Micro- and Nanostructure Research: Cleanroom Linz

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For Si/SiGe heterobipolar transistors, the incorporation of carbon was investigated in order to control the contamination for standard Si technology. In addition, self organized growth schemes for the development of nanoscale devices were studied in MBE deposition. In particular, on prepatterned Si substrates two dimensionally ordered Ge islands were deposited and a much narrower size distribution than previously reported was obtained. The interface roughness of Si/SiGe quantum cascade samples was investigated by x-ray reflectivity. The spin properties of Si quantum wells were investigated by electron-spin-resonance in order to contribute to quantum information technology. For two-dimensional GaAlAs structures, a modified ‘Hot Electron Injection Field Effect Transistor’ was developed by utilization of the ‘Gunn’ effect. Also quantum dots were fabricated and studied for the same material system. Optical properties were studied in the light emission of Er-doped Si and in lead-salt based vertical cavity surface emitting lasers. Photocurrent and photoluminescence experiments have been performed on self-assembled Si/SiGe quantum dots and quantum cascade injector structures. The growth of group III-Nitrides for optical applications in the blue region of the visible spectrum was systematically studied in an MOCVD system. The investigation of photonic crystals by a Christian-Doppler laboratory has been started in the same cleanrooms in Linz.

The funding of the activities in the two cleanrooms at the University of Linz, which are jointly used by three groups, is of vital importance for our micro- and nanostructure research activities. This basic funding allows for investigations that are made possible through additional funding coming from the FWF, the FFF, the European Commission, as well as through cooperations with industrial groups as listed in the report.

The activities of the year 2002 in the cleanrooms in Linz are described in a short overview here. The basic equipment that is available in these clean rooms allows for MBE growth of Si-based heterostructures, of II-VI and IV-VI heterostructures, for the deposition of ferromagnetic layers like Fe on II-VI compounds, as well as for MOCVD growth of III-V compounds like GaAs/GaAlAs and GaAs/GaInAs. The latest extension to those material systems happened with a European Project on the in-situ control of GaN deposition by MOCVD. Apart from in-situ and ex-situ structural characterization, lateral patterning is made possible through equipment like optical, holographic and electron beam lithography. Processing includes also facilities for the deposition on insulating as well as contact layers; in particular, a plasma deposition system for Silicon-Nitrides was installed recently. The operation of the transmission electron microscope has been expanded and is intensively used for the characterization of thin SiGeC layers. Research and development of a new Christian-Doppler Laboratory on photonic crystals is also conducted in the same cleanrooms.

The research efforts were mainly concentrated on high frequency and optoelectronic devices and on nanostructures as described in the following.

Si-SiGe heterobipolar transistors are now widely introduced into production for high speed bipolar and BiCMOS circuits, offering a great speed advantage over standard silicon technologies. In Linz, steps towards the optimization of the doping and composition profiles for the SiGeC HBT technology were continued in collaboration with Austria Microsystems, Unterpremstätten. While it is well known that co-doping of the p-type SiGe base layer of an HBT with carbon can completely suppress transient enhanced diffusion of the boron dopants, little is known about the behavior of carbon. Because of the small solid solubility of C in Si and SiGe, its propensity to form complexes, and its diffusion behavior, which follows the same mechanism as boron, C contaminations are usually avoided in standard Si technology. We therefore studied the behavior of 0.2 - 1 at.% of substitutional C in Si and SiGe under annealing conditions. Fourier-transform infrared spectroscopy (FTIR) was employed to measure the intensity of the local vibration modes of substitutional C and of cubic SiC precipitates. We could follow SiC precipitate formation as a function of annealing temperature and time. We found that, as expected, C in Si forms cubic SiC precipitates in thermal equilibrium. However, this process is kinetically impeded and requires long annealing times at elevated temperatures. The results were corroborated by high-resolution transmission electron microscopy to visualize the SiC precipitates in the Si and SiGe matrix material.

With minimum device dimensions of commercial processes already below 100 nm, and with progress being made regarding self-organized growth schemes, selective epitaxy and processing of nano-structured substrates at elevated temperatures become critical issues. During the in situ thermal cleaning step of nano-structured Si substrates before MBE deposition, we found a substantial amount of material transport on the surface. For example, wire structures of rectangular cross section are transformed into trapezoids with {311} facets after 5 min of annealing at 950°C in vacuum. The same mechanism leads to the development of negative slopes on the flanks of SiO_2 wires, which are wetted by mobile surface Si atoms, and desorb after reacting to SiO. To identify the dominating mechanism, we developed a decoration technique for transmission electron microscopy. It provides a means to distinguish oxide-covered and oxide-free surface regions during the course of thermal oxide desorption. It is well known that oxide desorption is not homogeneous, but proceeds via the formation and subsequent expansion of voids in the oxide. With our decoration technique, we were able to exclude any correlation of initial void formation with the presence of the nanostructured template. That means that most of the material transport responsible for facet formation occurs underneath a SiO_2 film, which follows the structural transformation. Once all oxide is desorbed, further mass transport is delayed by orders of magnitude. The results have important consequences for the structural integrity of nanostructured Si surfaces.

Self-organized Ge islands grown in the Stranski-Krastanow growth mode exhibit a statistical distribution of their lateral positions. By growing on prepatterned Si substrates, a two-dimensional periodic positioning of Ge islands can be achieved. In Linz, the patterning was accomplished both by holographic lithography as well as by electron beam lithography and subsequent reactive ion etching. In the laterally periodic pits, first a Si buffer layer was deposited by MBE in order to smoothen the surface and subsequently Ge domes were grown by molecular beam epitaxy at temperatures between 600 °C and 700 °C. Transmission electron microscopy investigations reveal that the islands are dislocation free. With these two-dimensionally periodic islands, by Si overgrowth a 2D pattern of tensely strained Si is formed which might be useful for the realization of the concept of field effect transistors, suggested by O.G. Schmidt and K. Eberl, so-called DOTFET's. The tensile strain in Si above the Ge islands leads to a lifting of the degeneracy of the conduction band states of Si, lowering the two valleys with the smallest transport mass, thus leading to an increase of electron mobility as compared to conventional Si MOS structures. Using x-ray diffraction techniques, we could actually prove the high strain state within the top Si layer.

The interface roughness of Si/SiGe quantum cascade samples, which are promising for the realization of Si-based light emitters and eventually lasers in the mid infrared, was determined from x-ray reflectivity. This is of consequence for quantum well fluctuations and consequently for a broadening of the emission. By growing such structures at temperatures as low as 350 °C, the r.m.s. interface roughness can be kept below 0.3 nm, despite Ge contents as high as 45% in the wells. A study using x-ray diffraction and x-ray reflectivity on a series of samples annealed at 700 °C for times between 10 minutes to several hours reveals the relaxation via interdiffusion of such Si/SiGe quantum cascade structures. Already short annealing times at 700 °C significantly change the structural sample properties.

A method to realize strained Si, which appears in the roadmaps of semiconductor industry for the coming years, is the introduction of SiGe nanostructures into Si. Using self-organized growth, SiGe structures with typical dimensions of 100 nm laterally and 10 to 15 nm vertically can be grown on Si substrates and capped with Si. As a result, the SiGe regions are compressively strained, whereas the Si regions above and below the SiGe islands are tensile strained. The advantage of using this approach is that high strain values up to 0.48% can be achieved without introducing lattice defects such as dislocations that deteriorate the electronic material properties. The particular properties of SiGe islands capped with Si depend sensitively on growth conditions. A study using x-ray diffraction reciprocal space mapping on a series of samples revealed that low substrate temperatures during Si capping are required in order to achieve high strain values in Si, which allow localizing electrons in the Si, while holes can be localized in the adjacent SiGe layers.

The spin properties of electrons in Si quantum wells were investigated making use of electron-spin-resonance (ESR). Here the main motivation is to judge the suitability of Si for spintronics applications, *i.e.*, devices that operate on spin orientation rather than on the displacement of free carriers. Spin-based devices are envisioned to have advantages in some specific applications like in quantum computing and cryptography. For such devices, the spin coherence time should be as long as possible, *i. e.*, much longer than the time required to manipulate spins. Making use of ESR techniques we were able to show that the spin coherence time is limited by the Bychkov-Rashba field which is a consequence of the asymmetric doping of the quantum well. The BR field reduces the spin coherence time to a few microseconds which is still by one or two orders of magnitude longer than the longest life times reported for GaAs, but by a factor of 30..50 shorter than the intrinsic life time implied by the unavoidable Elliott-Yafet mechanism. We conclude that Si is an excellent candidate for spin-based devices: if the Rashba field can be avoided, then the postulated ratio of 10^4 for spin coherence time and manipulation time appears attainable, particularly for quantum dots where quantization additionally limits spin relaxation.

The FECTED (Field Effect Controlled Transferred Electron Device) has been an attractive signal source at millimeter wave frequencies for many years. A remaining severe drawback of the device is its high operating voltage, typically around 7 V. By replacing the Schottky contact, which has been used as the anode up to now, with a combination of an ohmic contact and a Schottky contact, we have been able to reduce this voltage to values between 3 V and 4 V. Consequently, the field strength in the FECTED has been lowered considerably, reducing the risk of device breakdown. First oscillators, which have been realized with this modified FECTED, delivered up to 1 mW at a frequency of 58 GHz.

Quantum dot structures were fabricated by electron beam lithography on two-dimensional AlGaAs layers. The dot structure was defined by metallic gates on top of the layers. Electrical measurements were performed down to 300 mK. The typical Coulomb blockade peaks were observed as well as the strongly non-linear I-V curves for

large source-drain voltages. From the energetical separation of exited states, the size of the electrically active area was estimated to have a diameter of 125 nm.

Light emission from Si making use of Er as optical dopant was further investigated. We demonstrated that the enhanced luminescence yield in samples that were treated also with hydrogen results from an enhanced solubility of optically active Er in Si. Unsolved remains here the problem of avoiding the quenching of photoluminescence. Therefore Si:(Er,O) based light emitting diodes were further optimized for room temperature operation. In addition, we examined also the recently discovered efficient excitation of Erbium in Si-rich Si-oxide. Here Si nano-crystals are formed in SiO_2 surrounding as can be inferred by the observed photoluminescence in the visible. These nano-crystals were reported to act as sensitizers for Er in SiO_2. According to literature and internet announcements, light emitters with external efficiencies of 1-10% are possible. We found that the efficiency under optical excitation is by no means higher than without additional Si. The main effect of the Si nanocrystals apparently arises from their broad absorption band that allows making optimum use of the energy distribution of hot carriers in an electroluminescent device.

Lead-salt based vertical cavity surface emitting lasers with zero, two, and three dimensional laser active zones were grown by molecular beam epitaxy and tested at room temperature under optical excitation. These devices give stimulated emission at wavelength between 3.3 and 3.7 μm and are, therefore, highly suited for gas spectroscopy. Laser operation was demonstrated up to 44 °C, and the devices exhibit an circular output beam with a divergence of about 1°. The minimum effective threshold power, observed at 200 K, amounts 4 kW/cm^2 whereas at room temperature a somewhat higher threshold of 10 kW/cm^2 is found. Surprisingly, the best specifications (threshold power and operation temperature) are achieved by the laser resonators with three dimensional laser active media. The reason for this is that PbSe/PbEuTe quantum dots, used to obtain the zero dimensional laser active zones, exhibit a type 2 band alignment, which is unfortunate for optical transitions. Furthermore, in PbEuTe used as barrier material also for the 2D laser active medium samples, the 4f states of the Eu ions cause the optical transitions across the band gap to be electrically dipole forbidden. Therefore, to obtain laser active zones containing quantum structures other barrier materials than PbEuTe are required.

An alternative to PbEuTe is given by the use of PbSeTe. Therefore, $PbSe_{1-x}Te_x$ epilayers were grown with Te concentrations x varying between 0 and 1 and characterized by atomic force microscopy as well as by X-ray diffraction measurements. By these experiments it is shown that the number of dislocations can be minimized by choosing x in such a way that the epilayers are lattice matched to the BaF_2 substrates. For this concentration, also the best optical properties are expected, so that this alloy could substantially improve the performance of PbTe-PbSe based semiconductor laser structures.

Photocurrent (PC) spectroscopy and photoluminescence (PL) experiments have been performed on self-assembled Si/SiGe quantum dots and Si/SiGe quantum cascade injector structures. The quantum dots have been grown on substrates pre-patterned by both holographic and electron beam lithography. For all quantum dot samples, a clear PL signature of the quantum dots could be observed. For the dots grown on e-beam structured substrates, a narrower linewidth as compared to the dots grown on the substrate structured by holographic lithography is observed. Therefore, we conclude that the size distribution of the quantum dots grown on the former substrate is narrower than that of the dots grown on the latter. These findings are consistent with results obtained by x-ray scattering that also indicate a higher quality of the SiGe dots on the e-beam patterned substrates.

The PC experiments on doped quantum cascade injectors showed that these structures can be used as voltage-tunable 2-color detectors in the 3 – 6 µm region (MIR). The experimental results are in excellent agreement with the model calculations, allowing a detailed understanding of the features observed in the PC spectra of the cascade injectors. Starting with the results obtained on the current samples, improved samples designed for voltage tunable resonant enhanced cavity detection at 3 µm and 6 µm have been designed.

An MOCVD system was used for the growth of group III-Nitrides. Additional sources for Al and In are also available for the fabrication of ternary nitrogen based compounds. As dopant sources we have Si for n-type and Mg for p-type. So we are able to grow single and multilayers of group III nitrides together with the necessary doping profiles to fabricate blue light emitting diodes. However, our main task is the *in situ* growth control of the growth process by spectroscopic ellipsometry. So we can measure the growth rate and the layer composition during growth, which occurs at about 1000 °C in a very pure hydrogen atmosphere. Special software was developed that allows to calculate the Al content of the layers in real time with an accuracy of 1%. This system was tested first on single layers with constant composition. Finally we managed to monitor the concentration profile of superlattices of GaN/GaAlN as well as structures with graded composition profiles between GaN and AlGaN.

First growth runs were performed to grow cubic GaN. The standard and more thermally stable growth occurs in the hexagonal phase, therefore special templates, namely cubic GaN grown by MBE on GaAs, were used to initiate the growth in the cubic phase. The growth parameters were optimised to stabilise the growth in the cubic phase, which offers a much higher growth rate in comparison to MBE.

The ability to control the molecular order in organic thin films consisting of long anisotropic oligomers like oligo-thiophenes or oligo-phenylenes is essential to study the relation between their structure, surface morphology and their optical and electrical properties. We investigated ordered thin films of para-sexiphenyl (PSP) with the possible application in organic light-emitting diodes with polarized blue light emission. A self-organization of PSP molecules occurs during Hot Wall Epitaxy on mica, resulting in well-ordered crystalline needle-like structures with a length to width ratio up to 500. However, the growth regularities of such highly anisotropic films were not clear yet. We have used atomic force microscopy and X-ray diffraction to investigate the morphology, growth kinetic, and crystalline quality of these films in the early growth stages, in order to find the process controlling parameters.

The Christian Doppler Laboratory of Surface Optics is focussing on photonic crystal structures (respectively photonic band-gap materials). PhCs are periodic dielectric (or sometimes metallic) structures that have a photonic band gap (PBG) for photons, i.e. that light propagation is forbidden at certain frequencies. By scaling the size of the periodicity the PBG can be tuned from the microwave to the UV region. This property enables one to control (guide and split) light in a way that is almost impossible with conventional optics or with conventional integrated optics. Christian Doppler laboratories generally serve as a bridge between applied research and basic research. Photonic crystals are described exactly by Maxwell's Equations, which we can (and do) solve by the application of numerical techniques either in reciprocal space or in real space. This group works closely with other groups in the department and is one of the major users of the clean room, especially electron beam lithography and structural processing, evaporation, etc. The company partner of the Christian Doppler Laboratory is Photeon Technologies located in Bregenz, Austria.

Project Information

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Publications in Reviewed Journals

Published:

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11. H.Lichtenberger, M.Mühlberger, F.Schäffler, “Transient-Enhanced Si Diffusion on Native-Oxide Covered Si(001) Nanostructures during Vacuum Annealing”, Appl. Phys. Lett. (in print).
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14. Z. Wilamowski, W. Jantsch, N. Sandersfeld, M. Mühlberger, F. Schäffler, S. Lyon, “Spin relaxation and g-factor of two-dimensional electrons in Si/SiGe quantum wells”, Physica E, submitted.
15. Z.H. Chen, W. Heiss, G. Springholz, I. Souma, A. Murayama, Y. Oka, ”Anomalous magneto-optical properties of EuTe induced by magnetic polarons”, Physica E, submitted.
16. A. Bonanni, D. Stifter, A. Montaigne-Ramil, K. Schmidegg, K. Hingerl, H. Sitter, “In situ spectroscopic ellipsometry of MOCVD-grown GaN compounds for on-line composition determination and growth control”, J. Cryst. Growth.
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23. W. Heiss, M. Böberl, T. Schwarzl, G. Springholz, J. Fürst, H. Pascher, “Applications of lead-salt microcavities for mid-infrared devices”, Proc. IEE Optoelectronics.

Presentations

Invited Talks:

1. G. Bauer, “*Semiconductor nanostructures*”, annual meeting of the American Association for the Advancement of Science (AAAS), Boston, Feb. 2002.
2. J. Stangl, A. Hesse, T. Roch, V. Holý, G. Bauer, T. Schülli, T.H. Metzger, “*Structural investigation of semiconductor nanostructures by x-ray techniques*”, invited talk at the E-MRS Strasbourg, Juni 2002.
3. G. Bauer, A. Hesse, T. Roch, J. Stangl, V. Holý, “*Structural invstigations of semicondcutor quantum dots and quantum wires*”, invited talk at the CELDIS Workshop on Low Dimensional and Hybrid Diluted Magnetic Semiconductor Structures, 21.6. - 23.6.2002, Obory, Warsaw, Poland.
4. G. Bauer, “*Structural properties of semiconductor nanostructures*”, invited presentation an the COST meeting, Sevilla, 4. Okt. 2002.
5. G. Brunthaler, A. Prinz, and G. Bauer, “*The role of quantum interference for the metallic state in high-mobility Silicon inversion layers*”, invited talk at the 26th Int. Conf. on the Physics of Semiconductors, Edinburgh, 2002.
6. T. Fromherz, P. Rauter, W. Mac, G. Bauer, C. Miesner, K. Brunner, G. Abstreiter, G. Dehlinger, H. Sigg, D. Grützmacher, “*Intraband absorption and photocurrent spectroscopy of Si/SiGe quantum dots and cascades*”, invited talk at the E-MRS Strasbourg, Juni 2002.
7. H. Kojima, M. E. Gershenson, V. M. Pudalov, G. Brunthaler, A. Prinz, and G. Bauer, “*Interaction Effects in Electron Transport in Si Inversion Layers*”, invited talk at “Localization 2002”, Int. conf. on Quantum Transport and Quantum Coherence, August 16 – 19, Tokyo, Japan, 2002.
8. F. Schäffler, “*Spineffekte in SiGe/Si Elektronenkanälen*”, invited talk at the GMM Workshop: “*Integrierte Silizium-Hetero-Bauelemente*”, München, 25.04.2002.
9. C.Schelling, J.Myslivecek, M.Mühlberger, H.Lichtenberger, Z.Zhong, G.Bauer, and F.Schäffler, “*Kinetic and Strain-Driven Growth Phenomena on Si(001)*”, invited talk at Crystal Growth and Epitaxy, Wien Oct. 2002.
10. T. Schwarzl, W. Heiss, G. Springholz, M. Böberl, M. Aigle, J. Fürst, H. Pascher, K. Biermann, K. Reimann, G. Bauer, “*(Pb,Eu)Te-PbTe based vertical-cavity surface-emitting laser (VCSEL) structures for the 3 - 6 micron range*”, invited talk at the CELDIS Workshop on Low Dimensional and Hybrid Diluted Magnetic Semiconductor Structures, 21.6. - 23.6.2002, Obory, Poland.
11. G. Springholz, “*Molecular beam epitaxy of self-assembled semiconductor quantumd dots*”, Review Conference on Crystal Growth, 20.-24.10.2002, Vienna, Austria.
12. G. Springholz, “*Nanotechnologie – Methoden zur Herstellung von Nanostrukturen*”, Jahrestagung der Östereichischen Physikalischen Gesellschaft, 24.9.2002, Leoben, Austria.

13. G. Springholz, "Vertical and Lateral Ordering in Self-Organized Quantum Dot Superlattices", 35th IUVSTA Workshop on "Pattern Formation and Atomic Processes in Epitaxial Growth and Erosion", Trofaiach, Austria, 9.6. – 13.6.2002.
14. J. Stangl, A. Hesse, T. Roch, Z. Zhong, R.T. Lechner, G. Bauer, M. Meduna, V. Holý, T.H. Metzger, "*X-ray investigation of semiconductor nanostructures*", invited talk at the ESRF User Meeting, Feb. 2002, Grenoble.
15. J. Stangl, A. Hesse, T. Roch, Z. Zhong, R.T. Lechner, G. Bauer, M. Meduna, V. Holý, T. Schülli, T.H. Metzger, "*Investigation of nanoscale self-assembled islands in semiconductor heterostructures*", invited talk at the XTOP 2002, Sept. 2002, Aussois.
16. J. Stangl, A. Hesse, G. Bauer, V. Holý, U. Denker, O.G. Schmidt, O. Kirfel, D. Grützmacher, "*Structural properties of SiGe islands: Effect of capping"*, invited talk at the MRS Fall Meeting, Dec. 2002, Boston.
17. W. Heiss, T. Schwarzl, M. Böberl, G. Springholz, J. Fürst, M. Aigle, H. Pascher, "IV-VI microcavity devices grown by MBE", Crystal Growth and Epitaxy, Vienna, Austria (October 20-24, 2002)
18. W. Heiss, T. Schwarzl, M. Böberl, G. Springholz, "Applications of lead-salt microcavities for mid-Iinfrared devices", 5th International Conference on Mid-Infrared Optoelectronics Materials and Devices (MIOMD V), Annapolis, Maryland, USA (September 8-11, 2002).
19. T. Schwarzl, W. Heiss, M. Böberl, G. Springholz, J. Fürst, M. Aigle, H. Pascher "(Pb,Eu)Te-PbTe VCSEL laser structures", 2nd CELDIS Workshop on Low Dimensional and Hybrid Diluted Magnetic Semiconductor Structures, Warsaw, Poland (June 21-22, 2002)
20. W. Heiss, G. Springholz, T. Schwarzl, M. Böberl, T. Fromherz, A. Raab, "Correlated, self-organized PbSe quantum dots in vertical cavities: Absorption and stimulated emission", E-MRS 2002 Spring Meeting, Strasbourg, France (June 18-21, 2002)
21. W. Heiss, M. Böberl, T. Schwarzl, G. Springholz, J. Fürst, H. Pascher, "Blei-Salz-Mikroresonatoren für das mittlere Infrarot", Physikkolloquiium and der Universität Graz (26. November 2002).
22. H. Sitter, "Highly ordered organic eptaxial layers", Crystal Growth and Epitaxy, Vienna (Oct. 20-23, 2002)
23. H. Sitter, "Epitaxy – Close and away from thermodynamic equilibrium", 4th Int. Conf. on Advanced Semiconductor Devices and Microsystems, Smolenice, Slovakia (Oct. 14-16, 2002)
24. Z. Wilamowski, W. Jantsch, N. Sandersfeld, M. Mühlberger, F. Schäffler, S. Lyon Spin relaxation and g-factor of two-dimensional electrons in Si/SiGe quantum wells 12th International Winterschool on New Developments in Solid State Physics, Mauterndorf, Austria (February 25 – March 1 , 2002)
25. A. Kozanecki, V. Glukhanyuk, W. Jantsch, and B.J. Sealy, "Implantation Erbium doping In 6H SiC for optimum optical efficiency at 1.54 μm", 17th International Conference on the Application of Accelerators in Research and Industry, CAARI 2002, University of North Texas, Department of Physics, Denton, Texas, USA (November 12-16, 2002).

Seminar Talks:

1. G. Bauer, "*Structural investigations of semiconductor quantum dots*", seminar talk at the ETH Zurich, Switzerland, 28. March 2002.

2. G. Bauer, "*Semiconductor Nanostructures*", seminar talk at the Paul Scherrer Institut Villigen, Switzerland, 23. Sept 2002.
3. G. Brunthaler, "*The Role of Quantum Effects on the metallic state in two dimensions*", seminar talk at the Karl-Franzens University, Graz, 2. Dez. 2002.
4. F. Schäffler, "*SiGeC-Heterostrukturen: Wachstum, Eigenschaften und Anwendungen*", Seminar Universität der Bundeswehr, Neubiberg, Germany, 02.02.2002.
5. F. Schäffler, "*Nanoscale Challenges: Growth and Diffusion Phenomena in Si-based Heterostructures*", Seminar Paul-Scherrer-Institut, Villingen, Switzerland, 16.07.2002.
6. F. Schäffler, "*Spin-Effects in SiGe Heterostructures*", Seminar ETH Zürich, Switzerland, 17.07.2002
7. G. Springholz, "*Selbst-organisierte Halbleiter Nanostrukturen: Wachstum, Ordnungsphänomene und Anwendungen*", seminar talk at the Universität Hannover, Germany, 02.07.2002.
8. G. Springholz, "*Selbst-organisierte Halbleiter Nanostrukturen: Wachstum, Ordnungsphänomene und Anwendungen*", seminar talk at the Universität Würzburg, Germany, 18.06.2002.
9. J. Stangl, J. Grenzer, "*Investigation of semiconductor hetero- and nanostructures by x-ray diffraction and reflectivity*", seminar talk at the Forschungszentrum Rossendorf, Okt. 2002, Rossendorf bei Dresden.

Conference presentations (talks and posters):

1. G. Bauer, "Investigation of Si/SiGe cascade structures using x-ray diffraction and reflectivity", SHINE meeting at Cavendish Lab., Cambridge, Feb. 2002.
2. G. Brunthaler, A. Prinz, G. Pillwein, P.E. Lindelof, and J. Ahopelto, "Screening description of the metallic state in Silicon-on-insulator structures", Poster at the 12th Int. Winterschool on New Developments in Solid State Physics, Mauterndorf, Austria, Feb. 2002.
3. G. Brunthaler, G. Pillwein, A. Prinz, P.E. Lindelof and J. Ahopelto, "Screening description of the 2D-metallic state in Silicon-on-insulator structures", Int. Workshop on 2D-MIT, Princeton, USA, May, 2002.
4. L. Diehl, S. Mentese, H. Sigg, U. Gennser, T. Fromherz, D. Grützmacher, E. Müller, I. Sagnes, Y. Campidelli, O. Kermarrec, D. Bensahel, J. Faist, "Strain compensated Si/SiGe quantum well cascade emitters grown on SiGe pseudosubstrates", talk at the 26th International Conference on the Physics of Semiconductors, 29.7.-2.8.2002, Edinburgh, UK.
5. T. Fromherz, "Intersubband transitions in SiSiGe cascade structures", SHINE meeting at Cavendish Lab., Cambridge, Feb. 2002.
6. W. Heiss, R. Kirchschlager, R. T. Lechner, G. Springholz, "Giant magneto-optical effects in EuSe epilayers and EuSe/EuTe superlattices", 26th International Conference on the Physics of Semiconductors (ICPS 2002), Edinburgh, United Kingdom (July 29 - August 2, 2002).
7. W. Heiss, G. Prechtl, G. Springholz; "Giant tunability of excitonic photoluminescence transitions in antiferromagnetic EuTe epilayers induced by magnetic polarons"; poster at the 2nd International Conference on Physics and Application of Spin Related Phenomena in Semiconductors, 22.-26.7.2002,Würzburg, Germany.

8. A. Hesse, V. Holý, J. Stangl, T. Fromherz, G. Bauer, U. Denker, O.G. Schmidt, "Effect of overgrowth temperature on size and shape of SiGe islands", Poster at the 26th Int. Conf. on the Physics of Semiconductors, Edinburgh, 2002.
9. A. Hesse, J. Stangl, V. Holý, G. Bauer, O. Kirfel, E. Müller, D. Grützmacher, "Influence of capping on strain, composition and shape of SiGe islands", poster at the XTOP 2002, Sept. 2002, Aussois.
10. T. Ikaida, Y.H. Matsuda, N. Miura, S. Tsujino, P. Xomalin, S.J. Allen, G. Springholz, M. Pinczolits, G. Bauer, "Angular dependence and photon energy dependence of cyclotron resonance in PbSe/PbEuTe quantum dot crystals", talk at the 26th International Conference on the Physics of Semiconductors, 29.7.-2.8.2002, Edinburgh, UK.
11. R.T. Lechner, G. Springholz, J. Stangl, A. Raab, Z. Zhong, T. Schülli, G. Bauer, "Correlations and ordering in self-organized PbSe quantum dot superlattices", poster at the Spring Meeting of the European Materials Research Society, Strasbourg, 18. – 21.6.2002.
12. R.T. Lechner, T. Schülli, G. Springholz, G. Bauer, D. Lott, A. Schreyer, H. Clemens, H. Krenn, "Structural and magnetic properties of EuSe/PbSe, EuSe/PbTe and EuSe/EuTe superlattices grown by molecular beam epitaxy", talk at the Fall Meeting of the Materials Research Society, 1.-6.12.2002, Boston, USA.
13. R. T. Lechner, G. Springholz, T. Schülli, K. Wiesauer, H. Krenn, G. Bauer, "Structural and magnetic properties of EuSe/PbSe, EuSe/PbTe and EuSe/EuTe superlattices grown by molecular beam epitaxy", poster at the 26th International Conference on the Physics of Semiconductors, 29.7.-2.8.2002, Edinburgh, UK.
14. M. Mühlberger, C. Schelling, G. Springholz, F. Schäffler, "Step bunching and strain effects in SiGe layers and superlattices grown on vicinal Si (001) surfaces", poster at the 35th IUVSTA Workshop on "Pattern Formation and Atomic Processes in Epitaxial Growth and Erosion", Trofaiach, Austria, 9.6. – 13.6.2002.
15. M. Mühlberger, C. Schelling, G. Springholz and F. Schäffler, "Step-bunching in $Si_{1-x}Ge_x$ layers and superlattices on vicinal Si (001)", poster at the NANO7/ECOSS21, Malmö 2002.
16. J. Myslivecek, C. Schelling, B.Voigtländer, P. Êmilauer, J. Krug, M. Mühlberger, F. Schäffler, "Step-bunching during Si(001) homoepitaxy: The role of the surface diffusion anisotropy", poster at the NANO7/ECOSS21, Malmö 2002.
17. G. Pillwein, A. Prinz, G. Brunthaler, P.E. Lindelof, and J. Ahopelto, "Screening behavior of the two-dimensional metallic state in silicon-on-insulator structures", Poster at the 26th Int. Conf. on the Physics of Semiconductors, Edinburgh, 2002.
18. P. Rauter, T. Fromherz, G. Dehlinger, H. Sigg, D. Grützmacher, G. Bauer, "Voltage tuneable two-band MIR detection based on Si/SiGe quantum well cascade structures", 4th International conference on Low Dimensional Structures and Devices, Fortaleza, Dec. 2002.
19. F. Schäffler, "Spintronics in silicon-based heterostructures: a potential route toward quantum computing", COST P5 Workshop: Mesoscopic Electronics, Catania, Italy 18.10.2002.
20. D. Gruber, M. Mühlberger, T. Fromherz, F. Schäffler, M. Schatzmayr, "SiC Precipitation during Annealing of $Si_{1-x-y}Ge_xC_y$ Epilayers", oral presentation at the MRS Fall Meeting, 02.12.2002, Boston.
21. J. Mysliveček, C. Schelling, M. Mühlberger, F. Schäffler, B. Voigtländer, J. Krug, P. Šmilauer, "Step Bunching during Si(001) Homoepitaxy Caused by the Surface Diffusion Anisotropy", oral presentation at the MRS Fall Meeting, 02.12.02, Boston.

22. H. Lichtenberger, Z. Zhong, M. Mühlberger, G. Bauer, S. Senz, and F. Schäffler, "Transient-Enhanced Surface Diffusion on Native-Oxide Covered Si(001) Nanostructures during Vacuum Annealing", oral presentation at the MRS Fall Meeting, 03.12.2002, Boston.
23. T. Schwarzl, W. Heiss, G. Springholz, "Mid-infrared absorption of highly ordered PbSe/PbEuTe quantum dot superlattices in a high finesse microcavity", MRS Fall Meeting 2002, Boston, USA (December 2 – 6, 2002).
24. T. Schwarzl, W. Heiss, G. Springholz, H. Krenn, T. Fromherz, "Mid-infrared absorption of highly ordered PbSe/PbEuTe quantum dot superlattices in EuTe/PbEuTe microcavities", 26th International Conference on the Physics of Semiconductors (ICPS 2002), Edinburgh, United Kingdom (July 29 - August 2, 2002).
25. M. Simma, A. Raab, T. Fromherz, G. Springholz, G. Bauer , "Lateral photocurrent spectroscopy of self-organized PbSe quantum dot superlattices", poster at the 12th International Winerschool on New Developments in Solid State Physics – Low dimensional Systems from 2D to Molecules, Mauterndorf, Austria, 25.2. – 1.3.2002.
26. T. U. Schülli, M. Sztucki, T. H. Metzger, R. T. Lechner, J. Stangl, G. Springholz, G. Bauer, "Anomalous x-ray diffraction frm IV-VI semiconductor multilayers and quantum dots", talk at the Fall Meeting of the Materials Research Society, 1.-6.12.2002, Boston, USA.
27. G. Springholz, A. Raab, R. T. Lechner, Z. Zhong, V. Holy, P. Mayer, G. Bauer, "Investigation of self-organized later ordering in vertically aligned PbSe/Pb1-xEuxTe quantum dot superlattices", talk at the 26th International Conference on the Physics of Semiconductors, 29.7.-2.8.2002, Edinburgh, UK.
28. G. Springholz, A. Raab, R. Lechner, V. Holy, P. Mayer, and G. Bauer, "The phase diagram of vertical and lateral ordering in self-organized PbSe quantum dot superlattices", talk at the Fall Meeting of the Materials Research Society, 1.-6.12.2002, Boston, USA.
29. K. Wiesauer, G. Springholz, "Dislocation patterning in PbSe7PbTe (100) heteroepitaxy", poster at the 35th IUVSTA Workshop on "Pattern Formation and Atomic Processes in Epitaxial Growth and Erosion", Trofaiach, Austria, 9.6. – 13.6.2002.
30. K. Wiesauer, "Determination of the critical cluster size and diffusion length in PbTe (111) molecular beam epitaxy", oral presentation at the 12th EuroMBE Workshop, Bad Hofgastein, Feb. 2003.
31. K. Wiesauer, "Selbstorganisierte Nano-Musterbildung durch Versetzungen", talk at the NanoForum2002, Linz, Nov. 2002.
32. Z. Wilamowski, W. Jantsch, F. Schäffler, U. Rössler, S.A. Lyon, "Spin properties of two-dimensional electrons in Si/SiGe quantum wells", 26th int. Conf. Physics of Semiconductors (ICPS-26), Edinburgh (July 29 – August 2, 2002).
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40. A. Bonnani, D. Stifter, G. Neuwirt, A. Montaigne-Ramil, K. Schmidegg, K. Hingerl, H. Sitter, "On-line composition determination and growth control of MOCVD-deposited GaN and related ternary compounds via spectroscopic ellipsometry",
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41. C. Teichert, G. Hlawacek, H. Sitter, A. Andreev, G. Matt, N.S. Sariciftci,
"Self-organization in organic semiconductor thin films grown by Hot-Wall Epitaxy",
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43. A. Andreev, H. Sitter, G. Matt, S. Sariciftci, D. Meissner, H. Hope, H. Plank, R. Resel, A. Thierry, B. Lotz
"Oriented organic semiconductor thin films",
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44. H. Sitter, A. Andreev, G. Matt, S. Sariciftci, H. Plank, R. Resel,
"Hot-wall epitaxial growth of highly ordered organic epilayers",
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45. H. Sitter, A. Andreev, G. Matt, N.S. Sariciftci,
"Hot-Wall Epitaxy – the method of choice for the growth of highly ordered organic epilayers", 4th Int. Conf. On Electronic Processes in Organic Materials, Lviv, Ukraine (June 3-8, 2002)

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47. A. Andreev, H. Sitter, S. Sariciftci, R. Resel, D.M. Smilgies, "Morphology and growth kinetic of molecular organic thin film deposited by HWE", Crystal Growth and Epitaxy, Vienna, Austria (Oct. 20-23, 2002)
48. A. Bonanni, D. Stifter, A. Montaigne-Ramil, K. Schmidegg, K. Hingerl, H. Sitter, "In-situ spectroscopic ellipsometry of MOCVD grown GaN compounds for one line composition determination and growth control", 9th Int. Conference on MOVPE, Berlin, Germany (May 2002)
49. G. Kocher-Oberlehner, W. Jantsch, L. Palmetshofer, A. Ulyashin Luminescence enhancement by hydrogenation of Si:Er,O E-MRS Spring Meeting (June 18 - 21, 2002)
50. Z. Wilamowski, W. Jantsch Spin Relaxation in a 2d electron gas in Si quantum wells 2nd International Conference on Physics and Application of Spin Related Phenomena in Semiconductors, PASPS 2002, Würzburg (July 23 – 26, 2002)
51. Z. Wilamowski, W. Jantsch, N. Sandersfeld, F. Schäffler, S. Lyon Spin-coherance and –manipulation in Si/SiGe quantum wells E-MRS Spring Meeting, SYMPOSIUM Q (June 18 – 21, 2002)
52. B.A. Andreev, W. Jantsch, Z.F. Krasilnik, D.I. Kuritsyn, V.P. Kuznetzov, M.V. Stepikhova, A.N. Yablonsky Quantum efficiency and temperature quenching of the luminescence of uniformely and selectively Erbium-doped silicon structures produced by the sublimation MBE method 26th int. Conf. Physics of Semiconductors (ICPS-26), Edinburgh (July 29 – August 2, 2002)
53. G. Kocher- Oberlehner, W. Jantsch, A. Ulyashin Hydrogen-enhanced luminescence of Erbium doped Silicon 26th int. Conf. Physics of Semiconductors (ICPS-26), Edinburgh (July 29 – August 2, 2002)
54. Z. Wilamowski, W. Jantsch, F. Schäffler, U. Rössler, S.A. Lyon Spin properties of two-dimensional electrons in Si/SiGe quantum wells 26th int. Conf. Physics of Semiconductors (ICPS-26), Edinburgh (July 29 – August 2, 2002)

Diploma Theses

Finished in 2002:

1. Herbert Lichtenberger "Characterization and overgrowth of prestructured silicon-substrates" (June 2002)
2. Böberl Michaela: "Bauelemente mit vertikalen Resonatoren basierend auf Bleisalz-Metallstrukturen"

Current works:

1. Wolfgang Schwinger "*Epitaxial Overgrowth of Fullerenes on Si (100)*" (Technische Physik)
2. Mathias Simma "*Photoleitungsuntersuchungen an Quantenpunkten*"

3. Stefan Griesser
   "*Leitfähigkeitsmessungen an zweidimensionalem Elektronengas"*
4. Benjamin Lindner
   "*Metall-Isolator-Übergang in zweidimensionalen Siliziumstrukturen*"
5. Dietmar Pachinger
   "*High-mobility Si/SiGe heterostructures for spintronic applications*"
6. Patrick Rauter
   "*Intersubbandübergänge in SiGe-Strukturen*"
7. Eugen Wintersberger
   "*Röntgenbeugung und –reflexion an Si/SiGe/GaAs Hetero- und Nanostrukturen*"
8. Kirchschlager Raimund:
   "Magnetooptische Eigenschaften von Eu-Chacogeniden"
9. Roither Jürgen:
   "Mikroresonatoren aus dielektrischen Bragg-Spiegeln für lichtemittierende II-VI-Halbleiterbauelemente"
10. Söllinger Walter:
    "3-D Mikroresonatoren"

Doctor's Theses

Finished in 2002:

1. Dipl.Ing. Adrian Prinz
   "Magnetotransport investigations of the two-dimensional metallic state in silicon metal-oxide-semiconductor structures" (March 2002)
2. M. Sc. Tomas Roch
   "Structural investigations of SiGe cascade multilayers and self-organized SiGe wires using x-ray scattering techniques" (April 2002)

Current works:

1. Dipl. Phys. Anke Hesse:
   "Strukturelle Untersuchungen an Halbleiternanostrukturen"
2. Dipl. Ing. Michael Mühlberger
   "Epitaktisches Wachstum von modulationsdotierten Si/SiGe Si/SiGeC Heterostrukturen"
3. Dipl. Ing. Karin Wiesauer
   "Scanning tunneling microscopy studies of dislocation structures in IV-VI heterostructures"
4. Dipl. Ing. Anneliese Raab
   "Molecular beam epitaxy of self-assembled IV-VI quantum dots"
5. Mag. Rainer T. Lechner
   "Herstellung und Charakterisierung von EuSe- Nanostrukturen"
6. Dipl.Ing. Thomas Berer
   "Electronic and spin properties of Si/SiGe heterostructures"
7. Dipl.Ing. Georg Pillwein
   "Elektrische Untersuchungen von Quanteneffekten an Nanostrukturen"
8. Dipl.Ing. Herbert Lichtenberger
   "Kinetic and strain-induced self-organization of SiGe heterostructures"

9. Mag. Jiri Novak
   "Untersuchung der strukturellen Eigenschaften von Quantenpunkten"
10. Dipl.Ing. Daniel Gruber
    "Two-dimensional electron gases in Si/SiGe for spintronics
11. Dipl.-Ing. Joachim Achleitner:
    "Simulation magnetooptischer Effekte"
12. Dipl.-Ing. Michaela Böberl
    "Elektrooptische Bauelemente aus Bleisalz"
13. Dipl.-Ing. Gernot Fattinger:
    "Methoden zur statistischen und dynamischen Charakterisierung von Mikrostrukturen"
14. Mag. Erich Kaufmann:
    "Laterale Bleisalz-Strukturen"
15. Dipl.-Ing. Gudrun Kocher-Oberlehner:
    "Er-dotiertes Si und SiGe für optoelektronische Anwendungen im Bereich von 1,54 µm"
16. Dipl.-Ing. Hans Malissa:
    "Spin-Eigenschaften in niedrigdimensionalen Systemen"
17. M.Sc. Alberto Montaigne-Ramil:
    "Fabrication and ex-situ characterization of wide band gap semiconductor materials"
18. Dipl.-Ing. Klaus Schmidegg:
    "Growth and optical characterization of GaAlN and GaInN"
19. Dipl.-Ing. Thomas Schwarzl:
    "Vertikal emittierende Bleisalzlaser"

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