

Cleanroom Vienna

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In this report a summary of the main activities in the MISZ TU Wien (Mikrostrukturzentrum der Technischen Universität Wien) during the year 2003 will be given. Till the end of 2003, the MISZ was a central institution of the TU Wien. Since 2004, the institution is part of the Electrical Engineering department and was renamed to demonstrate the strong position it takes in the development of novel concepts and down-scaling strategies. The new name – *Zentrum für Mikro- und Nanostrukturen* – underlines the twofold mission we see in the development of mature technologies and the introduction of new concepts. Within this report we describe projects taking intensive use of the cleanroom and the available technologies within. This includes state of the art growth of III-V nanostructures and silicon processing, structuring techniques utilizing standard contact lithography, the production of patterned masks, ion milling as well as dry etching and plasma enhanced chemical vapor deposition, electron beam writing, focused ion beam etching and depositing, and different metallization techniques. A major part of the mission of the ZMNS is the development and production of optoelectronic and microelectronic prototype devices.

Introduction

An overview of the main research efforts with a high need of technological input is presented within this scientific report. This summary includes the majority of experimental projects of the solid state electronics institute (Festkörperelektronik TU Wien) during the year 2003. All the projects described below like transport studies in low dimensional semiconductor nanostructures, scanning probe spectroscopy, realization of new and improved optoelectronic devices, quantum cascade lasers, THz sources, and the characterization of microelectronic devices take full advantage of the technologies installed in the cleanroom of the MISZ (Reinraum Mikrostrukturzentrum der TU Wien), which is now part of the ZMNS.

To structure this yearly increasing number of various activities, six research areas are introduced, namely:

- Optoelectronics & THz technology
- Quantum Dots
- Transport in III-V Semiconductors
- Silicon Device Testing
- Focused Ion Beam Developments
- Novel Characterization Techniques and Devices

To satisfy this variety of topics and demonstrate e.g. optoelectronic devices as well as basic research and the development of new tools for semiconductor industry, different technologies have to be kept at state of the art performance.

This includes growth of semiconductor nanostructures (molecular beam epitaxy), as well as a complete process line including structure definition (lithography), structure transfer (reactive ion etching, focussed ion beam etching, ion milling, wet chemical etching techniques) and coating with metals and/or dielectrics (plasma-enhanced

chemical vapor deposition, sputtering, electron gun evaporation, focussed ion beam deposition). Surface morphology as well as local carrier concentration probing is done with a conventional Atomic Force Microscope (AFM) in combination with a Scanning Capacitance Microscopy (SCM) extension.

All the equipment necessary for the above mentioned technologies needs the cleanroom environment (cooling, filtered air, constant temperature and humidity, high quality water, various inert gases) as well as periodic maintenance of the equipment and the cleanroom itself, e.g. pumping systems (rotary pumps, turbo pumps), exhaust filtering, liquid nitrogen, and cleaning and repair. Testing of the cleanroom quality and adjustment (laminar airflow, filters, cooling, humidity, and temperature) is done periodically.

For a more general overview the listed projects and the attached publication list may give more insides on the broad range of activities in our facility.

Optoelectronics/THz technology

M. Austerer, C. Pflügl, W. Schrenk, T. Roch, and G. Strasser:

Surface Emitting Quantum Cascade Laser

C. Pflügl, M. Litzenberger, W. Schrenk, D. Pogany, E. Gornik, G. Strasser:

Interferometric Temperature Mapping of GaAs-based Quantum Cascade Laser

W. Schrenk, S. Anders, T. Roch, C. Pflügl, G. Strasser:

Tuning Quantum-Cascade Lasers by Postgrowth Rapid Thermal Processing

P. Schwaha, S. Anders, V. Tamosiunas, W. Schrenk, and G. Strasser:

Light field in Quantum Cascade Ring Lasers

V. Tamosiunas, R. Zobl, G. Fasching, J. Ulrich, G. Strasser, K. Unterrainer, R. Colombelli, C. Gmachl, L.N. Pfeiffer, K.W. West, F. Capasso:

Terahertz Quantum-Cascade Lasers in a Magnetic Field

S. Golka, W. Schrenk, and G. Strasser:

Fabrication of dry etched planar Photonic Crystals for THz regime

M.Coquelin, R.Zobl, G.Strasser, E.Gornik:

Plasmon Enhanced THz Emission

J. Darmo, G. Strasser, J. Kröll, and K. Unterrainer:

Heterostructure-Based Photoconductive Terahertz Emitters

Josef Kröll, Juraj Darmo, and Karl Unterrainer:

Metallic Anti-Reflection Coating for Terahertz Technology

Quantum dots

T. Müller, F. F. Schrey, G. Fasching, G. Strasser, and K. Unterrainer:

Ultrafast Intraband Dynamics in InAs/GaAs Quantum Dots

F.F. Schrey, G. Fasching, T. Müller; G. Strasser, and K. Unterrainer:

Confocal Micro-Photoluminescence and Micro-Photoluminescence Excitation Spectroscopy on Single Self Assembled InAs Quantum Dots

G. Fasching, F. F. Schrey, G. Strasser, and K. Unterrainer:

Photocurrent and Photoluminescence Measurements of InAs Quantum Dots

G. Pillwein, G. Brunthaler, G. Strasser:

Fabrication and Characterization of Lateral Quantum Dots in GaAs Heterostructures

Transport in III-V Semiconductors

M. Kast, C. Pacher, M. Coquelin, W. Boxleitner, G. Strasser, E. Gornik:
High-Resolution Hot-Electron Spectroscopy in Parallel Magnetic Fields

D. Rakoczy, G. Strasser, and J. Smoliner:
BEEM/BEES Investigations on AIAs/GaAs Single Barriers and RTDs

R. Heer, J. Smoliner, J. Bornemeier, H. Brückl:
Magnetic Tunnel Transistors Studied by Ballistic Electron Emission Microscopy

Silicon Device Testing

S. Bychikhin, D. Pogany, E. Gornik, M. Graf, F. Dietz, V. Dudek, W. Soppa, H. Wolf:
Thermal Mapping of the SMARTIS SOI Devices Under the vf-TLP and TLP Stress Conditions

V. Dubec, S. Bychikhin, M. Blaho, D. Pogany, E. Gornik, J. Willemen, N. Qu, W. Wilkening, L. Zullino, A. Andreini:
A Dual-Beam Interferometer for Investigation of ESD Protection Devices under vf-TLP Stress

M. Blaho, V. Dubec, D. Pogany, M. Denison, M. Stecher, E. Gornik:
Hot Spot Dynamics in Vertical DMOS under ESD Stress

E. Auer and E. Bertagnolli:
Investigation of the Parasitic FET in Sub-100 nm Trench-DRAM

Focused Ion Beam Developments

H. Langfischer:
Focused Ion Beam Prepared Contacts of Tungsten to Silicon Characterized by a Cross-Bridge Kelvin Resistor Approach

H. Wanzenboeck, E. Bertagnolli:
Active Field Effect Transistor Fabricated by FIB-implantation

G. Otto, G. Hobler:
Simulations of Ion Beam Induced Damage in Silicon: Coupled Kinetic Monte Carlo and Molecular Dynamics Simulations

A. Lugstein, B. Basnar, M. Weil, J. Smoliner, and E. Bertagnolli:
**Advanced Nanoscale Material Processing with Focused Ion Beams
Metallic Nano Dots Realized by a Subtractive Self Organization Process**

Novel Characterization Techniques and Devices

W. Brezna, M. Schramboeck, A. Lugstein, S. Harasek, H. Enichlmair, E. Bertagnolli, E. Gornik, J. Smoliner:
Quantitative Scanning Capacitance Spectroscopy

T. Roch, W. Schrenk, S. Anders, C. Pflügl, G. Strasser:
X-ray Investigation of Interface Broadening by Rapid Thermal Processing

H. D. Wanzenboeck, C. Almeder, C. Pacher, E. Bertagnolli, E. Bogner, M. Wirth, F. Gabor:
Cell Growth on Prestructured Microelectronic Materials

M. Coquelin, R. Zobl, G. Strasser, E. Gornik:
Recent Structures for Plasma Instability Search

J. Kuzmík, D. Pogany, E. Gornik, P. Javorka and P. Kordoš:

Electrostatic Discharge Effects in AlGaN/GaN High-Electron-Mobility Transistors

M. Trinker:

Development of a Silicon Deep Reactive Ion Etching Process for the Fabrication of Large Area Silicon Phase Gratings

Project Information

Project Manager

Cleanroom MISZ TU Wien (since 2004 ZMNS TU Wien)

G. Strasser, Floragasse 7, A-1040 Wien

Project Group

Last Name	First Name	Status	Remarks
Anders	Solveig	postdoc	
Auer	Erwin	student	
Austerer	Maximilian	student	
Basnar	Bernhard	postdoc	
Beiter	Klaus	student	
Bertagnolli	Emmerich	o. prof.	
Blaho	Matej	dissertation	
Boxleitner	Winfried	postdoc	
Bychikhin	Sergey	postdoc	
Brezna	Wolfgang	dissertation	
Coquelin	Michael	dissertation	
Darmo	Juraj	postdoc	
Dubec	Viktor	dissertant	
Dzidal	Elvira	technician	
Fasching	Gernot	dissertation	
Fürnhammer	Felix	dissertation	
Golka	Sebastian	dissertation	
Gornik	Erich	o. prof.	
Gruber	Karl	student	
Harasek	Stefan	dissertation	
Hobler	Gerhard	ao. prof.	
Kamvar	Parvis	student	
Kast	Michael	dissertation	
Kröll	Josef	student	
Kröll	Peter	technician	
Kuzmik	Ian	postdoc	
Langfischer	Helmut	dissertation	
Litzenberger	Martin	dissertation	
Lugstein	Alois	univ. ass.	
Müller	Thomas	dissertation	

Last Name	First Name	Status	Remarks
Otto	Gustav	dissertation	
Pacher	Christoph	dissertation	
Pogany	Dionyz	univ. ass.	
Prinzinger	Johannes	technician	
Pflügl	Christian	dissertation	
Rebohle	Lars	postdoc	
Rakoczy	Doris	dissertation	
Riegler	Erich	technician	
Roch	Tomas	postdoc	
Schinnerl	Markus	technician	
Schenold	Helmut	technician	
Schrenk	Werner	cleanroom director	
Schrey	Frederik	dissertation	
Schwaha	Philipp	student	
Smoliner	Jürgen	ao. prof.	
Steinesberger	Gernot	dissertant	
Strasser	Gottfried	ao. prof.	
Tamosiunas	Vincas	postdoc	
Ulrich	Jochen	dissertation	
Unterrainer	Karl	ao. prof.	
Wanzenböck	Heinz	univ. ass.	
Zobl	Reinhard	dissertation	

Books and Contributions to Books

1. S. Anders, G. Strasser, E. Gornik; "Long wavelength laser diodes"; in Handbook of Laser Technology and Applications; Ed.: C. Webb, IoP Publishing, Bristol, UK

Publications in Reviewed Journals

1. M. Lackner, C. Forsich, F. Winter, S. Anders, and G. Strasser: "Investigation of biomass steam gasification gas using a GaAs based quantum cascade laser emitting at 11 μm ", Optics Communications 216, 357 (2003)
2. C. Pflügl, M. Litzenberger, W. Schrenk, D. Pogany, E. Gornik, G. Strasser; "Interferometric study of thermal dynamics in GaAs-based quantum cascade lasers"; Appl. Phys. Lett. 82, 1664 (2003)
3. Selected for the Virtual J. of Nanoscale Science & Technology 7 (12) 2003
4. D. Rakoczy, R. Heer, G. Strasser, J. Smoliner; "High Energy Ballistic Transport in Hetero- and Nanostructures"; Physica E 16, 129 (2003)
5. W. Brezna, H. Wanzenböck, A. Lugstein, E. Bertagnolli, E. Gornik, J. Smoliner, "Focussed Ion Beam Induced Damage in Silicon Studied by Scanning Capacitance Microscopy", Semicond. Sci. Technol. 18, 195 (2003)

6. J. Darmo, T. Müller, G. Strasser, K. Unterrainer, G. Tempea; "Terahertz emitter with an integrated semiconductor Bragg mirror"; *Electron. Lett.* 39, 460-462 (2003)
7. S. Harasek, H.D. Wanzenboeck, E. Bertagnolli, "Compositional and electrical properties of zirconium dioxide thin films chemically deposited on silicon", *J. Vac. Sci. Technol. A* 21, 653-658 (2003)
8. S. Anders, W. Schrenk, A. Lugstein, G. Strasser; "Room temperature lasing of electrically pumped quantum cascade micro-cylinders"; *Physica E* 17, 626-628 (2003)
9. L. Rebohle, F.F. Schrey, S. Hofer, G. Strasser, K. Unterrainer; "Energy level engineering in InAs quantum dot stacks embedded in AlAs/GaAs superlattices"; *Physica E* 17, 42-45 (2003)
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15. M. Blaho, D. Pogany, E. Gornik, M. Denison, G. Groos, M. Stecher, "Study of internal behavior in a vertical DMOS transistor under short high current stress by an interferometric mapping method", *Microel. Reliab.*, 43 545 (2003)
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17. H. Langfischer, E. Bertagnolli, "Focused ion beam prepared contacts of tungsten to silicon characterized by a cross-bridge Kelvin resistor approach", *Journal of Applied Physics*, 93, 5827 (2003)
18. A. Lugstein, W. Brezna, M. Stockinger, B. Goebel, L. Palmetshofer, E. Bertagnolli, "Nonuniform-channel MOS device" *Appl. Phys. A* 76, 1035-1039 (2003)
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- protection elements under high current stress in CDM-like time domain using backside laser interferometry" J. of Electrostatics 59, 241 (2003)
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 48. G. Hobler and G. Otto, "Amorphous pocket model for silicon based on molecular dynamics simulations", Nucl. Instr. Meth. B 206, 81 (2003)
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Conference Proceedings

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- investigation of trigger dynamics in ESD protection devices under very fast TLP stress, *Microel. Reliab.*, 1557 (2003)
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18. D. Pogany (invited), "Local Thermal and current imaging of power devices", Gesellschaft für Mikroelektronik (Microelectronics Society) GME Forum, April 10-11, 2003 Vienna, Austria
19. S. Harasek, H. D. Wanzenboeck, B. Basnar, J. Smoliner, E. Bertagnolli: "Zirconium Dioxide Thin Films for Microelectronics Deposited by Metal Organic Chemical Vapor Deposition", Gesellschaft für Mikroelektronik (Microelectronics Society) GME Forum, April 10-11, 2003 Vienna, Austria
20. H. D. Wanzenboeck, S. Harasek, H. Langfischer, E. Bertagnolli: "Deposition Mechanism of Direct-Write Processes – An Application-Oriented Approach to Custom-Tailored Material Properties", Gesellschaft für Mikroelektronik (Microelectronics Society) GME Forum, April 10-11, 2003 Vienna, Austria
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24. H. Langfischer, S. Harasek, H. Wanzenboeck, A. Lugstein, B. Basnar, and E. Bertagnolli: "Morphological Studies of Focused Ion Beam Induced Tungsten Deposition", 203rd Meeting of the Electrochemical Society, 27. April-02. May 2003, Paris, France
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27. M. Kast (invited), "Current spectroscopy of quantum states in semiconductor superlattices", 38th IUVSTA Workshop on Electronic Processes and Sensing on the Nano-Scale, May 25-29 2003, Eilat, Israel
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68. F. F. Schrey, T. Müller, K. Unterrainer, G. Strasser; "THz Manipulation of Excitonic levels in InAs Quantum Dots"; talk at 2003 MRS Fall Meeting; Boston/MA, USA, 01.-05.12.2003
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81. C. Kranz, A. Kueng, A. Lugstein, E. Bertagnolli, B. Mizaikoff, "Simultaneous electrochemical and AFM Imaging in Tapping Mode of Soft Samples with Bifunctional Scanning Probe Tips", ACS Fall National Meeting 2003, New York/NY, September 7-11, 2003.

Habilitations

1. Dionyz Pogany, "Reliability and Testing of Semiconductor Devices", TU Wien, March 2003

Doctor's Theses

1. Gernot Steinlesberger, "Scaling limits of copper damascene lines for future interconnect technology", TU Wien, April 2003
2. Martin Litzenberger, "Investigation of Internal Behavior in CMOS ESD Protection Devices under High Current Stress", TU Wien, Juni 2003
3. Helmut Langfischer, "Focused Ion Beam basierte Metallisierung für sub-100nm-Bauelemente", TU Wien, Juni 2003
4. Stefan Harasek, "Zirkoniumdioxiddünnschichten als hoch-e Gate-isolatoren für die Siliziumtechnologie", TU Wien, September 2003
5. Michael Kast, "High-Resolution Hot-Electron Spectroscopy", TU Wien, November 2003
6. Thomas Müller, "Ultrafast THz Response of Optically Exited Quantum Semiconductor Structures", TU Wien, November 2003

Diploma Works

1. Johann Kreuter, "Long wavelength GaAs/AlGaAs quantum cascade lasers with low-loss waveguide", TU Wien, März 2003
2. Josef Kröll, "Few-cycle Terahertz spectroscopy and imaging", TU Wien, Mai 2003

Cooperations

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19. Technische Universität Berlin, A. Wacker, Deutschland
20. Heinrich Hertz Institut, Berlin, H. Künzel, Deutschland
21. Paul Drude Institut, Berlin, H. Grahn, Deutschland
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35. Avant! Corp., V. Moroz, USA
36. Univ. of California, Lawrence Berkeley Laboratories, E. E. Haller , USA
37. Univ. of California, Los Angeles, S. Prussin, USA
38. Univ. of California, Santa Barbara, J. Allen, A. Gossard, USA
39. Columbia University, New York, H. Störmer, USA
40. Princeton University, S. Lyon, USA
41. IBM Fishkill, C.S. Murthy, USA
42. Lucent Technologies, C. Gmachl, USA
43. Boston College, Boston, MA, K. Kempa, P. Bakshi, USA
44. EPI MBE Components, St. Paul, Minnesota, USA
45. Univ. Osaka, C. Hamaguchi, Japan
46. Univ. Nagoya, N. Sawaki, Japan
47. RIKEN, K. Ishibashi, Japan
48. Herriot Watt University, Edinburgh, C. Pidgeon, Schottland
49. Univ. Glasgow, C. Ironside, Schottland
50. Imperial College, London, C. Phillips, England
51. Univ. Leeds, M. Chamberlain, England

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52. University of Sheffield, M. Skolnick, J. Coburn, England
 53. University of Surrey, B.N. Murdin, England
 54. INFN-SNS Pisa, F. Beltram, Italien
 55. TASC Trient, L. Sorba, Italien
 56. Universita Bari, G. Scamarcio, Italien
 57. STMicroelectronics, A. Andreini, Italien
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 59. University Neuchatel, J. Faist, Schweiz
 60. EPFL Lausanne, M. Illegems, Schweiz
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