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Abstracts of the Contributions

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Thursday, June 6, 2013

10:00 – 10:30	Welcome, Coffee
10:30 – 11:00	Opening
11:00 – 12:00	**Keynote:** G. TRÄNKLE (Ferdinand Braun-Institut Berlin): *Micro-Integrated Diode Laser Systems: New Applications in Communication, Sensing and Production*
	Optoelectronics:
12:00 – 12:45	S. ROTTER (TU Wien): *Controlling a Laser by Spatial Variation of the Pump Profile*
12:45 – 14:00	Lunch Break
	Sensors:
14:00 – 14:45	M. EICKHOFF (Justus-Liebig-Universität Gießen): *Group III-Nitride Nanowires: Fundamental Properties and Application for Optochemical Nanosensors*
14:45 – 15:30	M. LEESTER-SCHÄDEL (TU Braunschweig): *Micro Sensors for Use in Life Science Systems*
15:30 – 16:30	Poster Session & Coffee Break
	Defect Investigation:
16:30 – 17:15	P. HADLEY (TU Graz): *Defects in Semiconductors Investigated by EBIC and EDMR*

Friday, June 7, 2013

	Advanced Materials and Devices:
10:00 – 10:45	A. RASTELLI (JKU Linz): *Strain-Tunable Optoelectronic Devices*
10:45 – 11:15	Coffee Break
11:15 – 12:00	A. LUGSTEIN (TU Wien): *Si and Ge Nanowires as Building Blocks for Novel Devices*
	Power Electronics:
12:00 – 12:45	S. ZERLAUTH (Infineon Technologies AG): *The Transition of Power Semiconductor to 300 mm*

Micro-Integrated Diode Laser Systems: New Applications in Communication, Sensing and Production

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Micro-integrated, ultra-compact diode laser systems open a variety of new applications in communication and display technologies, sensing and high resolution atomic spectroscopy as well as for diode-direct applications in materials processing.

One basic scheme targets on the integration of the full optical and electronic functionality in the tiny volume of a matchbox. Here concepts are based on the integration of single mode diode lasers with passive and non-linear optical as well as electronic elements in MOPA or ECDL configurations. Modules are optimized for precise wavelengths, narrow line widths and high modulation speeds at moderate power levels in the W range.

Another basic scheme targets on the integration of broad area lasers or laser bars with coupling optics and heat management elements to laser systems with cw-power levels in the multi-kW range. Modules are optimized for small beam parameter products below 10 mm·mrad and conversions efficiencies beyond 70%.

Examples will be given based mainly on research and production activities in Berlin-Brandenburg’s Photonics Cluster.

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Controlling a Laser by Spatial Variation of the Pump Profile

Stefan Rotter

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I will show that the spatial profile of the pump applied to a laser can be used to control many of the laser's properties. In my talk I will focus on a few recent findings which we made in this context, including counter-intuitive effects associated to so-called exceptional points which occur when the laser is pumped non-uniformly [1]. In the vicinity of these points the laser may turn off even when the overall deposited pump power is increased. For the case of so-called "random lasers" we find that a suitably optimized pump profile allows us to control the angular emission pattern of the laser such as to achieve highly directional emission or any other desired pattern [2].

References

[1] Liertzer, Ge, Cerjan, Stone, Tureci, and Rotter, Phys. Rev. Lett. 108, 173901 (2012).

[2] Hisch, Liertzer, Pogany, Mintert, Rotter, arXiv:1303.5292

Group III-Nitride Nanowires: Fundamental Properties and Application for Optochemical Nanosensors

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Group III-nitride (III-N) nanowires (NWs) and nanowire heterostructures (NWHs) are a topic of current research. Part of these activities is motivated by the possibility of realizing novel, nanoscaled optoelectronic devices with improved stability and efficiency or the perspective of improving electronic devices due to the low density of structural defects. We will report on recent results concerning the growth of AlGaN/GaN nanowire heterostructures and we will report on the relation between structural and optical properties with a focus on the carrier confinement and internal electric fields in axially embedded quantum wells. We will further demonstrate that control of the growth mode allows the realization of more complex structures and will discuss the self-assembled growth of GaN quantum wires with lateral dimensions below 5 nm on the edges of AlN/GaN NWHs that act as a template. Photoluminescence emission from single GaN quantum wires will be demonstrated.

Generally, the dynamics of optically excited carriers in GaN nanostructures have been demonstrated to be affected by surface effects, modification of the internal field due to surface adsorption or non radiative surface recombination. Such effects can be used for the realization of optically addressable chemical sensors, where chemically induced variations of the surfaces potential or interaction with surface states leads to a variation of the luminescence characteristics of GaN nanostructures.

We show that the photoluminescence properties of GaN and InGaN nanodiscs embedded in NWHs sensitively responds to the exposure to different gases and allows the realization of novel optochemical transducers. Complementary response mechanisms for the optical detection of reducing and oxidizing gases will be discussed.

For application in liquid solutions we address the bias-dependent luminescence response of III-N NWs to variations of the pH value in electrolyte solutions and we discuss this behavior in terms of photoactivated hole transfer to RedOx-levels in the electrolyte solution.

Concepts for integration of III-nitride NW transducers into optochemical sensor systems are also presented.

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Micro Sensors for Use in Life Science Systems

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Over the past years, micro sensors have become of increasing scientific and commercial interest especially in the field of life science systems. Life science fields are, for example, (micro-)biology, biotechnology, environmental science, health sciences, medical devices, pharmacology and process engineering. The motivation to use micro sensors instead of common analysis systems and laboratory equipment is to save time as well as money and to enlarge the reliability of analysis methods. Micro sensors have the huge advantage of being small and lightweight. Thus, they can be easily integrated into automatic as well as portable analysis devices. In particular, microfluidic sensors consume a very small amount of sample fluid which makes them well suited for miniaturized process plants and Point-of-Care (POC) diagnostic systems.

For nearly 15 years, the Institute of Microtechnology (IMT) at TU Braunschweig has been working for a diverse portfolio of micro sensors for use in life science systems. The result of one of the first life science projects at the IMT was a highly sensitive quartz microbalance for the detection of C-reactive protein (CRP). The microbalance was combined with a blood separation device, a blood collection chamber and an affinity chromatography cell to a Lab-on-Chip (LOC) system for Point-of-Care (POC) diagnostic.

Actually the IMT is working on the use of paper for microfluidic devices. Paper-based analytical devices (µPads) are already used for different rapid health tests like for example pregnancy and diabetes tests. Paper as sensor material is cheap, bio- and medical compatible and flammable. Furthermore there is no need for additional actuation. The fluid is transported only due to capillary forces. Different fabrication methods like wax printing, photolithography and Laser-Induced-Forward-Transfer (LIFT) are being investigated to provide custom-made 3-D µPads for new POC diagnostic devices.

Another innovative and promising approach for the development of new micro sensor networks for life science applications is the use of flexible substrate materials. Flexible microsystems are robust, bendable, rollable, wearable and expendable. In addition, their fabrication is highly effective. At the IMT three different flexible substrate materials are currently investigated: Polydimethylsiloxan (PDMS), thinned silicon and polyimide foil.

Motivated by the demand of molecular cell researchers to automatically manipulate single cells, a 3-D micro force sensor based on the piezoresistive effect has been developed and further optimized. The sensor is implemented upon a motorized system which is settable through a user interface. The first force measurement procedures during penetrating a cell with a thin capillary have been very promising. It should also be mentioned that the IMT has significant experience with the development and fabrication of micro grippers and other micro actuator systems. To compensate the disadvantages of the 3-D micro force sensor (non-transparency, high fragility, restricted applications), it will be replaced by a system based on the gripper principle. Therefore, the smallest gripper of the available modular kit will be further equipped with a force sensor and hollow needles. With this, new and enriching opportunities for cell injection and mechanical characterization of muscle tissue are expected to be opened.

Defects in Semiconductors Investigated by EBIC and EDMR

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Silicon is one of the most thoroughly studied materials and yet there are many things that we don't understand about defects in silicon. The defects we are studying are thermal donors, hydrogen donors, and radiation induced acceptors. These dopants have been studied by Spreading Resistance Profiling (SRP), Electron Beam Induced Current (EBIC), and Electrically Detected Magnetic Resonance (EDMR). Spreading resistance profiling measures the conductivity locally under a sharp conducting contact. In electron beam induced current measurements, an electron beam is focused on a semiconductor and generates charge carriers in a small region. If the minority carriers diffuse to a pn-junction, they are collected and a current flows. This is similar to the operation of a solar cell. These measurements make it possible to locally determine the diffusion length which shows where recombination is occurring in a device. Electrically detected magnetic resonance is a spectroscopic measurement that uses microwaves to measure the g-factor of the defect. The challenge is to determine which defects are present in which concentration and to determine the electrical activity of the defects.

Strain-Tunable Optoelectronic Devices

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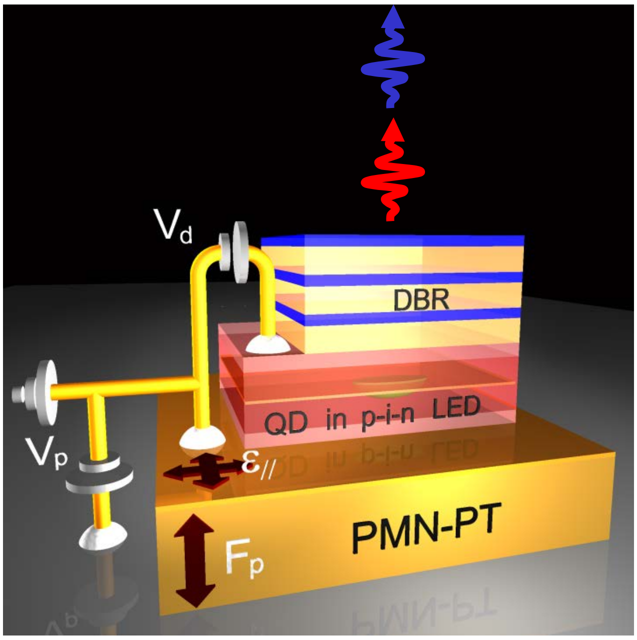
Optically active quantum dots (QDs) can be made as nanoinclusions of a low energy bandgap semiconductor in a matrix with larger energy bandgap. Many recent experiments have demonstrated that these QDs are excellent quantum emitters, which can be used as sources of triggered single photons, indistinguishable photons and polarization entangled photon pairs. These features, combined with the possibility to integrate such QDs in opto-electronic devices, make QDs particularly appealing for envisioned applications in quantum communication.

However, the structural properties of self-assembled QDs are affected by unavoidable fluctuations, which make it difficult to obtain QDs with electronic and optical properties which meet (sometimes very stringent) requirements for their use in advanced quantum optics experiments. Post-growth techniques are therefore required to fine-tune the optical properties of QDs.



In this talk I will present hybrid QD-based devices in which the semiconductor structures are integrated on top of piezoelectric actuators made of PMN-PT material [1].

This combination allows us to study in detail the effects produced by variable strains (up to about 0.2%) on the excitonic emission of single QDs and to add a “tuning knob” to QDs. In fact, by combining strain with electric fields we are able to obtain (i) independent control of emission energy and charge-state of a QD, (ii) wavelength-tunable single-QD light-emitting diodes [2], and (iii) QDs suitable for generation of entangled photon pairs, independent on their structural properties [3].

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Si and Ge Nanowires as Building Blocks for Novel Devices

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In order to continue the Moore's law new material for electronic components is been developed. Nanowire has been tested to have novel properties for application in electronic devices which will provide application in computer electronics.

The purpose of the presentation is to illuminate several aspects regarding the synthesis of silicon and germanium nanowires, their electrical properties, and the fabrication of a first device made thereof. Following an introductory survey of nanowire growth methods, experimental results concerning the epitaxial growth of nanowires are presented. The diameter dependence of the nanowire growth velocity and crystallographic growth direction of nanowires, a parameter that is of great importance especially in view of the technical applicability of epitaxially grown nanowires will be discussed. After these partially theoretical considerations with regard to the nanowire morphology, the electrical and optical properties of nanowires will be shown.

Having electronic applications of nanowires in mind, the fabrication of a nanowire field-effect transistor is naturally the first step. The feasibility of the fabrication process and the basic functionality of nanowire based devices such as gate all around FETs or "straintronic" devices will be demonstrated.

The Transition of Power Semiconductor to 300 mm

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Power electronics play a major role in the efficient usage of energy around the world, following a global trend. This is reflected in emerging markets, which are in the focus of Infineon Technologies (IFX), which is a semiconductor manufacturer. The position of Infineon in its target markets as well as the role of Infineon Austria within the corporate group build a solid base to drive innovation.

In 2010 the 300 mm project was started in Villach using “bridge-tools” to allow a fast development. Massive invest of capital and engineering efforts have been made, today Infineon is the first company worldwide to produce power semiconductors on 300 mm thin wafers.

In power devices the electrical current flows vertical through the whole bulk, whereas in CMOS technologies mainly lateral structures are used, close to the surface.

A comparison of standard CMOS technologies with power semiconductor requirements shows some challenges, which have to be overcome. On the one hand the 300 mm equipments are not designed to produce power devices, which require different materials as well as modified processes. On the other hand a fast development of the existing 8” technologies in 300 mm is mandatory for a quick entry in the market – this could be achieved with a smooth 1:1 transfer from 8” to 12”. Those differentiation factors suggest an in-house manufacturing approach, which has been considered in the future landscape of the IFX production sites.

The newly developed 300 mm manufacturing technology enables better chip performance at lower costs, putting Infineon into a prime position for delivering power devices manufactured with significantly enhanced frontend capacities based in Europe. One key is the thin wafer technology, which enables leading edge product roadmaps in the future, shown by the example of IGBTs, which are nowadays commonly produced in 150 mm and 200 mm wafer diameters.

The 300 mm wafer technology enables the development and manufacturing of new power semiconductor devices with higher energy efficiencies at lower manufacturing costs, which strengthens the position of IFX in the market.

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Applications of Nanostructured Materials

M. GAVAGNIN *et al.*:
Fe-based Nanostructures from Single to Multi-Domain Magnetic Configurations

M.M. SHAWRAV *et al.*:
Electronic Applications of Focused Electron Beam Induced Deposited Noble Metals

Microstructures for Neuroscience

A. AMON *et al.*:
A Novel Microelectronic Platform for Neuronal Electrical Activity Measurements of Neurites

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M. BRANDSTETTER *et al.*:
THz Quantum Cascade Lasers with Wafer Bonded Active Regions

M. KRALL *et al.*:
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M. MARTL *et al.*:
Multi-Cavity Terahertz Quantum Cascade Laser Systems

B. SCHWARZ *et al.*:
Bi-Functional Quantum Cascade Devices for Emission and Detection

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Impedance Matched Resonant Cavities for Quantum Well Infrared Photodetectors

C. SCHWARZER *et al.*:
Substrate and Surface Emitting Ring Cavity Quantum Cascade Lasers

MEMS Technology and Applications

M. SCHNEIDER *et al.*:
Investigation on the Dielectric Breakdown Behavior of Aluminum Nitride Thin Films at Different Temperatures Applying a Time-Zero Approach

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Properties of ICP-CVD-Deposited Amorphous Hydrogenated Silicon Nitride Layers for Fabrication of MEMS

F. STEINHÄUSSER *et al.*:
Effect of the Material Distribution on the Effective Permittivity of Porousified LTCC Substrates Applying Finite 3D Field Simulations

Fe-based Nanostructures from Single to Multi-Domain Magnetic Configurations

M. Gavagnin, H.D. Wanzenböck, D. Belic, M. Shawrav, E. Bertagnolli

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In the last few decades many efforts have been devoted on the fabrication of magnetic nanosystems which are suitable for magnetic sensing, data storage and logic applications. Focused electron beam induced deposition (FEBID) is a nanofabrication method which allows an exceptional control of the deposition at the nanoscale level. During a FEBID process the precursor molecules are injected in proximity of the impinging area of an electron beam which promotes the deposition of the desired material. In this work Fe-rich nanostructures with different shapes have been synthesized by FEBID and their magnetic configurations have been studied by magnetic force microscopy (MFM). The results have shown how FEBID allows the precise control of the shape anisotropy of magnetic nanostructures, a fundamental property of the key-elements in magnetologic devices.

Electronic Applications of Focused Electron Beam Induced Deposited Noble Metals

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Focused electron beam induced deposition (FEBID) has gained much popularity due to the possibility to deposit different structures with nanometer precision. This mask-free direct writing technique offers much more benefits over classical resist based process. This technique allows depositing metals with a single process step. It is also a potential candidate for 3D Noble metal nanostructures.

In this work, gold nanostructures of various sizes and shapes were fabricated using Focused Electron Beam Induced Deposition (FEBID). Morphological, structural and compositional properties have been investigated by Atomic Force Microscopy (AFM), Scanning Electron Microscopy (SEM), High Resolution Transmission Electron Microscopy (HR-TEM) and Energy Dispersive X-ray Spectroscopy (EDX). This approach was used to fabricate nanodevices – nanowires and capacitors whose electrical properties have been examined by means of I-V and C-V characterization.

Acknowledgement

- European Community's Seventh Framework Programme (FP7/2007-2013) under grant agreement number ENHANCE-238409
- Center for Micro- and Nanostructures (ZMNS), TU Wien
- University Service Centre for Transmission Electron Microscopy (USTEM), TU Wien

A Novel Microelectronic Platform for Neuronal Electrical Activity Measurements of Neurites

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Extracellular recording of neural activities is a powerful tool in neuroscience to investigate the communication within neural cell cultures. The extensive and complex wiring in cell cultures makes it very difficult to observe and analyze neural electrical behavior. We present a versatile microelectronic platform that allows for direct electrical measurement of extracellular potentials originating from isolated axons from dissociated neural cell cultures. The platform consists of a microstructured axon isolating device (AID) atop of a microelectrode array (MEA), whereby specific electrical recording of neural activity of axons can be performed. The AID is a microfluidic device and was fabricated by a soft lithographic process using a SU-8 structured master template with 35 microchannels for axon isolation. The MEA was fabricated by microstructuring techniques and equipped with 60 electrodes. The proof of isolated axon growth was performed with sympathetic neurons from the superior cervical ganglion of P5 WT mice grown on the AID-MEA platform. 3-days post seeding, neural activity was recorded and analyzed with the fabricated platform. The transparent structures enabled optical monitoring of the cultured cells. The benefit of the presented approach is the capability to design the whole platform to the requirements of the experiment. The presented platform will facilitate studies where axons and somata can be treated independently of each other.

THz Quantum Cascade Lasers with Wafer Bonded Active Regions

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We present terahertz (THz) quantum cascade lasers (QCLs) with doubled active region thickness by using direct wafer bonding of two active regions with a thickness of 15 µm [1]. We employed a double-metal waveguide providing high optical confinement. By increasing the waveguide thickness to 30 µm the waveguide losses are reduced by almost a factor of 2 and the far-field is improved due to the larger facet aperture. Furthermore due to the doubled active region thickness more optical power is produced inside the waveguide.

Figure 1 compares the measured voltage/ light vs. intensity plots of THz QCLs with 15 µm and 30 µm active region thicknesses. The devices show similar threshold current densities and maximum operating temperatures. The threshold voltage is increased by a factor of 2 indicating excellent electrical properties at the bonding interface in terms of contact resistance. The measured output power is increased by significantly more than a factor of 2.

With this concept the optical output power and the far-field of THz QCLs with double metal waveguide can be improved without reducing the maximum operating temperature and without increasing the threshold current as in a single plasmon waveguide [2].

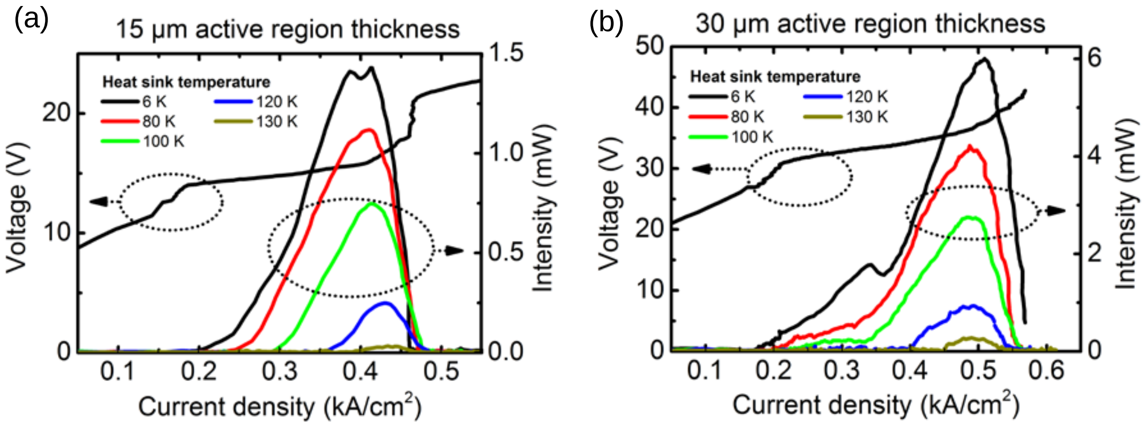

Fig. 1: Measured temperature dependent voltage/ light vs. intensity plots. The threshold current and the maximum operating temperature are comparable for devices with 30 µm and 15 µm active region thicknesses.

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Micropillar Arrays of Terahertz Quantum Cascade Emitters Based on InGaAs/GaAsSb

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We have fabricated and characterized micropillar arrays of InGaAs/GaAsSb quantum cascade devices grown by molecular beam epitaxy and etched with a highly anisotropic reactive ion etching process. The InGaAs/GaAsSb material system has been recently studied for quantum cascade lasers in the mid-infrared and terahertz spectral range [1], [2]. In addition to its low effective electron mass (0.043 m_0) and relatively low conduction band offset (360 meV) its lack of aluminum compounds is very favorable because it leads to less surface oxidation potentially causing less surface depletion in the micropillars.

The heterostructure has been designed for a strong optical transition in the terahertz and shows lasing action when fabricated into bulk double-metal waveguide devices. The micropillars are on the order of micrometers in diameter and integrated into a double-metal waveguide using a planarization technique. Measurements show electroluminescence from these devices on top of thermal background radiation. These results are very promising, since the process is scalable down to nanowire arrays with much smaller diameters, which might be able to increase the maximum operating temperature of THz quantum cascade lasers.

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Multi-Cavity Terahertz Quantum Cascade Laser Systems

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Terahertz quantum cascade laser (THz QCL) research focuses on the design of robust terahertz intersubband transitions within the conduction band of a semiconductor heterostructure. Thereby the carrier transport in THz QCLs is designed to be photon-assisted. For a full description of the QCL current additionally carrier scattering processes have to be considered. On the other hand, the electromagnetic field feedback of the laser cavity strongly modifies the distribution of charge carriers over the subbands and hence determines the amount of intersubband gain and loss within a THz QCL [1]. This effect until now was mostly underestimated. In this contribution we focus on multi-cavity systems for studying cavity coupling effects and bias controlled absorption to address this phenomenon.

The investigated system is shown in Fig. 1 (right panel). It consists of two Fabry-Pérot cavities and a short section used as a monitor for the optical field confined in the system. The gap between individual sections is 3 µm. First we explored the working conditions of the short as well as the long section for monitoring of the optical field and to effectively control the overall gain of the coupled system. We demonstrate extra-ordinary strong coupling between the photons and electrons traversing the QCL (Fig. 1, left panel). This provides a very sensitive tool for accessing the intra-cavity optical power.

Further, we utilized the internal THz power monitor (i.e. the short section of the multi-cavity system) to access the interaction between individual sections. The sub- and above-threshold coupling analysis revealed thermal and optical coupling of the cavities, respectively. Further the use as an optical modulator turns the entire system into an on-chip THz 'lab' that is extensively explored and preliminary results will be presented.

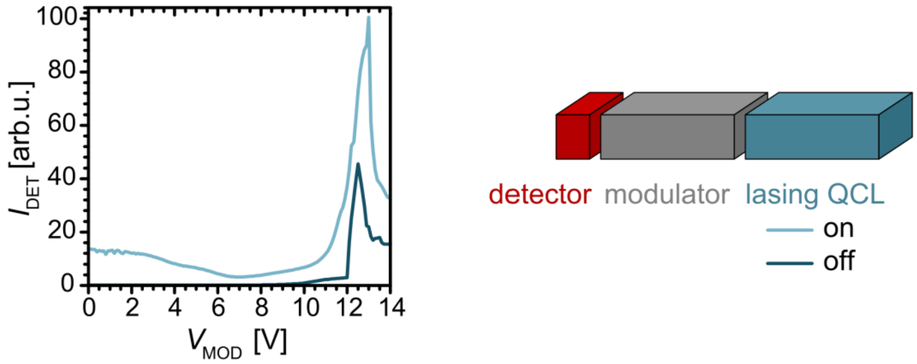

Fig. 1: Optical coupling of three cavities. The current through the detector section is shown dependent on the modulation by the second section and lasing/non-lasing of the third section.

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Bi-Functional Quantum Cascade Devices for Emission and Detection

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Quantum cascade lasers and detectors are powerful mid-infrared devices. A Quantum cascade laser can also act as a photovoltaic detector, but normally at a significant lower wavelength. Thus quantum cascade structures are commonly designed as either lasers or detectors. In our recent study we have demonstrated a quantum cascade structure that can act as coherent source and photovoltaic detector at the same wavelengths range [1]. Moving a significant step towards monolithic integrated photonic circuits such multipurpose devices open up new possibilities for on-chip applications by emitting and detecting light on the same chip [2]. Apart from typical real world applications like chemical sensing, spectroscopy and free space communication it can be used to study optical couplings, interaction of light and matter, as well as non-linear effects within one chip.

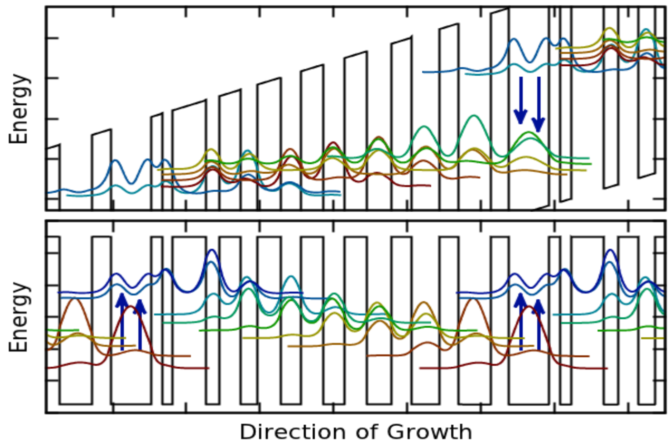

Fig. 1: Band structure of a Quantum cascade structure that can act both as a coherent emitter (upper) and a photovoltaic detector (lower).

Due to its complexity, such a device structure requires a careful quantum design to maximize performance while matching the designed wavelength at both laser and detector operation. When a certain voltage is applied, the structure acts as a laser. At zero bias it acts as a photovoltaic detector. In this case, the injector states form a phonon ladder leading to a built-in electric field. After optical excitation the electrons can scatter via this phonon ladder to the lower level of the next period. The fine tuning is done by optimization of the device structure based on a high efficient semi-classical Monte-Carlo quantum cascade simulator.

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Impedance Matched Resonant Cavities for Quantum Well Infrared Photodetectors

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The detection of mid-infrared light with intersubband optoelectronic devices, so called quantum well infrared photodetectors (QWIPs), has become a reliable and mature technology. QWIPs are frequently used in focal plane arrays due to their high uniformity, featuring megapixel imaging systems with high sensitivity. However, these detectors have to be operated at low temperatures to suppress the dark current from thermally excited electrons. A lower quantum well doping will reduce the dark current and enable operation at higher temperatures, but the photon absorption probability is reduced as well.

To enhance the responsivity of a QWIP with low dark current and low absorbance, we combined it with a resonant cavity. Due to the high lifetime of photons in the active material, the absorption probability is increased. QWIPs are sensitive only to an electric field along the growth direction, caused by a quantum mechanical selection rule. Therefore, we use a photonic crystal slab (PCS) as a resonant cavity. Surface-normal incident light couples into resonant PCS modes, which have a polarization that can be absorbed by the QWIP. With such a PCS-QWIP we have shown that the temperature performance [1] and detectivity [2] can be significantly improved. Further optimization of these devices is possible by matching the absorption of the QWIP to the quality factor of the cavity. Our simulations predict that for such impedance matched PCS-QWIPs a quantum efficiency of up to 80% can be achieved even for very low doping levels.

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Substrate and Surface Emitting Ring Cavity Quantum Cascade Lasers

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Quantum cascade lasers (QCLs) evolved to versatile and reliable light sources in the mid-infrared (MIR) and terahertz (THz) spectral region. Recently, our group reported the ring cavity surface emitting QCL [1]. The ring-type resonator, in combination with a second order DFB grating provides highly collimated beam profiles, along with robust single-mode emission. DFB gratings also diffract a certain amount of light towards the substrate [2]. Within this work we perform investigations regarding the emission direction of ring-QCLs and strategies towards enhancement of the substrate emitted optical power. The devices are based on an $In_{0.53}Ga_{0.47}As/In_{0.52}Al_{0.48}As$ superlattice with an emission wavelength around 8 µm. The second order DFB grating period is 2.412 µm and the grating duty cycle (GDC) was varied between 14 and 83 percent.

All devices showed single-mode operation at frequencies around 1296 cm^{-1}. Peak optical power values of 16.6 mW for surface emission and 9.25 mW for substrate emission were measured. When the GDC is not optimized for surface emission (around 70%), a far greater amount of light is emitted through the substrate. Maximum values for substrate emission are found for GDCs around 56%. This agrees very well with the simulation results. When accounting for the substrate absorption and the transmission coefficient at the substrate-air interface, it is demonstrated that the whispering gallery modes are predominantly diffracted towards the substrate [3].

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Investigation on the Dielectric Breakdown Behavior of Aluminum Nitride Thin Films at Different Temperatures Applying a Time-Zero Approach

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In MEMS (micro electromechanical system) devices, piezoelectric aluminum nitride (AlN) thin films are commonly used as functional material for sensing and actuating purposes. Additionally, AlN features excellent dielectric properties as well as a high chemical and thermal stability, making it also a good choice for passivation purposes. With those aspects and current trends towards minimization in mind, the dielectric reliability of thin AlN films is of utmost importance.

In this study, we present results on the transversal dielectric strength of 100 nm AlN thin films deposited by dc magnetron sputtering. The dielectric strength was measured using a time-zero approach, where the film is stressed using a fast voltage sweep up to the point of breakdown. The measurements were performed using different contact area sizes, different sweep speeds and temperatures. In order to achieve statistical significance, a couple of measurements were performed for each environment parameter set and the results analyzed using the Weibull approach.

The results show that the breakdown field in positive direction increases with pad size and voltage ramp sweep speed, as expected. Furthermore, a decrease of the breakdown field with increasing temperature up to 598 K is observed with the mean field to failure following an exponential law typical for temperature activated processes. The activation energy was determined to 27 meV, allowing an extrapolation of the breakdown field towards even higher temperatures. In negative field direction no breakdown occurred, which is attributed to the MIS structure of the sample and hence, the increasing depletion layer forming in the silicon dominating the observed current behavior. The influence of the depletion layer is analyzed using different voltage ramp speeds.

Properties of ICP-CVD-Deposited Amorphous Hydrogenated Silicon Nitride Layers for Fabrication of MEMS

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The deposition process of amorphous hydrogenated silicon nitride (a-SiN_x:H) thin films using the inductively coupled plasma enhanced chemical vapor deposition technique was investigated, by means of a design of experiments study. The a-SiN_x:H thin films were deposited on single-crystalline Si(100) substrates. The depositions took place at temperatures of 120 °C and 350 °C, varying the process pressure, plasma power and N_2 flow rate as well. Thicknesses of the as-deposited films have been measured using the spectral reflectance method, and have been found to be between 81 and 401 nm, strongly dependent on the plasma power and N_2 flow rate. Residual stress values of the layers have been determined via capacitive wafer curvature measurements. Films deposited with a high flow rate of N_2 exhibit a low residual stress, which drifts over time in the compressive direction. Layers deposited at a lower N_2 flow rate are under strong compressive stress "as-deposited", but they are stable over time. Etch tests in diluted hydrofluoric acid showed a notably large gap in the etch rate between the above two types of layers, which is a sign of strong compositional differences. The chemical composition of the deposited thin films was studied using Fourier-transform infrared spectroscopy (FT-IR) and X-ray photoelectron spectroscopy (XPS). The assessed FT-IR spectra show that depending on the deposition conditions hydrogen is contained either in N-H bonds or in Si-H bonds. XPS depth profiles show that the oxygen content of the former films is above 10 atomic %, which – along with the drifting of mechanical stress – is presumed to be caused by diffusion of atmospheric H_2O into the layers.

Effect of the Material Distribution on the Effective Permittivity of Porousified LTCC Substrates Applying Finite 3D Field Simulations

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In the recent years, Low Temperature Cofired Ceramics (LTCC) have proved their benefit for high frequency applications, as the technology allows the integration of three dimensional structures and passive electronic components by the multilayer approach into a gas proof glass-ceramic body. Moderate values of the permittivity compared to organic materials decrease the field expansion and allow small structure sizes and minimize radiation losses.

For the implementation of patch antennas, however, areas of low permittivity are required for an optimized radiation performance. Combinations with organic substrates lead to disadvantages due to the presence of thermo-mechanical stress, sophisticated electrical wiring and therefore increased manufacturing costs.

By a selective porousification process, these drawbacks are substantially minimized by locally introducing air into the sintered substrate. This process, based on wet chemical etching, only affects certain material phases surrounding the alumina grains [1].

In the present study, a mathematical model of the porousification gradient was derived from cross-sectional views of surface-near porousified LTCC substrates using FIB (focused ion beam) and SEM (scanning electron microscopy) techniques. The analysis of SEM micrographs recorded in the BSE (back scattered electrons) and SE (secondary electrons) mode was used to create a material phase contrast image by means of image editing procedures. This image was processed further to determine the relative amount of material as a function of the penetration depth.

A sigmoid function was used for fitting the porousification gradient. Subsequently, field simulations of a microstrip line on those LTCC substrates were performed at 77 GHz while the gradient was implemented via 30 layers, each being constant in its electrical properties so that the relative permittivity was approximated by the material gradient. The resulting frequency dependent effective relative permittivity $\varepsilon_{r.eff}$ was calculated from the simulated phase constant β [2].

Due to the locally narrowed field distribution at the simulated frequency, the decreased permittivity of the substrate material has to be located near the bottom of the microstrip line in order to provide the highest impact.

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