYSICA POLONICA A 103 Nr 6 (2003), p.637-642 B Macieja, K. Korona, M Piersa, A.Witowski, Dariusz Wasik, A.Wysmołek, G Strzelecka, A Hruban, B Surma, M Palczewska, M. Kamińska, A.Twardowski

84. Mixing of impurity levels by a built-in electric field in a CdMgTeCdZnTe heterostructure PHYSICA STATUS SOLIDI C-CONFERENCES 2 (2003), p.605-608 Jerzy Łusakowski, Grzegorz Cywiński, K. Korona, Wojciech Knap, Jacek Kossut

85. Properties of Zinc Acceptor and Exciton Bound to Zinc in Ammonothermal GaN PHYSICA STATUS SOLIDI B-BASIC RESEARCH 235 (2003), p.40-43 K. Korona, Roman Doradziński, Maria Palczewska, M. Pietras, M. Kamińska, Juergen Kuhl

86. Anomalous behaviour of the photoluminescence from GaN / AlGaN quantum wells PHYSICA STATUS SOLIDI C-CONFERENCES 2 Nr 3 (2005), p.1010-1013 Barbara Chwalisz, A.Wysmołek, K. Korona, R.Stępniewski, C Skierbiszewski

87. Dynamics of ground and excited states of bound excitons in gallium nitride JOURNAL OF LUMINESCENCE 112 (2005), p.30-33 K. Korona, A.Wysmołek, R.Stępniewski, J Kuhl, D Look, S Lee, J Han

88. Formation of Mn-Related Defect Band in InP ACTA PHYSICA POLONICA A 103 Nr 6 (2003), p.637-642 B Macieja, K. Korona, M Piersa, A.Witowski, Dariusz Wasik, A.Wysmołek, G Strzelecka, A Hruban, B Surma, M Palczewska, M. Kamińska, A.Twardowski

89. Magnetic Properties of (Ga, Fe)N JOURNAL OF SUPERCONDUCTIVITY 16 Nr 1 (2003), p.79-82 J.Gosk, M.Zając, M Byszewski, M. Kamińska, Jacek Szczytko, A.Twardowski, B Strojek, S Podsiadło

90. Mn Impurity in GaN Studied by Electron Paramagnetic Resonance ACTA PHYSICA POLONICA A 103 Nr 6 (2003), p.595-600 A.Wołoś, M Palczewska, Z Wilamowski, M. Kamińska, A.Twardowski, M Boćkowski, I Grzegory, S Porowski

91. Observation of Magnetic Anisotropy in Bulk GaMnN:Mg Crystals ACTA PHYSICA POLONICA A 103 Nr 6 (2003), p.665-669 J.Gosk, M.Zając, M. Kamińska, A.Twardowski, I Grzegory, M Boćkowski, S Porowski

92. Possible origin of ferromagnetism in (Ga, Mn)N JOURNAL OF APPLIED PHYSICS 93 Nr 8 (2003), p.4715-4717 M.Zając, J.Gosk, E Grzanka, M. Kamińska, A.Twardowski, B Strojek, T Szyszko, S Podsiadło

93. S-d exchange interaction in GaN : Mn studied by electron paramagnetic resonance APPLIED PHYSICS LETTERS 83 (2003), p.5428-5430 A.Wołoś, M Palczewska, Z Wilamowski, M. Kamińska, A.Twardowski, M Boćkowski, I Grzegory, Sylwester Porowski

94. Synthesis of bulk Ga(1-x)Mn(x)N: A prospective spintronic material CHEMISTRY OF MATERIALS 15 (2003), p.4533-4535 S Podsiadło, T Szyszko, W Gębicki, J.Gosk, Romuald Bacewicz, L Dobrzycki, K Woźniak, M.Zając, A.Twardowski

95. Ferromagnetic resonsnce in epitaxial (In0.53Ga0.47)(1-x)Mn(x)As: Angle- and temperature-dependent studies PHYSICAL REVIEW B **70** (2004), p.115202 / 1-12 Konrad Dziatkowski, M Palczewska, asz Słupiński, A.Twardowski

96. Neutral Mn acceptor in bulk GaN in high magnetic fields PHYSICAL REVIEW B 70 (2004), p.245202 / 1-8 A.Wołoś, A.Wysmołek, M. Kamińska, A.Twardowski, M Boćkowski, I Grzegory, S Porowski, M Potemski

97. Optical and magnetic properties of Mn in bulk GaN PHYSICAL REVIEW B 69 (2004), p.115210 / 1-7 A.Wołoś, M Palczewska, M.Zając, J.Gosk, M. Kamińska, A.Twardowski, M Boćkowski, I Grzegory, S Porowski

98. Proporties of arsenic antisite defects in Ga(1-x)Mn(x)As JOURNAL OF APPLIED PHYSICS 96 Nr 1 (2004), p.530-533 A.Wołoś, M. Kamińska, M Palczewska, A.Twardowski, X Liu, T Wojtowicz, J Furdyna

99. Fabrication and Physical Properties of SiC-GaAs Nano-Composites ACTA PHYSICA POLONICA A 108 Nr 4 (2005), p.717-722 G Kalisz, E Grzanka, Dariusz Wasik, A Świderska-Środa, S Gierlotka, J Borysiuk, M. Kamińska, A.Twardowski, B Pałosz

100. Infrared Spectroscopy of GaAs Doped with Mn ACTA PHYSICA POLONICA A 108 Nr 5 (2005), p.845-850 A Rutkowska, Dariusz Wasik, A.Witowski, M Sadowski, W Orłowski, G Strzelecka, A Hruban, M. Kamińska, A.Twardowski, M Potemski

101. Magnetic anisotropy of bulk GaN:Mn single crystals codoped with Mg acceptors PHYSICAL REVIEW B 71 (2005), p.094432 / 1-7 J.Gosk, M.Zając, A.Wołoś, M. Kamińska, A.Twardowski

102. Mn Impurity in Bulk GaAs Crystal ACTA PHYSICA POLONICA A 108 Nr 5 (2005), p.825-830 M Pawłowski, M Piersa, A.Wołoś, M Palczewska, G Strzelecka, A Hruban, J Gosk, M. Kamińska, A.Twardowski

103. Photoluminescence Study of Bulk GaN Doped with Beryllium ACTA PHYSICA POLONICA A 108 Nr 4 (2005), p.705-710 M Jaworek, A.Wysmołek, M. Kamińska, A. Twardowski, M Boćkowski, I Grzegory

104. R Kaczorowski, J Gosk, I Kulszewicz-Bajer, A.Twardowski, Synthesis, spectroscopic and magnetic properties of m-p aniline tetramers SYNTHETIC METALS 151 (2005), p.106-113

105. M. Kamińska, A.Twardowski, LT GaMnAs and GaMnN - Prospect Materials for Spintronics w: Proceedings 12th International Conference on Semiconducting & Insulating Materials, Bratislava 2002, p.133-138, (2003)

106. A.Wołoś, A.Wysmołek, M. Kamińska, A.Twardowski, M Boćkowski, I Grzegory, S Porowski, M Potemski Neutral Mn Acceptor in GaN Studied in High Magnetic Fields w: Proc. of the 27th Intern. Conf. Phys. Semicond., Flagstaff, Arizona 16-30 July 2004, p.251-252, AIP (American Institute of Physics) Publishing, (2005)

107. A.Wysmołek, B.Chwalisz, M Potemski, R. Stępniewski, A. Babiński, S Raymond, V Thierry-Mieg, Emission from Mesoscopic-Size Islands Formed in GaAs / AlAs Double Layer Structure ACTA PHYSICA POLONICA A 106 Nr 3 r. 2004, str. 367-381

108. B.Chwalisz, A.Wysmołek, R.Stępniewski, A.Babiński, M Potemski, V Thierry-Mieg, Magneto-luminescence of a single lateral island formed in a type - II GaAs / AlAs QW INTERNATIONAL JOURNAL OF MODERN PHYSICS B **18** (2004), 3807-3812,

109. A Lesiak, B.Chwalisz, A.Wysmołek, M Potemski, R.Stępniewski, V Thierry-Mieg Carriers Diffusion in GaAs / AlAs Type II Quantum Well ACTA PHYSICA POLONICA A **108** Nr 5 r. 2005, str. 755-760

110. K. Korona, A. Wysmołek, Roman Stępniewski, J Kuhl, D Look, S Lee, J Han,Dynamics of ground and excited states of bound excitons in gallium nitride JOURNAL OF LUMINESCENCE **112** (2005) str. 30-33

111. M Godlewski, V Ivanov, E Łusakowska, Rafał Bożek, S Miasojedovas, S Jursenas, K Kazlauskas, A Żukauskas, E Gołdys, M Phillips, T Bottcher, S Figge, D Hommel Influence of n-type doping on light emission properties of GaN layers and GaN-based quantum well structures PHYSICA STATUS SOLIDI C-CONFERENCES **2** ,1056-1059 (2005).

112. K. P. Korona, K. Pakuła, R. Bożek, A. Drabińska, K. Surowiecka, R. Stępniewski, E. Zielińska-Rohozińska and J.M. Baranowski, „Potential and Carrier Distribution in AlGaN Superlattice", Acta Phys. Pol. A **108**, p. 723-729 (2005),

113. K. P. Korona, A. Wysmołek, J. Kuhl, M. Kamińska, J. M. Baranowski, D. C. Look, S. S. Park, "Coupling of phonons with excitons bound to different donors and acceptors in hexagonal GaN", to appear in physica status solidi

114. K. P. Korona, C. Skierbiszewski, M. Siekacz, A. Feduniewicz, T. Suski, G. Franssen, I. Grzegory, J. Borysiuk, M. Leszczyński, "Barrier-to-Well Carrier Dynamics of InGaN/GaN Multi-Quantum-Wells grown by plasma assisted MBE on bulk GaN substrates", to appear in physica status solidi

5. List of Annexes:

- **Annex A:** Book of abstracts of the XXXII International School on the Physics of Semiconducting Compounds Jaszowiec, 2003
- **Annex B1 and B2:** The Proceedings of the XXXII International School on the Physics of Semiconducting Compounds, Jaszowiec 2003
- **Annex C:** Book of abstracts of the XXXIII International School on the Physics of Semiconducting Compounds Jaszowiec, 2004
- **Annex D1 and D2:** The Proceedings of the XXXIII International School on the Physics of Semiconducting Compounds, Jaszowiec 2004
- **Annex E:** Book of abstracts of the XXXIV International School on the Physics of Semiconducting Compounds Jaszowiec, 2005
- **Annex F1 and F2:** The Proceedings of the XXXIV International School on the Physics of Semiconducting Compounds, Jaszowiec 2005.
- **Annex G:** The Proceedings of the International Workshop on Optical Properties of 2D Systems with Interacting Carriers
- **Annex H:** The Proceedings of the Symposium C **"**Science and Technology of Nitrides and Related Materials**"** of The Fall Meeting of E-MRS, Warsaw 2004
- **Annex I:** The booklet of abstracts of the IX Workshop on Semimagnetic Semiconductors 2004,
- **Annex J:** The booklet of abstracts of the X Workshop on Semimagnetic Semiconductors 2004,
- **Annex K:** The booklet of abstracts of the XI Workshop on Semimagnetic Semiconductors 2005.
- **Annex L:** The presentations given during the meeting of Meeting of the Members of the International Advisory Board (see attached disk):

Annex L1: Electroreflectance investigations of AlGaN/GaN heterostructure with a QW placed inside AlGaN layer by Dr Aneta Drabińska

Annex L2: Intriguing Properties of Single Natural Quantum Dot-like Objects Formed in Type – II GaAs/AlAs QWs by Ms. Barbara Chwalisz

Annex L3: Temporal evolution of multi-carrier complexes in single GaN/AlGaN quantum dots by Ms Katarzyna Surowiecka

Annex L4: Kelvin Probe Microscopy principle & applications by Mr Rafał Bożek

Annex L5: Interaction of THz radiation with semiconductors by Dr Krzysztof Karpierz

Annex L6: Semiconductor quantum structures for spintronics by Prof. Jan Gaj

Annex L7: Diluted Magnetic Semiconductors with carriers by Dr Piotr Kossacki

Annex L8: Magnetospectroscopy of shallow impurities in GaN by Prof. Roman Stępniewski

Annex L9: Properties of manganese in III-V semiconductors by Prof. Maria Kamińska