Microstructure Research: Cleanroom Linz

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The GMe supports the microstructure research in the cleanrooms of the Institut für Halbleiter- und Festkörperphysik and of the Institut für Mikroelektronik in Linz. In the field of high-frequency devices a fast frequency counter at 35 GHz for a distance sensor device was realized in 1999, capable of measuring the frequency with a 20 bit resolution in 120 microseconds. In the field of Si/SiGe devices, the activities were concentrated on the deposition of Si/SiGeC heterobipolar transistors on preprocessed wafers provided by an Austrian industrial partner. The structuring activities were concentrated on nanometer length Schottky gates. The optoelectronic activities were pursued for Er-doped Si diodes for light generation and by realizing vertical cavity surface emitting lasers for the 4 to 6 μm wavelength range. Magnetic structures were realized by depositing Fe on GaAs and ZnSe, and steps towards an in-situ optical process control for molecular beam epitaxial growth involving reflection difference spectroscopy were made. Semiconductor nanostructures like wires and dots, fabricated by self-assembled growth were investigated with respect to their elastic and optical properties.

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 microstructure research activities. This basic funding allows for investigations which are made possible through additional funding coming from the FWF, FFF, the OeNB, as well as through cooperation with industrial groups as listed below.

In the following short presentations an overview is given on the achievements made in the cleanrooms in Linz in 1999. The basic equipment which 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 as well as III-V compounds, as well as for MOCVD growth of III-V compounds like GaAs/GaAlAs and GaAs/GaInAs. 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 this respect, a major investment has been made: Equipment for the deposition of oxide and nitride layers has been purchased for the clean room of the semiconductor physics building which will be installed in 2000. Furthermore, through funds made available by the Ministry of Science and Traffic a transmission electron microscope has been ordered which will also be installed in the year 2000. This will greatly enhance our analytical possibilities for device oriented work.

Consequently, studies related to high frequency electronic and to optoelectronic devices can be performed which are described in the following.

For the section on HF-systems, a fast frequency counter at operating at 35 GHz, applied to a microwave distance sensor for short-range applications was realized. The main feature of this device is its capability to measure frequencies with a 20 bit resolution. It allows for system linearization of the oscillator characteristics.

Si-SiGe heterobipolar transistors are now widely introduced in the production for high speed bipolar and BiCMOS circuits, offering a speed advantage without sacrificing the compatibility to standard Si technologies. In Linz steps towards the optimization of the doping and composition profiles for the SiGeC HBT technology were made in a collaboration with Austria Microsystems (AMS), Unterpremstätten. Processed wafers provided by AMS were overgrown in Linz, and the essential conditions for the optimization of the layer sequence were studied.

In the field of lateral nanostructuring of Si/SiGe, work has been performed on selective Si and Si/SiGe epitaxy employing shadow masks. In particular, the lateral boundary between crystalline and polycrystalline Si areas was studied. It was shown that a defined undercut can be created thermally in a simple SiO_2 mask. This has led to the controlled deposition of Si/SiGe wire structures, which show excellent material quality as evidenced by their structural as well as by their optical (luminescence) properties.

Furthermore, work on growth instabilities found in Si homoepitaxy was pursued, extending the investigations to Si/SiGe in order to find out which role is played by the lattice strain due to the mismatch. In this respect, also studies were made towards a better understanding of the surface undulations which occur in lattice mismatched heteroepitaxy. The lateral and vertical ordering of self-organized structures has been studied in detail and the role of the anisotropy of the elastic properties for this ordering has been established quantitatively.

In the section on optoelectronics several contributions are incorporated into this report: The studies on electroluminescence from Si diodes by using Er doping were pursued, and in particular a mid-infrared vertical cavity surface emitting laser was realized, which has found international esteem. Work on reflectance difference spectroscopy was performed in order to allow for a real-time in-situ growth control in MBE as well as in MOCVD systems. In the framework of a European project, this system will be adapted for the process control of GaN in cooperation with partners from industry and from several universities.

Studies aimed towards the rapidly developing field of spintronics are being done: So far, growth studies have been performed by depositing Fe on GaAs and ZnSe, and by investigating the optical response of heterostructures containing manganese.

Project Information for 1999

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46. W. Heiss, T. Schwarzl, G. Springholz: "Lead Salt Based Bragg Mirrors and Microcavities for the Mid Infrared", World Scientific

Presentations

Invited Talks:

1. G. Bauer: "Magnetic Semiconductor Superlattices", 9th Brazilian Workshop on Semiconductor Physics, Belo Horizonte, Brasilien, Feb. 1999.
2. M. Helm: "Minibands and Wannier-Stark ladders in semiconductor superlattices studied by infrared spectroscopy", 9th Brazilian Workshop on Semiconductor Physics, Belo Horizonte, Feb. 1999.
3. W. Heiss, T. Schwarzl, G. Springholz: "Lead Salt based Bragg Mirrors and Microcavities for the Mid-Infrared", 9th International Conference on Narrow Gap Semiconductors, Berlin, 27.9.-1.10. 1999.
4. V. Holy, G. Springholz, M. Pinczolits,G. Bauer: "Lateral Ordering in Quantum Dot PbSe/PbEuTe Superlattices", 9th International Conference on Narrow Gap Semiconductors, Berlin, 27.9.-1.10, 1999.
5. F. Schäffler: "High-Speed Transport in Si/SiGeC Heterostructures", Int. Joint Conference on Si Epitaxy and Heterostructures, Zao, Mijagi, Japan, Sept. 1999.
6. F. Schäffler: "Application of Silicon-Based Heterostructures in Microelectronics", Semicond. Dev. Res. Symp., Charlottesville VA, USA, Dec. 1999.
7. G. Springholz, M. Pinczolits, V. Holy, G. Bauer: "Self-organized growth of three-dimensional quantum dot crystals with fcc-like vertical stacking and tunable lattice constant", 18th European Conference of Surface Science, 21. - 24.9. 1999, Vienna, Austria.
8. G. Springholz, M. Pinczolits, V. Holy, G. Bauer: "Self-organized growth of semiconductors quantum dot crystals", Annual Meeting of the Austrian Physical Society, 20. - 25.9. 1999, Innsbruck, Austria.
9. G. Springholz: "Fabrication of Semiconductor Nanostructures and their Characterization by High Resolution X-ray Diffraction Techniques", 28th International School on Physics of Semiconducting Compounds, 6.-11.6.1999, Jaszowiec, Poland.
10. J. Stangl, V. Holy, G. Springholz, M. Pinczolits, P. Mikulik, G. Bauer: "Vertical and Lateral Arrangement in Dot Superlattices", Spring Meeting of the Materials Research Society, San Fransisco, USS, 5.-9. April 1999.
11. M. Helm: "Infrarotspektroskopie von Halbleitern", Heraeus-Ferienkurs "Festkörperspektroskopie", TU Dresden, BRD, 6.10. 1999.

12. F.Schäffler: “Silicon-Based Heterostructures for High-Speed Device Applications”, Electronic Materials and Devices Seminar, Princeton NJ, USA, Dec. 1999.
13. G. Springholz: “Molecular Beam Epitaxy and in situ Reflection High-Energy Electron Diffraction Growth Studies of IV-VI Semiconductor Heterostructures”, Fraunhofer Institut für physikalische Meßtechnik, 23.2.1999, Freiburg , Germany.
14. M. Helm: “Mid-infrared detectors and lasers based on intersubband transitions in quantum wells”, Institute of Industrial Science, Tokyo University (Roppongi), Tokyo, Japan, 2.8.1999.
15. M. Helm: “Interminiband spectroscopy of semiconductor superlattices”, Institute of Industrial Science, Tokyo University (Roppongi), Tokyo, Japan, 29.6.1999.
16. M. Helm: “Minibands and Wannier-Stark ladders in superlattices studied by infrared spectroscopy”, Dept. of Basic Science , Tokyo University (Komaba), Tokyo, Japan, 25.6.1999.
17. M. Helm: “Minibands and Wannier-Stark ladders in superlattices studied by infrared spectroscopy”, RIEC, Tohoku University, Sendai, Japan, 23.6.1999.
18. M. Helm: “Minibands and Wannier-Stark-ladders in semiconductor superlattices studied by infrared spectroscopy”, Institut für Festkörperelektronik, TU Wien, 17.5.1999.
19. H. Sitter, K. Hingerl, W. Heiß: “Optical Characterization of Low Dimensional II-VI Compound Heterostructures”, IX Latin American Congress on Surface Science and its Applications, Havanna, July 1999
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22. W. Jantsch, S. Lanzerstorfer, M. Stepikhova, H. Preier, L. Palmetshofer: “Status, Hopes and Limitations for the Si:Er-Based 1.54 μm Emitter”, GADEST 99, Höör, Schweden, Sept. 1999

Conference presentations (talks and posters):

1. G. Springholz, T. Schwarzl, W. Heiß, H. Seyringer, S. Lanzerstorfer and H. Krenn: “*Fabrication of highly efficient mid-infrared Bragg mirrors from IV-VI semiconductors*”, Current Topics in Microelectronics, 3.3. - 6.3.1999, Bad Hofgastein, Austria.
2. K. Wiesauer and G. Springholz: “*Fabrication of Semiconductor Nanostructures by Scanning Force Microscopy*”, Current Topics in Microelectronics, 3.3. - 6.3.1999, Bad Hofgastein, Austria.
3. M. Pinczolits, G. Springholz, V. Holy and G. Bauer: “*Nearly perfect 3D ordering in IV-VI quantum dot superlattices*”, Gordon Research Conference on Thin Films and Crystal Growth Mechanisms, 20.6. - 25.6.1999, Plymouth, NH, USA.

4. T. Schwarzl, W. Heiss and G. Springholz: "*High finesse IV-VI microcavities for the mid infrared*", International Conference on Modulated Semiconductor Structures, 12.7 - 16.7.1999, Fukuoka, Japan.
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8. G. Springholz, M. Pinczolits, V. Holy, G. Bauer, H. H. Kang, L. Salamanca-Riba: "*Vertical and lateral correlations in self-organized quantum dot superlattices*", Fall Meeting of the Materials Research Society, 28.11. - 3.12.1999, Boston, USA.
9. W. Heiss, G. Prechtl, D. Stifter, H. Sitter, G. Springholz, L. Toth (poster): "*ZnCdSe/ZnSe Quantum Wires Fabricated by Selective Molecular Beam Epitaxy on Prepatterned GaAs Substrates*": Current Topics in Microelectronics, 3.3. - 6.3.1999, Bad Hofgastein, Austria.
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11. G. Springholz and K. Wiesauer (poster): "*Depth resolution for scanning tunneling microscopy imaging of misfit dislocations in heteroepitaxial layers and multilayers*", Gordon Research Conference on Thin Films and Crystal Growth Mechanisms, 20.6. - 25.6.1999,Plymouth, NH, USA.
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