

IMN MacroNano®

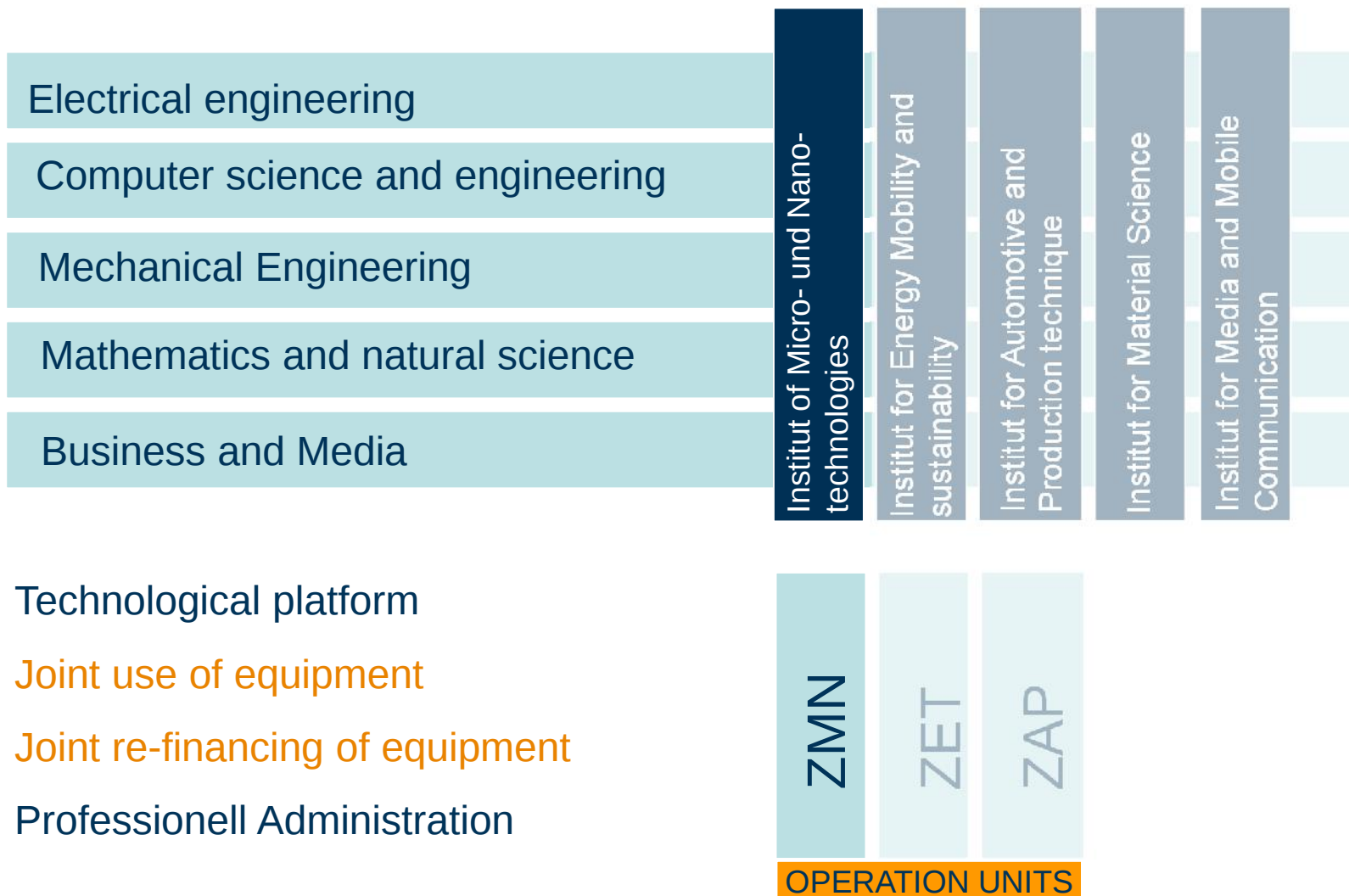
Institut für Mikro- und Nanotechnologien

an example for effective interdisciplinary education and research

S. Krischok, J. Müller, G. Gobsch



IMN MacroNano® of the TU Ilmenau



Core facility: Center for Micro- and Nanotechnologies



Laboratory area: 2000 m²

Including Cleanroom: 1180 m²

Classes: 100-10.000 (5-7)

S1 – labs for biological applications

~300 scientists and technicians



History ZMN/IMN MacroNano®

InQuoSens (Kooperation FSU und TUIL)

Innovation center Quantumoptics und Sensorics

DFG-core facility Mikro-Nano-Integration

wider use of Infrastructure, financing in projects

New clean room facilities

Meitner building becomes part of TU Ilmenau

Phase 2 ZIK MacroNano®

Junior research group 3D-Nanostructuring

**Joint strategy plan of the
39 members of IMN MacroNano®:**

Founding of the IMN MacroNano®

ZMN becomes operation unit of TU Ilmenau.

ZIK ZMN / MacroNano

Integration of 2 + 1 junior research groups and
new scientific topics (Life Sciences, Peripherals)

Opening Zentrum of Micro- und Nanotechnologies (ZMN)
am 27.3.2002

DFG



2017

2013

2011

2009

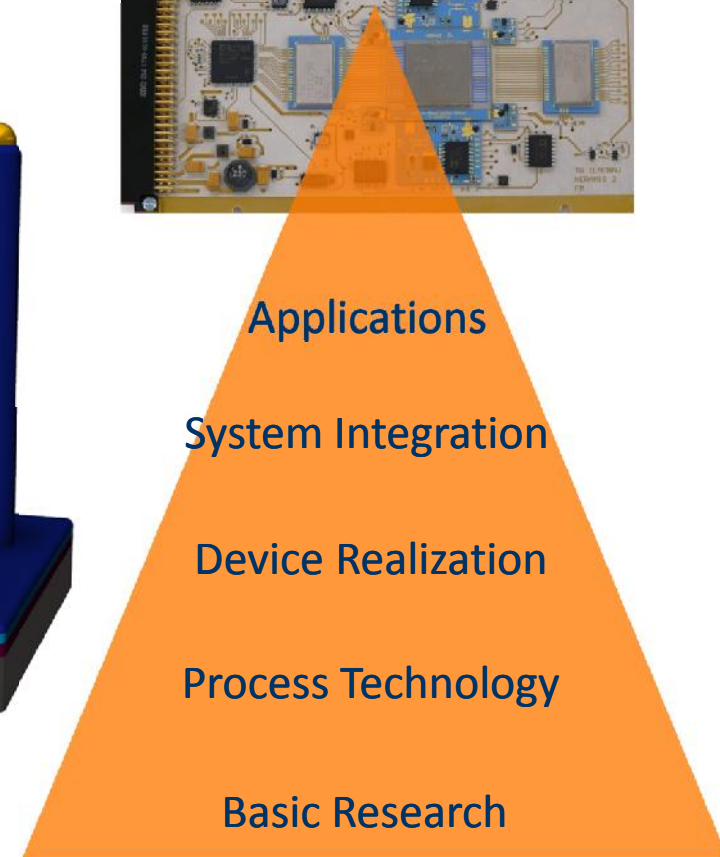
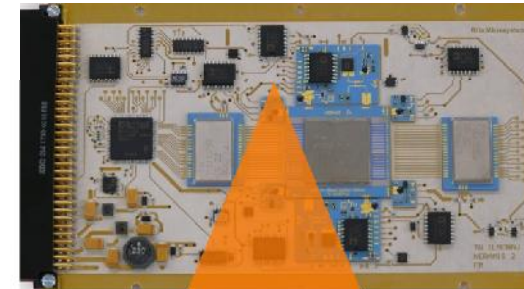
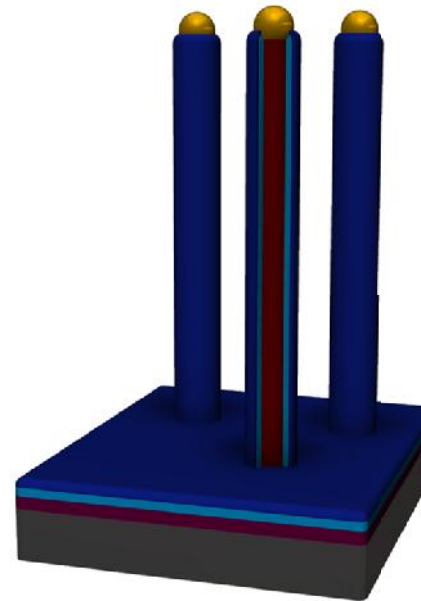
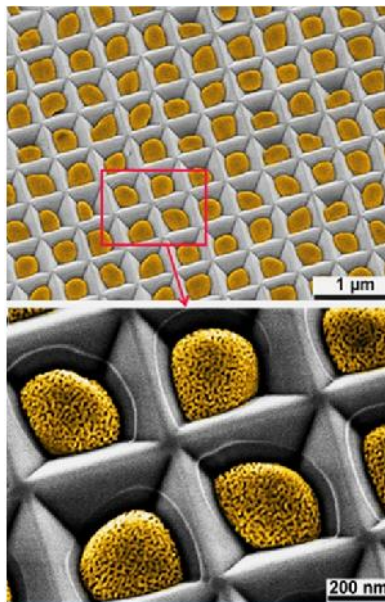
2006

2005

2002

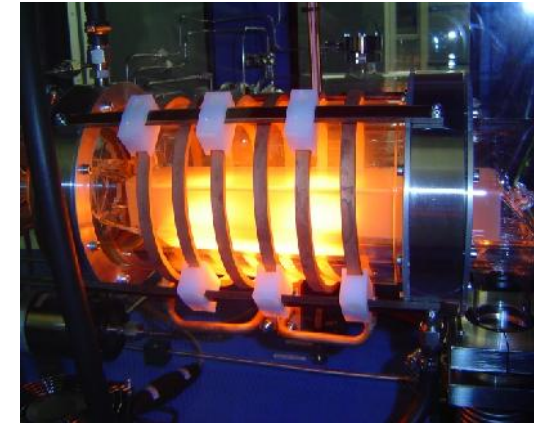
Research focus IMN MacroNano®

- Materials for Micro- und Nano-technologies
- Micro-Nano-Integration
- 3D Biosystems



Technology Lines

- **Silicon-MEMS** *cleanroom processing (6")*
- **Polymer Electronics** *(devices and solar cells)*
- **LTCC-technology** *(low temperature ceramics)*
- **Group III-V materials** *(MOCVD, MBE)*
- **Nanostructures** *(FIB and E-beam technology)*
- **Laser-technology** *for trimming and cutting of various materials*
- **SMD-technology** *and PCB-processing*
- **Application lab (S1)** *testing of complex biosensors*

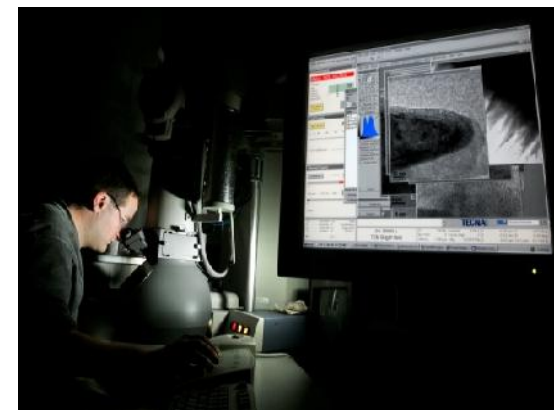


Material Analysis

Analytical systems *down to atomic resolution*

- Electrical characterization
- Morphological, structural, and elemental material characterization including:
 - bulk properties
 - thin film characterization and depth profiling
 - surface analysis

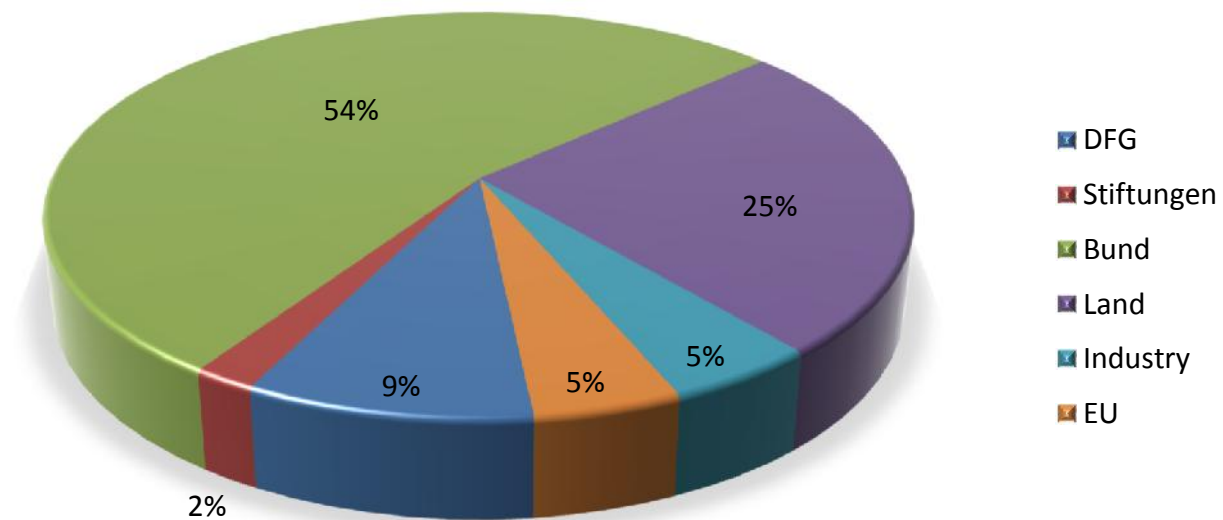
(e.g. by: TEM, spectroscopic ellipsometry, NMR, ESR, XRD, EDX, SEM, optical microscopy, PEEM, XPS, UPS, AES, RHEED, STM, AFM)



Scientific Projects at IMN MacroNano®

- 50-70 Projects/year
- Total volume 2002 ... 2015 **84,16 Mio €**
- Overhead from DFG and BMBF 2010-2015: **3,56 Mio €**

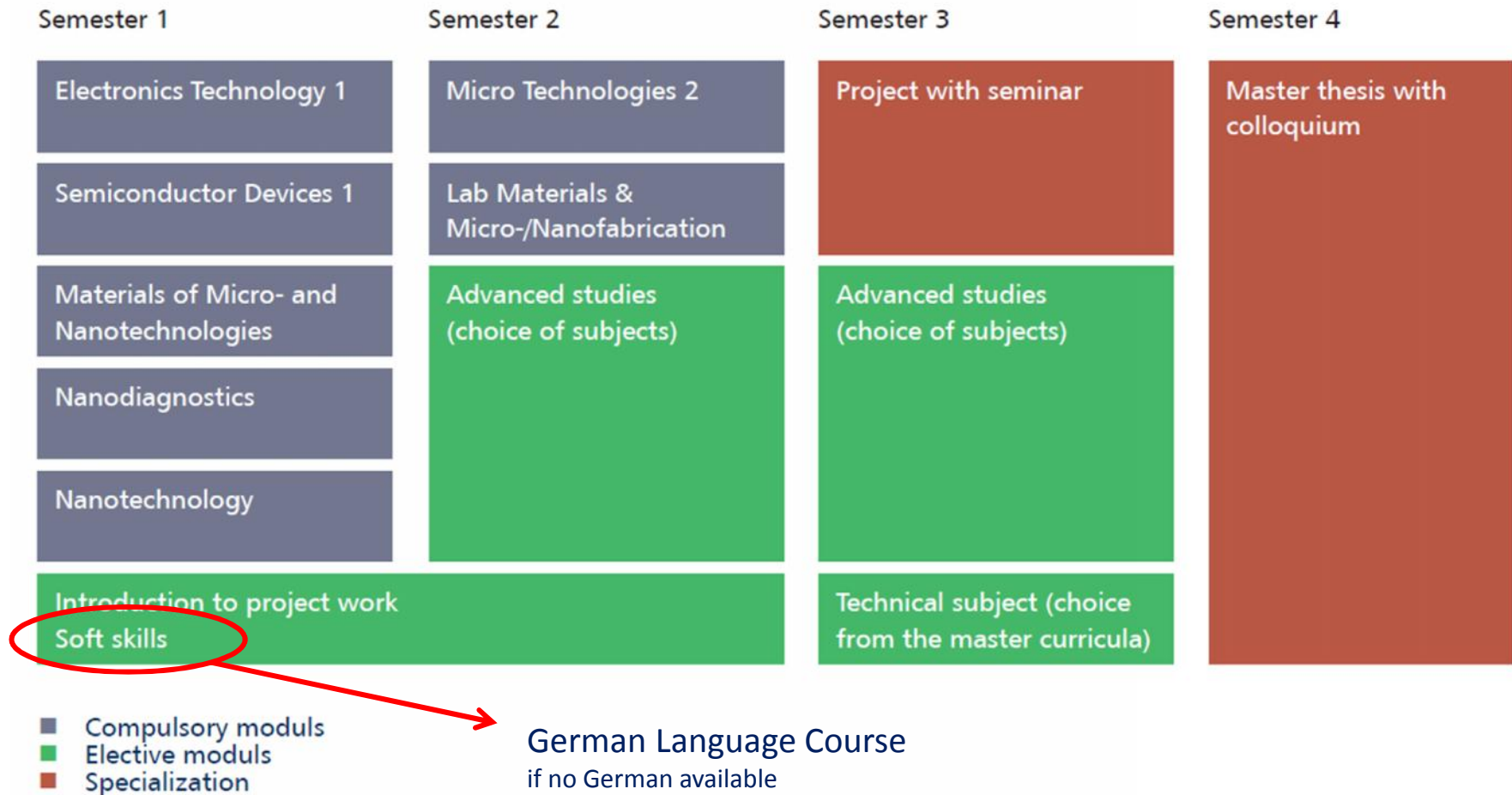
Funding source
2002 -2015



education

- Master course „Micro- and Nanotechnologies“

Master Program Overview



education

- Master course „Micro- and Nanotechnologies“
- Available for teaching students with modern equipment
 - Lab courses
 - BA-thesis
 - MA-thesis
- PhD and Habilitation

Possibilities for scientific cooperations



Core facility micro-nano-Integration



Phase I: 2013-2017

Phase II: ab Juli 2017

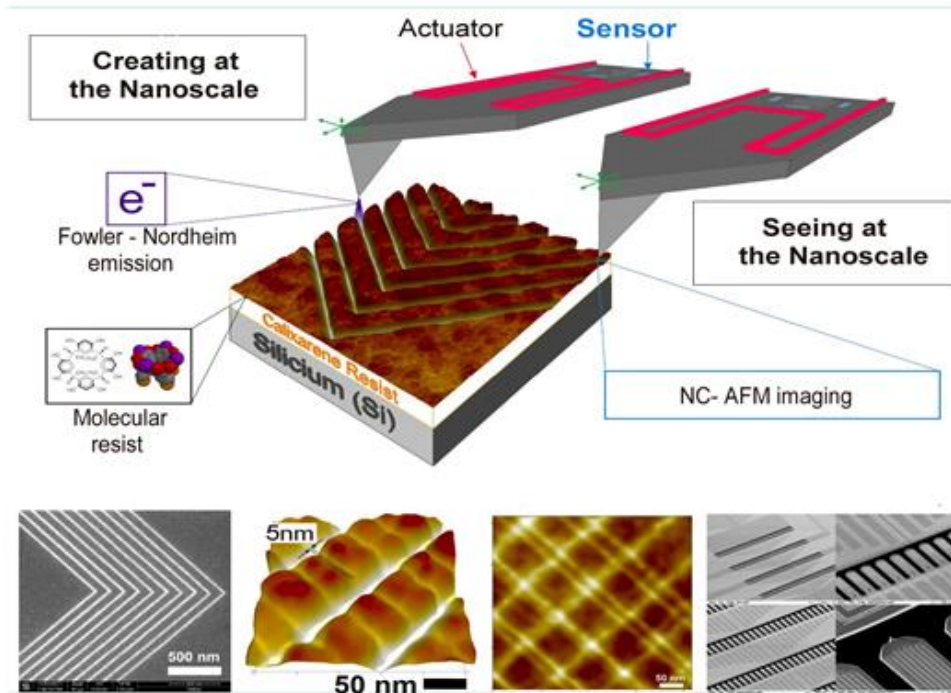
aim:

- Professional handling of tasks
internal and external user
- Higher utilization of infrastructure
- Initiation of new research cooperations
- Technological support of projects
- Better settlement of efforts within
DFG-Projects



Selected
**Research Highlights
of
IMN MacroNano[®]**

Single Nanometer Manufacturing for beyond CMOS devices “SNM” 2013-2017



Scope:

- Extending the ability to scale down today's circuits to single nanometer using novel lithographic technologies and tools

Tasks:

- SNM vision is to develop low cost, all dry, generic patterning technology for Single Nanometer Manufacturing for beyond CMOS devices
- Mask-less, “close-loop” lithography with high versatility and quick turnaround
- Nano Imprint Lithography for Low Cost Volume Manufacturing and Nanointegration
- SNM will enable new device concept based on 3D-nanostructuring

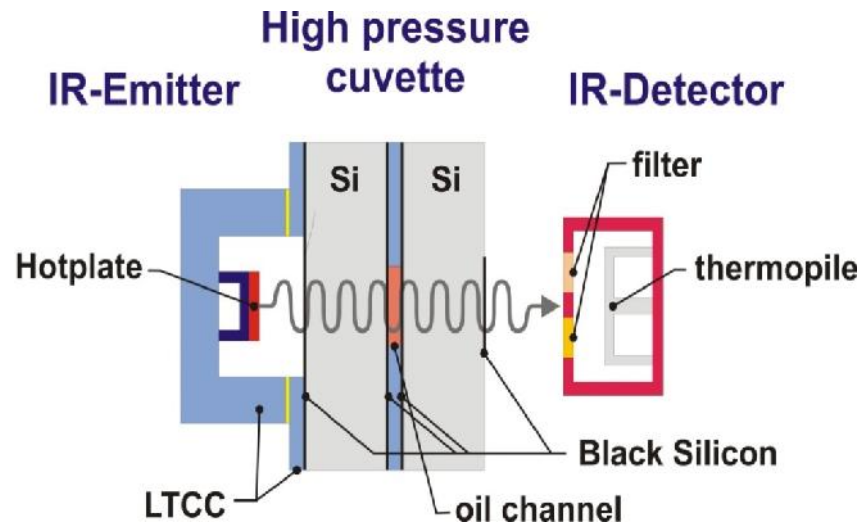
Operating units:

- Coordinator: Prof. Ivo W. Rangelow, Micro- and Nano-electronic Systems

Funded by:



High Pressure IR-Measurement Cuvette



Scope:

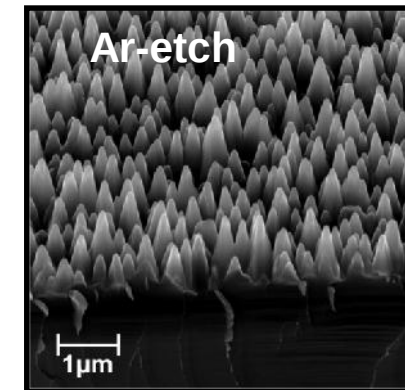
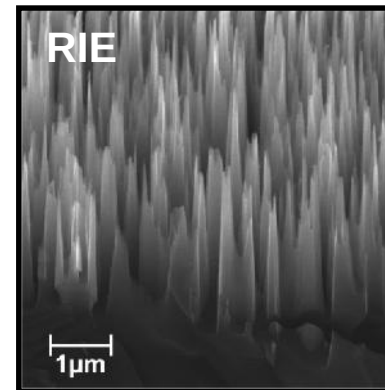
- Development of a high pressure cuvette for in-situ hydraulic oil monitoring for waste reduction
- Measurement principle: infrared spectroscopy

Tasks:

- Improvement of infrared optical properties of components by surface nano-structuring
- Development of processes for silicon to LTCC bonding with high mechanical strength

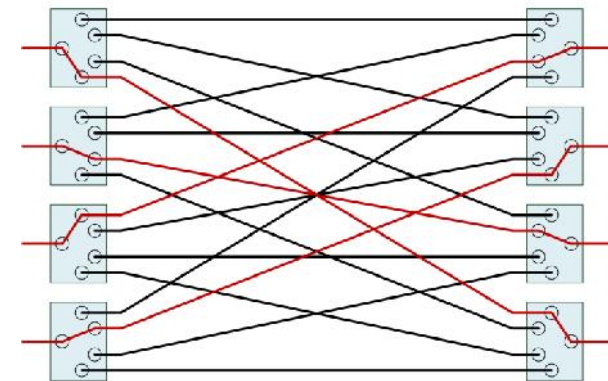
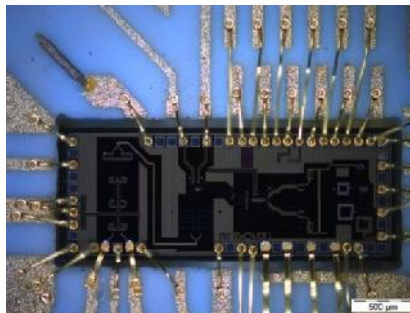
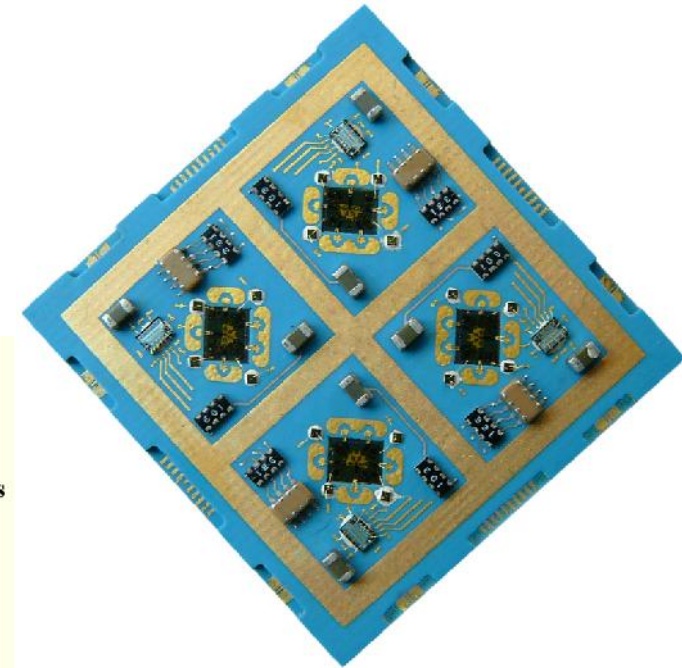
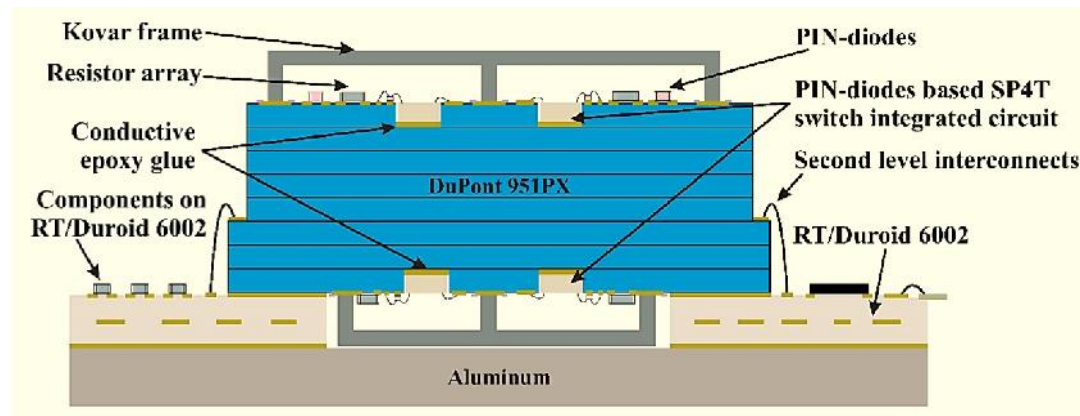


Oil cuvette made of silicon and LTCC



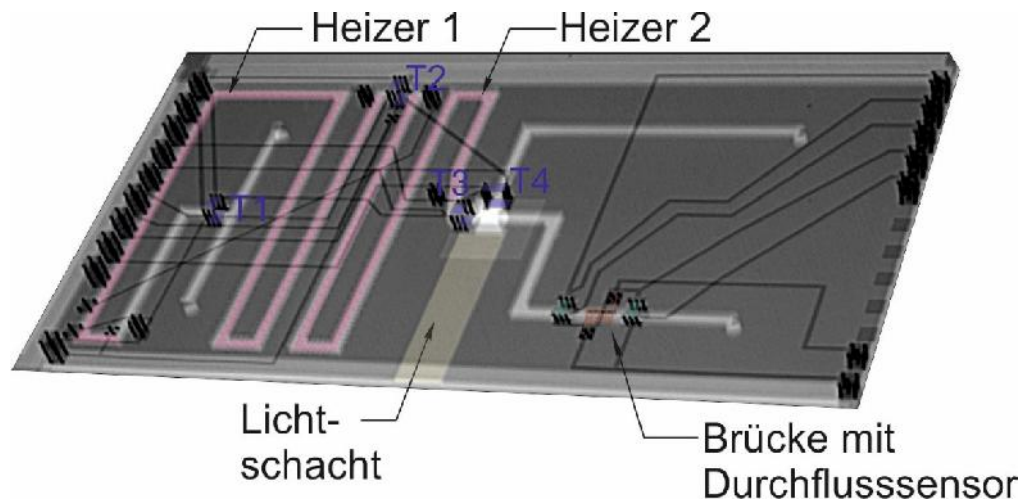
LTCC Microwave and Harsh Environment Packaging

- Ka-band module: LTCC – PCB – FPGA
- Complete package w/ interfaces, digital control
- Fully space qualified

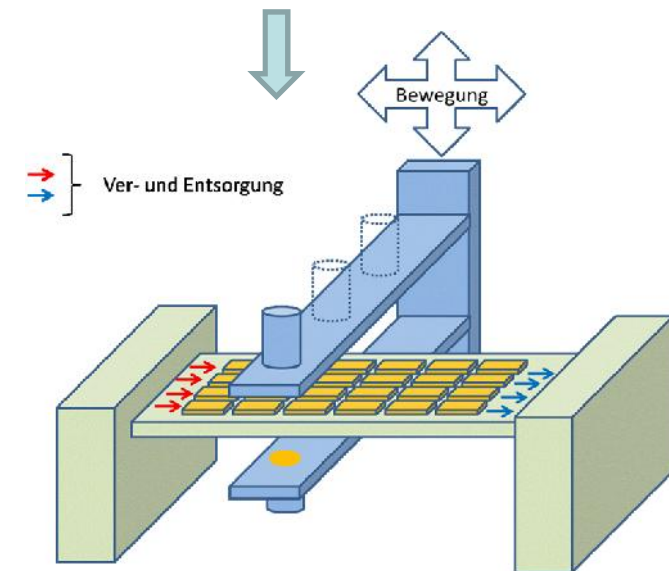


Zeiss-Project: System for Automated Cell Cultivation

- Development of an automated workbench for cell cultivation
- High reproducibility of cell cultures under constant conditions
- Defined stress application (mechanical, optical, electrical, chemical)
- Multiple sensing principles



FG: BMT, MMS, TO, ET



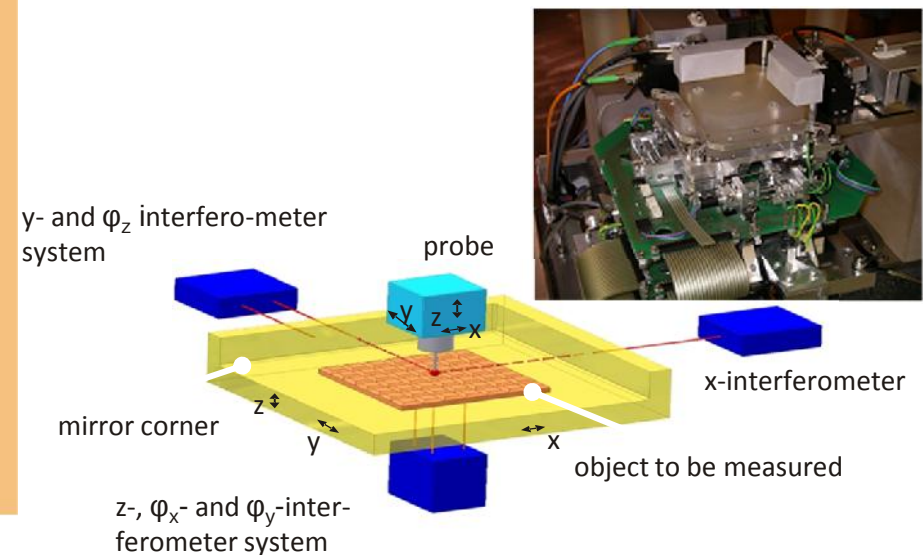
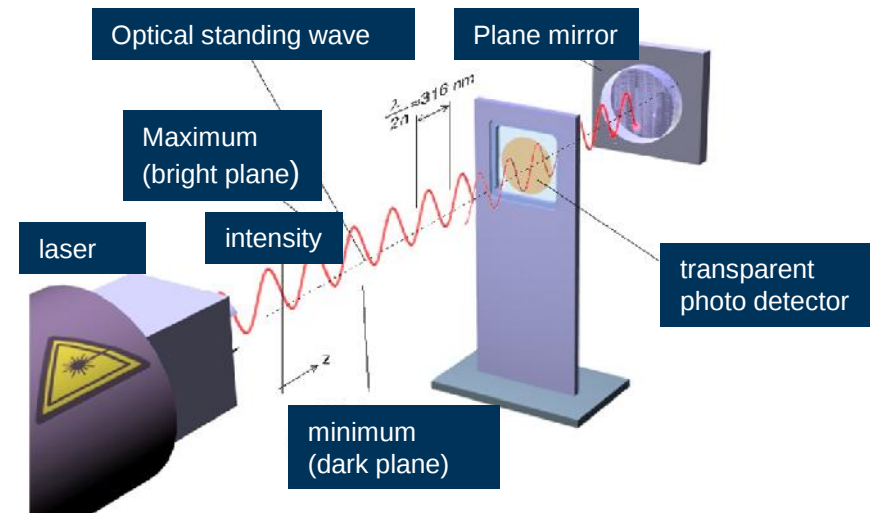
Nanopositioning

Nano Interferometer

- new ultra compact standing wave interferometer concept
- transparent photo detectors
- ultra-small volumina measurement

Nanopositioning and Nanomeasuring Machine

- Collaborative Research Center
- Subnanometer resolution in large decimetre measuring volume



Summary

Exzellente technologische Ausstattung

- + Professionale Organisation
- + Exzellente Möglichkeiten für junge Forscher und Studenten
- + Zahlreiche drittfundierte Projekte in vielversprechenden Bereichen
- + Unterstützung durch die Universitätsleitung

= interdisziplinäre / interfacultative Forschung

- + mit einem breiten Themenspektrum

= wichtiger Bestandteil des Profils der TU Ilmenau

Contact:

Director:

Prof. Jens Müller

Technische Universität Ilmenau

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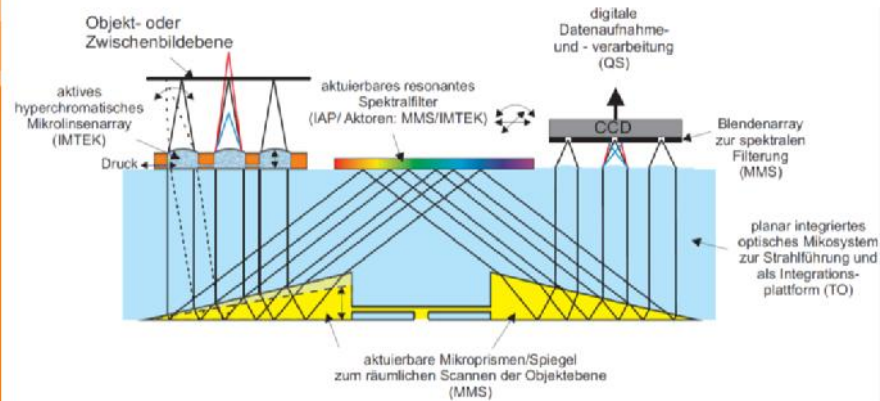


Technische Universität Ilmenau

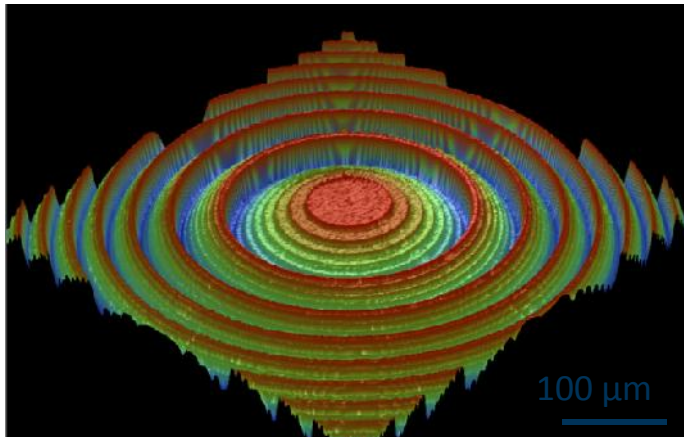


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OpMiSen (2011-2014)



System concept



Diffractive microlens for hyperchromatic imaging systems

Scope:

- Innovative optical systems for hyperspectral sensing and imaging based on active microsystems

Tasks:

- Concepts for integrated optical microsystems for hyperspectral sensing
- Micromechanical actuators
- Algorithms for hyperspectral data recording and handling

Operating unit:

- Technische Optik
- Mikromechanische Systeme
- Qualitätssicherung und industrielle Bildverarbeitung

External partners:

Funded by:



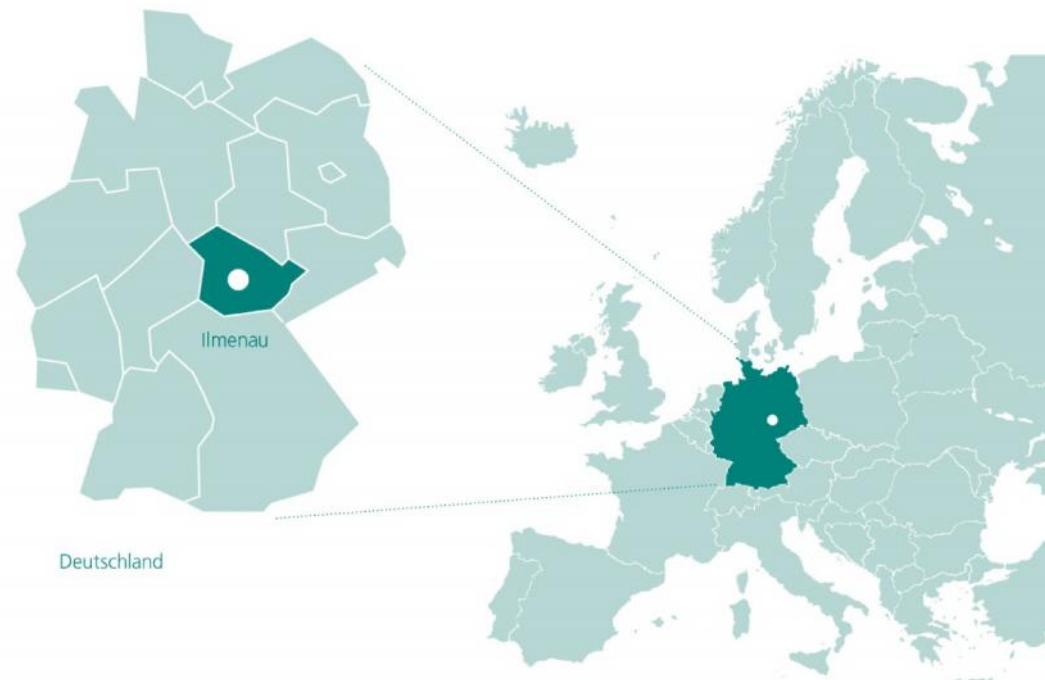
Bundesministerium
für Bildung
und Forschung

equipment IMN MacroNano® (>450k€)

Gerät	Finanzierung	EFRE?	Jahr	Preis
FIB Auriga 60 Zeiss (Analyse)	Infrastrukturmaßnahme	x	04.12.2012	1.088.850,00 €
TEM TECNAI 20S Twin Philips FEI	Erstausstattung		10.12.2001	1.001.800,49 €
FIB FEI Helios NanoLab	Berufungsmittel	x	13.04.2011	777.318,26 €
E-Beam-Writer Raith 150 Raith	Erstausstattung		29.07.2004	886.947,00 €
Cluster CS400 Ardenne	Infrastrukturmaßnahme	x	24.11.2010	1.143.349,67 €
MOCVD AIX200/AIX 200RF Aixtron	Erstausstattung		23.08.2004	1.530.978,14 €
Tempress LPCVD EQR531, Tempress Loadstation EQR531, PumpeR028	Erstausstattung		05.12.2001	653.416,09 €
AES Microlab 350 Thermo	Erstausstattung		29.03.2005	772.722,40 €
MBE/PECVD UMS500Balzers	Projektmittel		20.06.1995	1.177.968,77 €
Wachstumsmodul Omicron	Erstausstattung		30.11.2001	1.320.420,30 €
3D-Pikosekunden-Laserablationsanlage	Berufungsmittel		30.06.2015	648.817,69 €
DRIE - Estrelas	Infrastrukturmaßnahme	x	26.09.2014	507.211,77 €
Ultrapräzisionsbearbeitungszentrum Micro-Gantry nano4x Kugler incl. Drehzahlmesser	Berufungsmittel	x	08.06.2007	703.778,86 €
Laser Scanning Microscop + Rechner Olympus IX 81	Projektmittel		21.02.2008	472.538,95 €
XPS Analytik SAGE HR 150	Infrastrukturmaßnahme	x	26.11.2013	490.038,22 €
Diffraktometer D8 µXRD	Projektmittel		13.06.2017	490.451,07 €
REM Gemini SEM 500	Berufungsmittel		04.08.2016	543.532,50 €

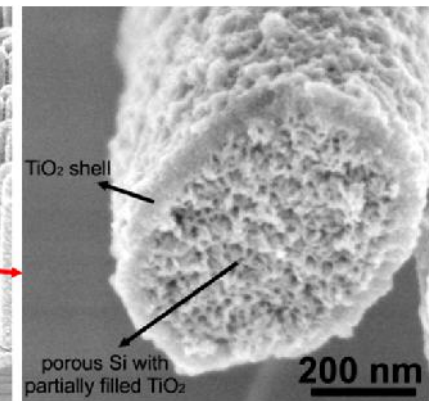
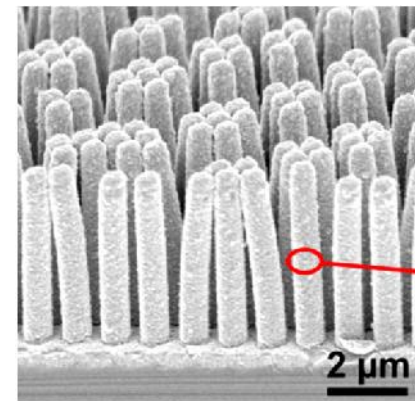
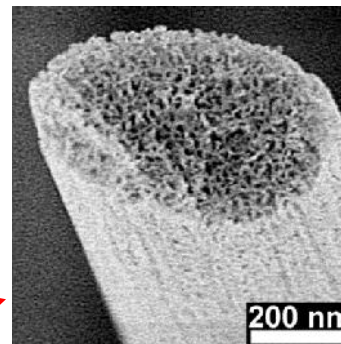
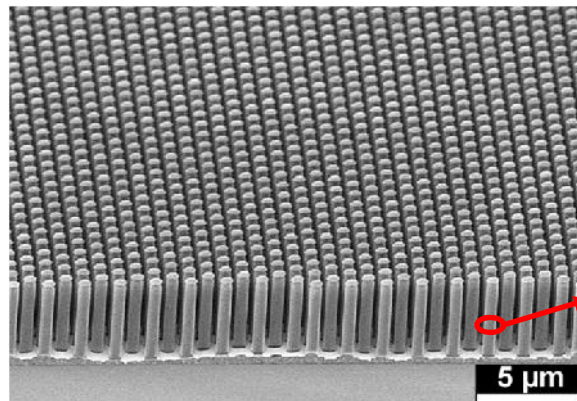
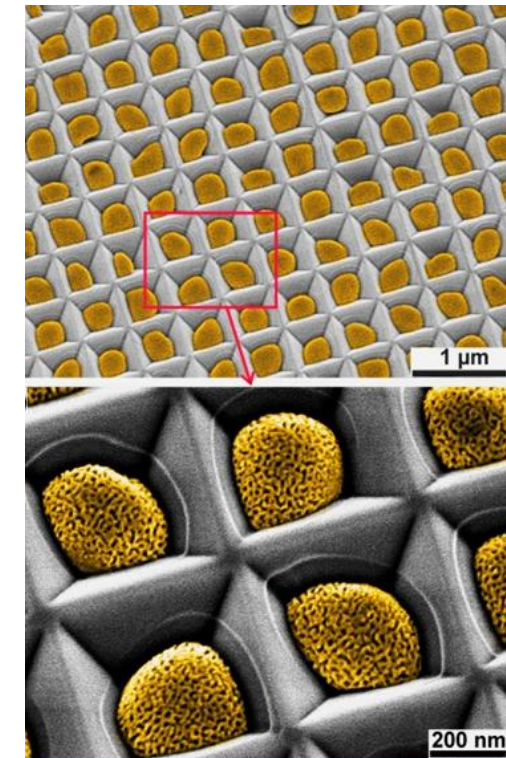
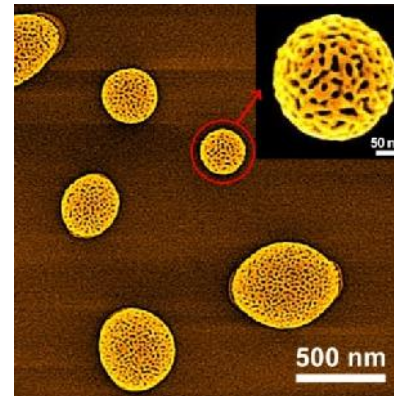
Technische Universität Ilmenau

State: Thuringia

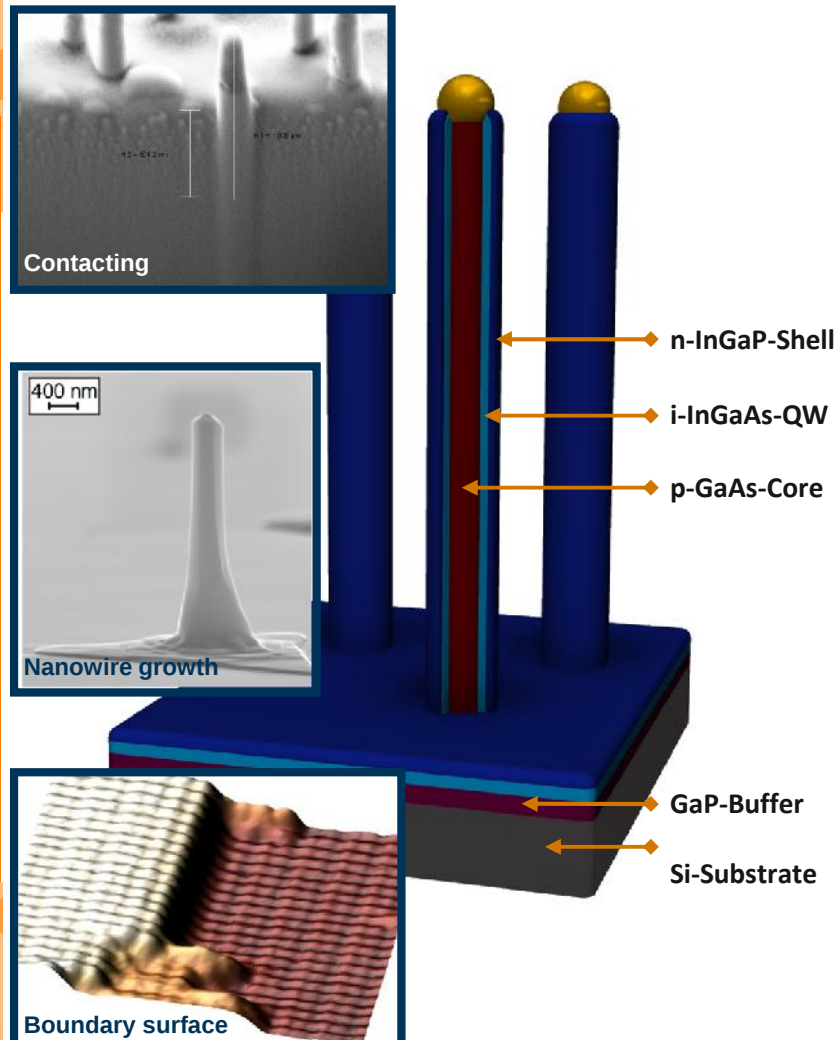


Novel nanomaterials

- mesoporous gold nanoparticles with ultrahigh specific surface area and novel optical properties
- ordered arrays of single crystalline mesoporous Si nanopillars as functional materials
- Novel core/shell nanocomposites as functional materials (TiO_2 , ZnO)



High efficiency solar cells



Scope:

- Integration of III-V materials on Si technology
- Growth of III-V based radial nanowire structures for photovoltaic applications
- Evaluation of quantum well structures as light absorber in photovoltaic devices

Tasks:

- In-situ analysis and UHV-characterization of MOVPE-prepared surfaces (XPS, LEED, FTIR, STM, etc.)
- Contacting of nanowire based devices with TCOs by MOCVD-growth

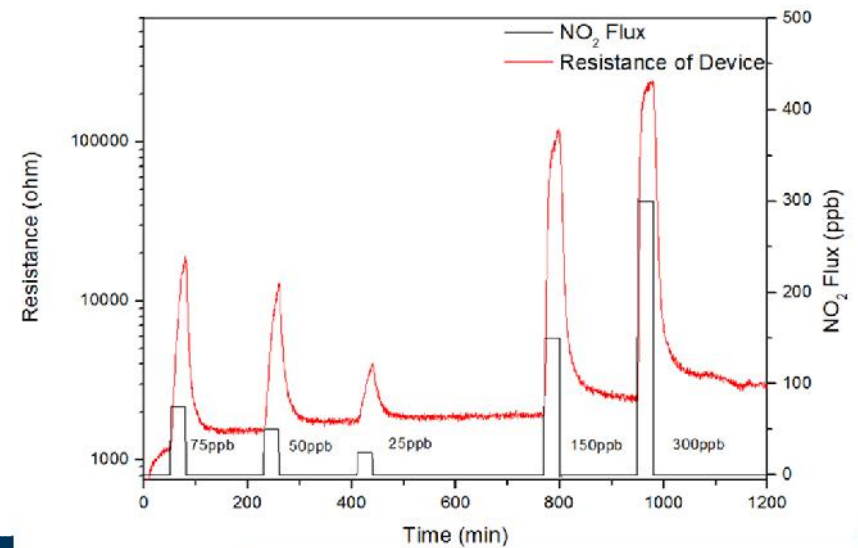
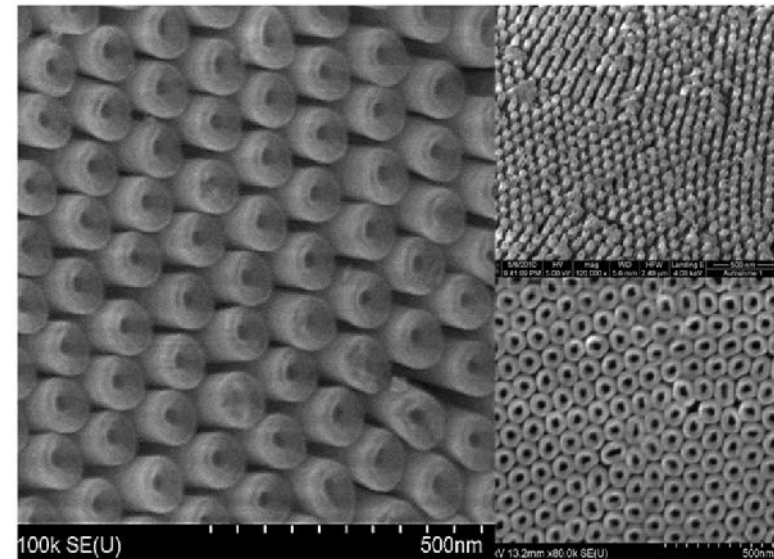
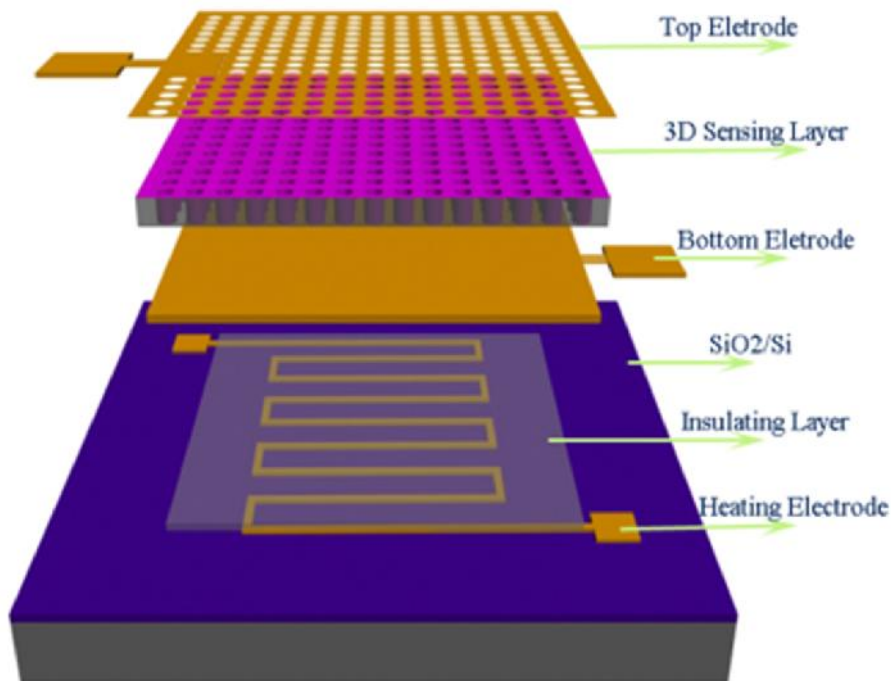
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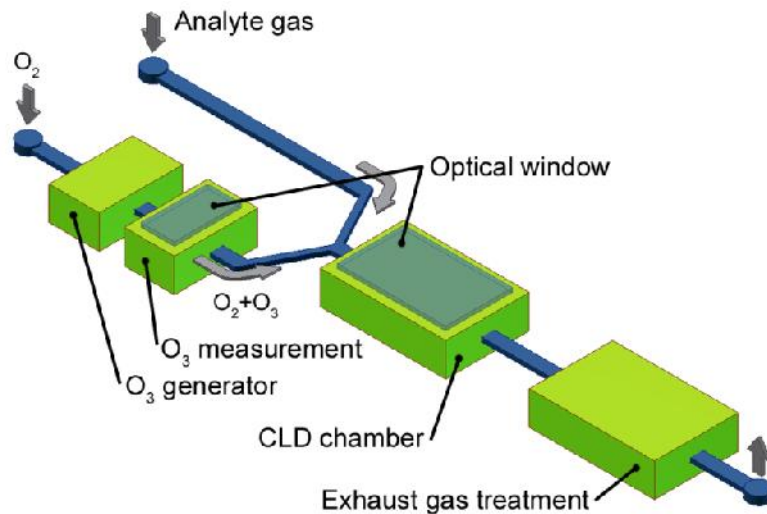
Bundesministerium
für Bildung
und Forschung

Gas sensor based on 3D-nanoarchitectures

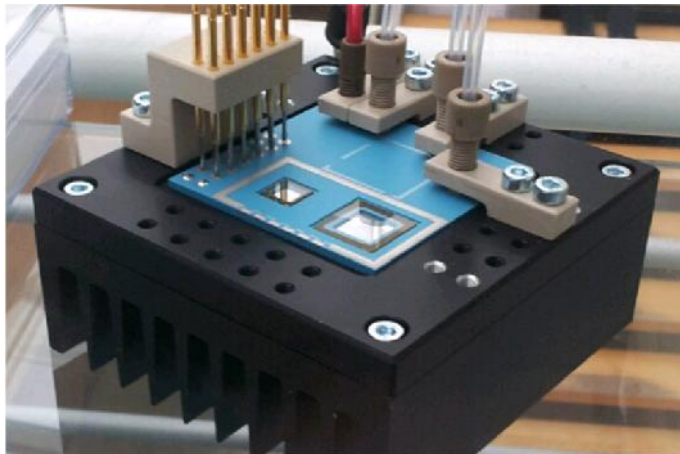
- 3D ZnO nanotube-array gas sensor realized on anodic alumina template by ALD
- sensitivity 25 ppb NO₂



NO-Sensor based on Chemiluminescent Reaction



System concept



System demonstrator

Scope:

- Measurement of Nitrogen Monoxide Levels in Gas Flows with a Micro Total Analytical System (μ TAS) based on LTCC

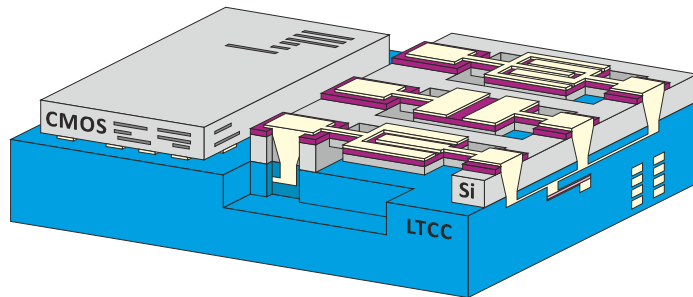
Tasks:

LTCC-integration of:

- Micro-fluidic structures (in- and outlets, channels, chambers, gas mixing)
- Optical transparent encapsulation
- Passive electrical components
- Ozone generating structure
- Exhaust gas treatment

Electro-Mechanical-Integration of Complex RF Circuits

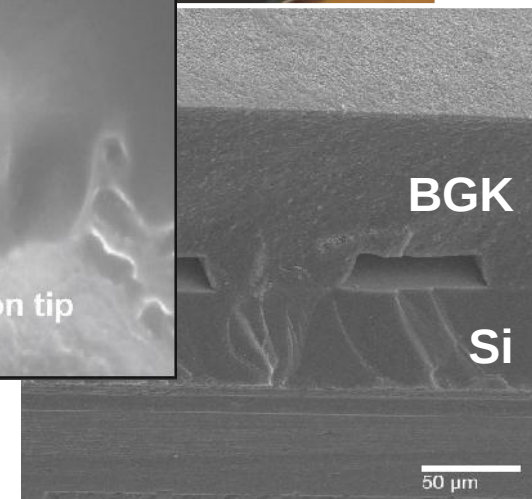
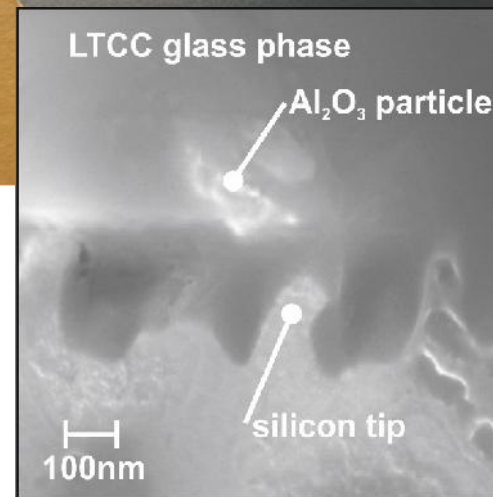
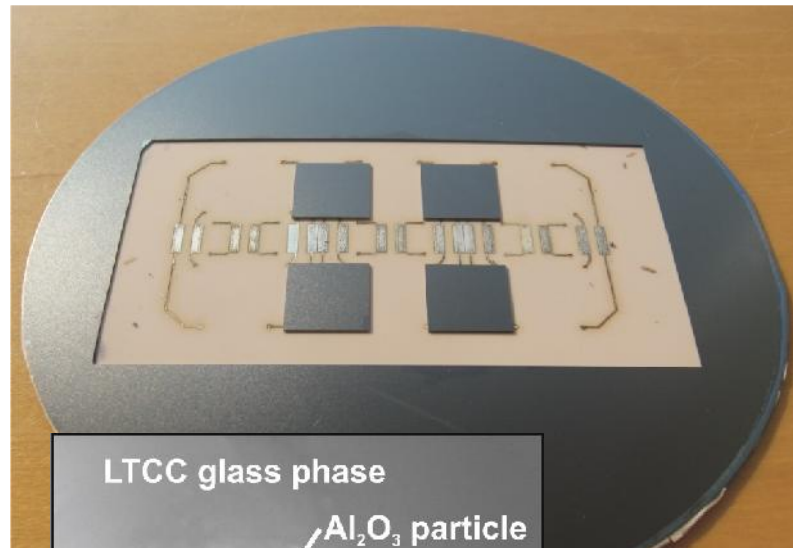
**Silicon RF MEMS + CMOS
Actives + Passives**



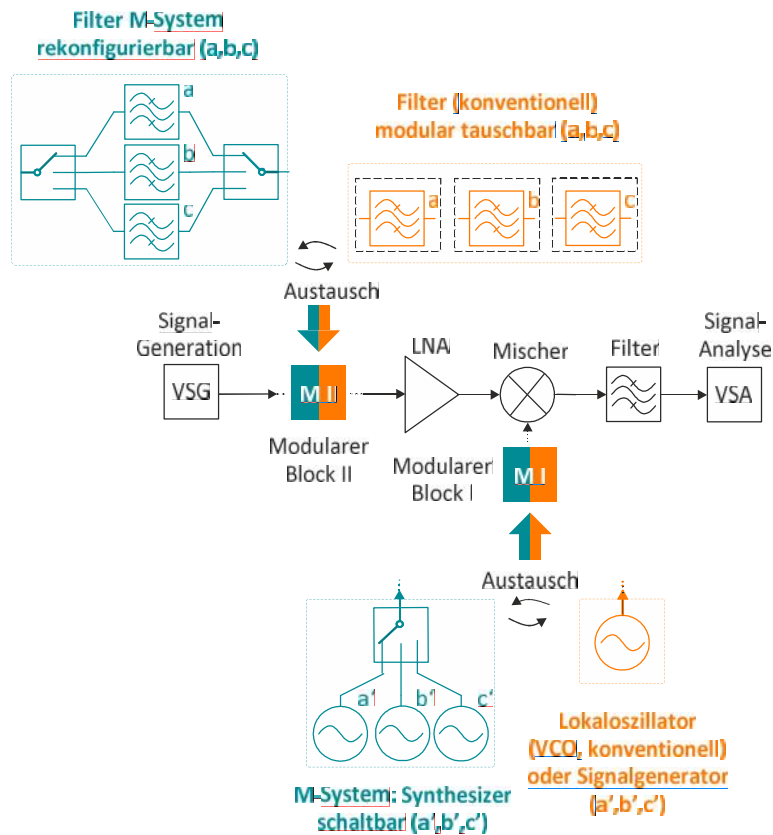
on Ceramics

**SiCer Compound
Substrate Technology**

- Complex, functionalized SiCer-substrate with integrated and external RF-devices
- Integrated RF-suitable housing



Project MUSIK (2012-2015/2018)



Sketch of envisioned RF-MEMS frontend demonstrator



Contributing and associated partners

Scope:

- Combine and merge microelectronics and micro-electromechanical worlds to establish “RF micro-mechatronics”, employing unique hybrid substrate SiCer

Tasks:

- Scientific co-ordination
- Monitor and supplement 7 workpackages
- Joint research and education activities
- Industrial interfaces

Operating units:

- RF&Microwave Research Lab
- Electronics Technology
- Micromechanical Systems
- Electronic Circuits and Systems

Funded by:

- Research Unit (Forschergruppe)



Project OK-Tech (2012-2013)



Digitally controllable switch-matrix circuit board



Satellite payload and rocket launch

Scope:

- On-orbit verification (low-earth orbit) of PIN-diode LTCC switch matrix experiment

Tasks:

- Autonomous payload module for LEO-verification aboard TET-1 mission (launch 07/2012 from Baikonur)
- Autonomous addressing, reconfiguring, and processing of data acquisition
- Technology verification
- Technology readiness level TRL 9 (LEO)

Operating unit:

- RF & Microwave Research Lab



TUHH
Technische Universität Hamburg-Harburg



ASTRIUM
AN EADS COMPANY



Astro-
und Feinwerktechnik
Adlershof GmbH



Federal Ministry
of Economics
and Technology

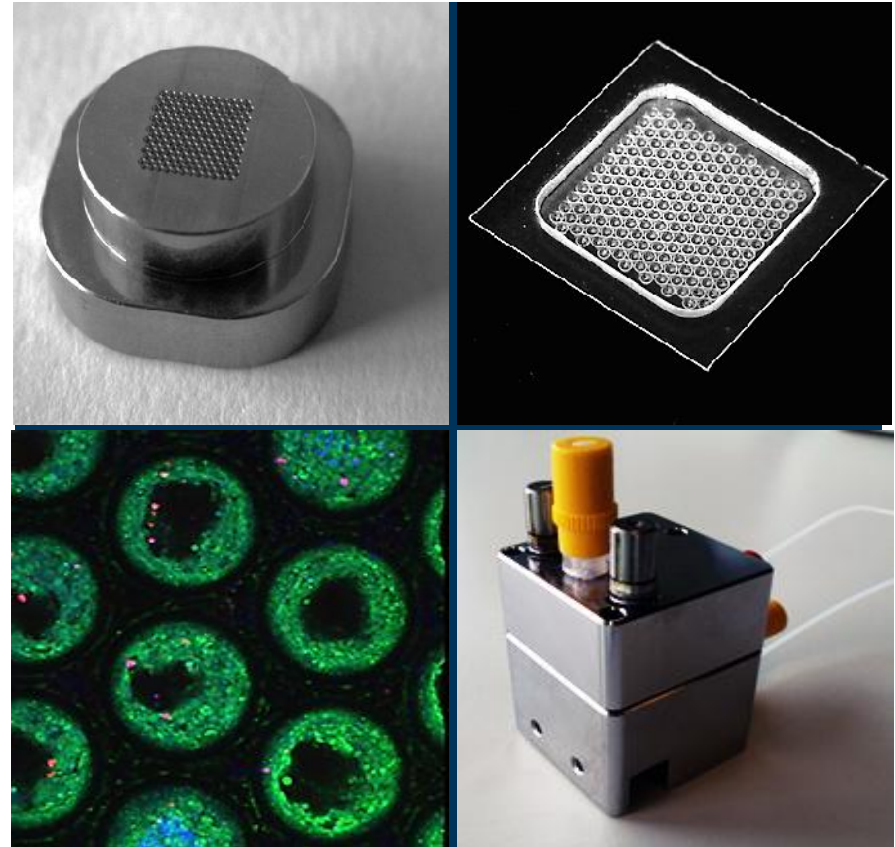


Engineering of 3D cell cultivation systems

- Highly reproducible processing of 3D cell culture scaffolds
- Biofunctionalization of polymers
- Design and realization of microreactor systems and related microfluidic 3D cell culture equipment
- 3D sensors for 3D cell cultivation

In-house biological application

- Qualification and characterization of 3D cell culture of hepatocytes, neuronal and stem cells

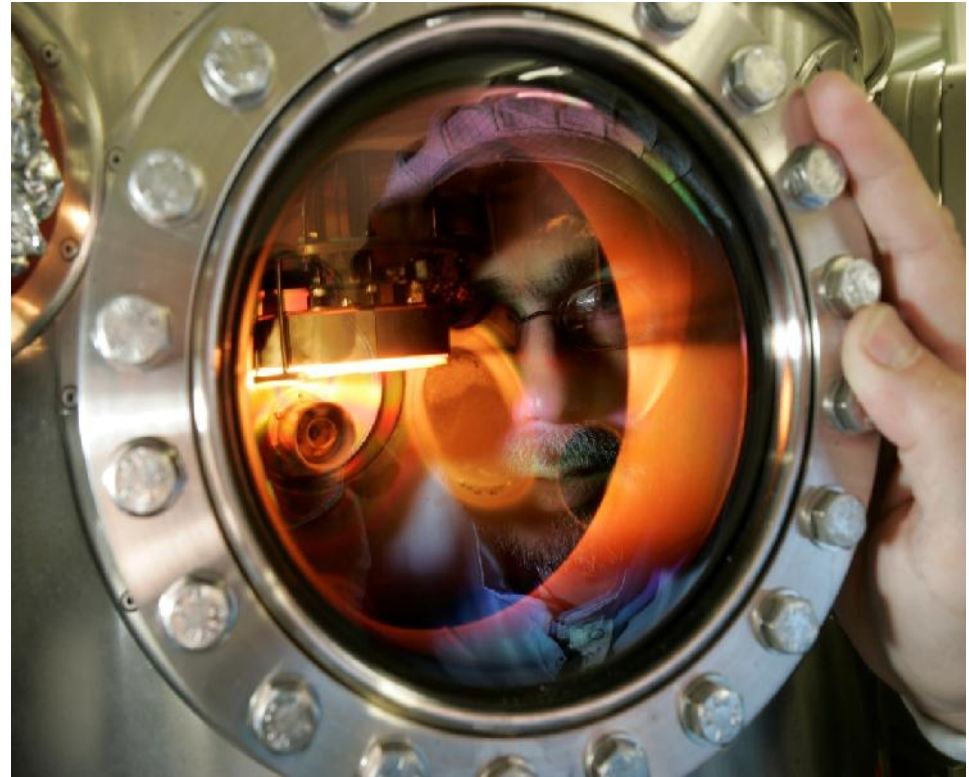


Core facility: Center for Micro- and Nanotechnologies



Materials in focus

- Silizium (*Poly-Si, SiO₂, Si₃N₄*)
- Metal carbides (*SiC, WC*)
- Metal nitrides (*GaN, AlN*)
- Metal oxides (*ZnO, TiO₂*)
- Arsenides/Phosphides
- Metals (*Ni, Pt, Cr, Au, Al, Cu*)
- Ceramics (*LTCC, Al₂O₃*)
- Polymeres (*P3HT, PEDOT*)
- Glasses



Master Program Overview

Master Micro- and Nanotechnologies (2016)

Modul / Fach	1. FS			2. FS			3. FS			4. FS			Abschluss	LP	Details
	V	Ü	P	V	Ü	P	V	Ü	P	V	Ü	P			
Electronics Technology 1													MP	6	
Electronics Technology 1	2	2	1										mPL 30 min	6	
Semiconductor devices 1													MP	5	
Semiconductor devices 1	2	2	0										mPL 30 min	5	
Materials of Micro- and Nanotechnologies													MP	5	
Materials of Micro- and Nanotechnologies	2	2	0										sPL 90 min	5	
Nanodiagnostics													MP	5	
Nanodiagnostics - Seminar and Practical course	0	1	1										SL	2	
Spectroscopic methods	2	0	0										mPL 30 min	3	
Nanotechnology													MP	5	
Nanotechnology	2	2	0										mPL 30 min	5	
Micro Technologies 2													MP	5	
Mikrotechnologie 2				2	1	1							mPL 30 min	5	
Laboratory for Materials & Micro/Nanofabrication														5	
Laboratory for Nanomaterials				0	0	1							SL	2	
Micro/Nanofabrication Laboratory				0	0	2							SL	3	

Modul / Fach	1. FS			2. FS			3. FS			4. FS			Abschluss	LP	Details
	V	Ü	P	V	Ü	P	V	Ü	P	V	Ü	P			
Introduction to Project work / Soft skills													MP	9	
Introduction to advanced research				2	0	0							aPL 60 min	3	
Introduction to scientific work				1	0	0							SL	2	
Soft skills (Choice from the non-technical subject catalogue of the TU Ilmenau)														4	
Project with seminar													MP	10	
Project with seminar							300h						PL 300 Stunden	10	
Advanced Studies (Choice of subjects according to the actual catalogue)													MP	30	
Advanced Packaging and Assembly Technology				2	2	0							mPL 30 min	5	
MEMS (Micro Electro Mechanical Systems)				2	1	0							sPL 120 min	4	
Material states and material analysis				2	1	1							PL	5	
Micro- and nanosystems technology 2				2	2	0							mPL 30 min	5	
Micro and nano sensor technology				2	2	0							mPL 30 min	5	
Micro and semiconductor technology 2				2	2	0							mPL 30 min	5	
Micro sensor technology				2	0	0							mPL 30 min	3	
Nanoelectronics				3	1	0							mPL 30 min	5	
Nanostructure physics				2	1	0							mPL	4	
Semiconductor devices 2				2	2	0							mPL 30 min	5	
3D material analysis							2	2	0				mPL 30 min	5	
Design von Mikrosystemen							2	1	0				mPL 30 min	4	
Functional materials							2	2	0				sPL 90 min	5	
Functional peripherics							2	1	1				mPL 30 min	4	
Ghz- and Thz- electronics							2	2	0				mPL 30 min	5	
Microactuators							2	0	0				mPL 30 min	3	
Thin films and surfaces							2	0	0				sPL 90 min	3	