GMe Forum 2012

Abstracts of the Poster Presentations

Vienna University of Technology
March 29 and 30, 2012

Society for Micro- and Nanoelectronics
Vienna, 2012

Society for Micro- and Nanoelectronics
c/o Institute of Sensor and Actuator Systems
Vienna University of Technology
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Photonics and Optoelectronics:

M. BRANDSTETTER *et al*., *THz Quantum Cascade Lasers with Coupled Microdisk Cavities*

M. MARTL *et al.*, *Analysis of THz Quantum Cascade Laser Gain Properties Using a Coupled Cavity*

D. DIETZE *et al.*, *Generation of Intense Broadband THz Pulses*

M. FURCHI *et al.*, *Cavity Enhanced Graphene Photodetector*

S. KALCHMAIR *et al.*, *Photonic Crystal Slabs for Resonant Photodetection in Quantum Wells*

R. JANNESARI *et al.*, *Enhancement of Light Extraction from SiGe-Based Photonic Crystals*

F. HACKL *et al.*, *Micro-Photoluminescence and Strategies Towards Perfect Ordering of SiGe Nano-Islands Grown on Pit-Patterned Si(001) Substrates with Widely Scaled Pit-Periods*

M. STEINDL *et al.*, *Development of Experimental Methods for Single SiGe Quantum Dot Photocurrent Spectroscopy*

S.I. AHN *et al.*, *Reduction of Facet Reflectivity of Quantum Cascade Lasers by Tilted Facets*

H. DETZ et al., *Improved InGaAs/GaAsSb MBE Growth of Quantum Cascade Lasers*

A. KHIAR *et al.*, *Optically In-Well Pumped VECSEL Emitting Beyond 3 µm*

Nanostructures and Quantum Devices:

A. ALEXEWICZ *et al.*, *InAlGaN/AlN GaN-HEMTs with In-Situ SiN Passivation*

M. KRALL *et al.*, $In_{0.53}Ga_{0.47}As/GaAs_{0.51}Sb_{0.49}$ *Semiconductor Nanowires: Fabrication and Electrical Characterization*

G. CHEN *et al.*, *Self-Assembly and Growth of In-Plane, Prism-Shaped SiGe Nanowires on Rib-Patterned Si (001) Substrates*

T. ETZELSTORFER *et al.*, *X-ray Scattering Studies of SiGe Superlattice Interfaces*

Novel Materials and Technologies:

O. Bethge *et al*., *Impact of the ALD Process on the Inversion Capacitance in Ge Based MOS Capacitors*

Sensors and Microfluidics:

A. AVDIC *et al.*, *Application of FIB Induced Sb Nanowires – Micro Scale pH Sensor*

S. CLARA *et al.*, *An Electromagnetically Actuated Orbiting Sphere Viscometer*

V. LAVCHIEV *et al.*, *Mid-Infrared Optoelectronic Sensors*

W. HILBER *et al.*, *Droplet and Particle Manipulation in Emulsions and Suspensions Using 3D Electro-Osmotic Micropumps*

THz Quantum Cascade Lasers with Coupled Microdisk Cavities

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The compact size and high output power in the range of several milliwatts makes terahertz (THz) quantum cascade lasers (QCLs) highly attractive for applications like spectroscopy, heterodyne detection or imaging. QCLs are currently emitting in the range between 0.74 and 5 THz [1],[2] and thus covering a huge part of the THz spectral region. Using double-metal (DM) waveguides, where the light is confined in the active region between a top and bottom metal layer, different types of resonators can be fabricated.

In this work we have employed disk shaped resonators, where the light is guided via total internal reflection at the outer facet, forming a whispering gallery mode [3]. Single mode emission is achieved by using small diameters of the disks. We have investigated the coupling of two adjacent microdisk THz QCLs which are electrically insulated. In order to achieve coupling via the evanescent field the microdisk resonators have been fabricated in very close vicinity. It can be seen that the lasing behavior of one microdisk QCL can be influenced or even completely suppressed by the other one. This can be attributed to the strong absorption of the active region at certain bias conditions below threshold. In this way the gain and loss behavior of THz QCLs can be studied.

The authors acknowledge financial support by the Austrian Society for Microelectronics (GMe), the Austrian Scientific Fund FWF (SFB-IRON F2511, and DK CoQuS W1210) and the Austrian Nano Initiative project (PLATON).

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Analysis of THz Quantum Cascade Laser Gain Properties Using a Coupled Cavity

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The usability of quantum cascade lasers (QCL) is strongly dependent on the output efficiency; wheras typical parameters for the laser efficiency are the maximum output power, the threshold current density and the wall-plug efficiency. The gain of the lasing medium determines these parameters and hence the gain is in the center of theoretical and experimental studies of THz QCLs. Recently, experiments using THz time-domain spectroscopy have shown broadband gain above threshold and bias-dependent losses below threshold [1],[2].

In this contribution a coupled cavity THz QCL is employed for the study of gain and absorption within the conduction band states of a THz quantum cascade laser. Terahertz time-domain spectroscopy is used to study a double metal THz QCL, which is the waveguide type used for the highest operating temperature THz QCLs so far. A short emitter section is used for the THz pulse generation and the longer cavity is used as the THz QCL device under test. The THz pulses are generated in the short section and propagate within the waveguide and by means of a bypassing plasmon-like mode. Time-domain analysis reveals only a weak cross-modulation from the longer QCL section onto the unmodulated emitter section. This proves the coupled cavity fabrication process and enables unperturbed gain measurements. Gain measurements show bias dependent losses at the lasing transition which are explained by absorption from the lower laser level. The results demonstrate the potential of coupled cavity THz QCLs for the investigation of optical properties of THz QCLs.

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Generation of Intense Broadband THz Pulses

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In this contribution, we present our recent results on high intensity THz pulse generation using table-top laser sources. The setup is based on a combination of an Er-doped fiber laser and a regenerative Ti:Sapphire amplifier. For the generation of broadband single-cycle THz pulses, several different technologies have been tested. These include optical rectification in large area (110)-cut GaP crystals [1], emission from coherent surface plasmons [2], THz current pulses in photoconductive antenna arrays [3] and four-wave mixing in dual-color laser filaments [4],[5]. THz peak fields above 40 kV/cm and bandwidths up to 6 THz (limited by the crystal used for electro-optic detection) have been achieved, thereby filling the high field THz gap between 1.5 and 10 THz.

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Cavity Enhanced Graphene Photodetector

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Graphene, a two-dimensional allotrope of carbon, is reported to have extraordinary electrical and optical properties [1]. Photodetectors, based on graphene [2], show a nearly wavelength independent sensitivity [3] and have been proven to work at high speeds [4]. Although the optical absorption coefficient of graphene is very high in comparison to most semiconductors, the optical absorption in graphene is weak (≈2.3 %) due to the thickness of only 0.335 nm.

In order to overcome this problem, we integrated a graphene photodetector into an optical cavity with two distributed Bragg-mirrors [5]. This allows us to increase the absorption of the incident light on the graphene sheet. As design wavelength, we have chosen 850 nm, due to its wide use in optical communications. In order to ensure that the maximum of the field amplitude occurs at the position of the graphene sheet, a Si_3N_4 buffer layer was placed between the mirrors.

From reflectivity measurements we determine a 26-fold enhancement in absorption compared to the 2.3 % for freestanding graphene. This enhancement results into an increase of the responsivity from less than 1 mA/W to 21 mA/W, which makes such devices promising for future optoelectronic applications.

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Photonic Crystal Slabs for Resonant Photodetection in Quantum Wells

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Mid-infrared optoelectronic devices, in particular quantum well infrared photodetectors (QWIPs) and quantum cascade lasers (QCLs), have made remarkable progress towards real market applications. However, while QCLs support high power and continuous wave operation at room temperature, QWIPs still need to be operated at cryogenic temperatures to exhibit reasonable detector sensitivity [1]. The detector's noise increases exponentially with temperature, what makes expensive cooling equipment necessary.

We present a QWIP, which is designed as a photonic crystal slab (PCS) resonator [2]. To keep the detector noise low, we doped the quantum wells only to an equivalent sheet carrier density of 4×10^{9} cm^{-2}. When the surface-normal incident radiation is coupled to the PCS modes, it is absorbed by the QWIP. Since the photon lifetime at the resonance frequency is increased, the absorption efficiency is enhanced significantly. This means that the detector responsivity is resonantly enhanced without inducing additional noise [3]. In fact, by etching the photonic crystal holes into the QWIP, the detector volume and, hereby, the noise are effectively reduced. The resulting detectivity in our PCS-QWIP is up to 20 times higher compared to a standard QWIP. Signal current could still be measured up to 200 K when illuminated with a globar light source. We envision that this detector design will permit room temperature operation of QWIPs with reasonable detectivities for cost-efficient applications including thermal imaging or high speed data transmission.

The authors acknowledge the support by the Austrian FWF project IRON (F2503-N17) by the Austrian Science Fund, the PLATON projects within the Austrian NANO initiative and the "Gesellschaft für Mikro- und Nanoelektronik" GMe.

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Enhancement of Light Extraction from SiGe-Based Photonic Crystals

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An optical micro-resonator traps light, thus enhancing the spontaneous emission rate. During the last decades photonic crystals became one of the most promising optical devices with good performance for this application. Because of the low losses in glass fibers, the interesting spectral range for telecommunication applications is 1.3 – 1.5 µm. For various applications, it is often critical to design photonic crystals in this spectral range. Of course, the active material should emit light in the same spectral range.

For this purpose, self-assembled Ge dots were chosen here. Two-dimensional photonic crystals of holes were fabricated in a layer stack on a silicon-on-insulator (SOI) substrate. The active layers were grown by molecular beam epitaxy (MBE), and consist of a Si buffer, 10 monolayers of Ge that form the self-assembled dots, and a 500 nm top silicon layer. In order to design the photonic crystals, plane wave expansion (PWE), and finite difference time domain (FDTD) methods were used. As a result, the ratio of the hole radius to the period was chosen to be around 0.35.

In the fabrication process electron beam lithography (EBL) and reactive ion etching (RIE) were employed. Micro photoluminescence (µPL) measurements were performed with an Argon laser (λ = 458 nm). As a result, we found an enhancement of the µPL signal by about a factor of 20 in the photonic crystal area in comparison with the unpatterned areas of the same sample.

To achieve further improvements, we began to design and implement structures, where photonic crystals are combined with ordered Ge islands in registry with the high-symmetry locations in between the holes of the photonic crystal. This requires optimized geometrical parameters and proper assignments of the photonic crystal modes that have high electric fields and high local densities of states in the regions where the Ge dots are located. Both, simulations and first device implementations, will be presented.

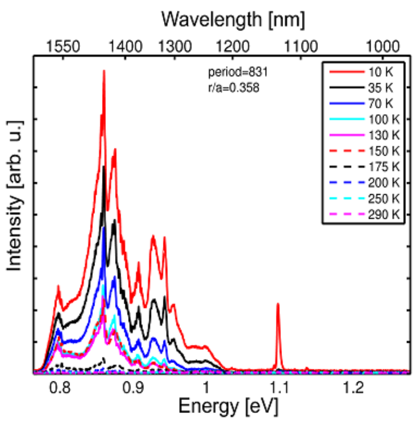

Fig. 1: PL spectra for a temperature series of a photonic crystal slab with 10 layers of quantum dots inside a hexagonal photonic crystal of period 831 nm and an aspect ratio of r/a = 0.358.

Micro-Photoluminescence and Strategies Towards Perfect Ordering of SiGe Nano-Islands Grown on Pit-Patterned Si(001) Substrates with Widely Scaled Pit-Periods

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Any meaningful application of self-organized SiGe islands requires size homogeneity, chemical uniformity and addressability. These aims can be achieved by growth on pre-patterned Si(001) substrates [1]. In this work we investigate the dependence of the island morphology and homogeneity on the substrate pattern period. By photoluminescence (PL) experiments the influence of the statistical size distribution on the optoelectronic properties of an island ensemble is monitored.

Ge islands were grown by molecular beam epitaxy at different temperatures (650 °C, 690 °C, 725 °C and 760 °C) and a constant Ge deposition rate (0.05 Å/s) on substrates pit-patterned by e-beam lithography with various pit periods p from 300 nm to 900 nm. A low Si capping temperature (300 °C) was used to preserve the island shape, size and Ge composition. Uncapped samples were grown for atomic force microscopy investigation.

At the given growth rate, we determine from the uncapped samples a clear correlation between the deposited amount of Ge per unit cell of the pattern with the size distribution and the morphological shapes of the islands. For the optimal amount, we observe significantly narrowed island photoluminescence emission peaks that are ascribed to the improvement of the Ge distribution homogeneity in the islands rather than to their shape homogeneity [2]. Beyond this optimal amount (i.e. for increasing p), dislocated superdomes are formed. As a consequence, the island PL becomes almost completely quenched once superdomes are formed.

On patterned substrate areas with further increased p, nucleation of islands between the pits is observed. We give evidence that this scenario resulting in an un-addressable island sub-ensemble can be fully suppressed by carefully adjusting the Ge deposition rate to a value smaller than the time- and area-averaged rate at that Ge is incorporated into the islands growing in the pits. By these means, the thickness of the Ge wetting layer (WL) between the pit positions stays below the critical one for spontaneous island formation [3]. In turn, the observed onset of spontaneous island nucleation allows to estimate the global Ge incorporation rate and, thus, the average lifetime a Ge atom stays mobile on the WL. The obtained value of ~20 s is in excellent agreement with results from surface diffusion experiments [4].

Our findings emphasize that for the ordered growth of heteroepitaxial islands a precise control over a huge parameter space including the deposition rate, the amount of deposited material, the pit period and the growth temperature is a prerequisite.

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Development of Experimental Methods for Single SiGe Quantum Dot Photocurrent Spectroscopy

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On SiGe island ensembles, a clear photo current (PC) signal in the energy region below the fundamental Si absorption edge was observed for p-i-n diodes containing SiGe islands in the i-regions that is absent in reference diodes without islands. An unexpected MIR PC response was observed at energies far below the fundamental bandgap of the SiGe islands as determined by PL experiments. This signal was tentatively ascribed to intersubband absorption of non-equilibrium holes confined to the SiGe islands. Such non-equilibrium hole transitions would open the possibility to investigate the electron capture kinetics of the SiGe islands by 2-color pump(NIR)-probe(MIR) PC experiments.

However, because of averaging over ensembles, statistically broadened signals are observed in our work, which make a clear assignment of the observed PC signals difficult. We report on our attempts to implement single island PC experiments in the SiGe material system, where so far no results on the spectroscopic investigation of single islands have been published. As compared to photoluminescence (PL) experiments, PC experiments take advantage of the photo-conductive gain that is especially large for islands with spatially separated electron and hole groundstate wave functions (type II alignment) like in SiGe islands. Thus, we conclude that single island PC experiments are better suited than single island PL experiments for revealing the energy level structure of a single, type II island.

Facet Reflectivity Reduction of Quantum Cascade Lasers by Tilted Facets

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Quantum cascade lasers (QCLs) have been spotlighted as high-power coherent light sources in the mid-infrared (MIR) region of the electromagnetic spectrum [1], [2]. Reduction of the facet reflectivity is desirable for certain applications, such as distributed feedback (DFB) lasers, superluminescent quantum cascade light-emitting diodes and external cavity light sources in order to minimize Fabry-Pérot resonances. The unipolarization of the light emitted by a QCL is determined by the intersubband selection rules. Namely, the electric field of the optical wave is along the growth direction, creating TM polarized light. This polarization purity enables utilizing the facet angle to reduce reflectivity and, hereby, Fabry-Pérot resonances. In this work, we present a reduction in facet reflectivity of quantum cascade lasers by tilting the facet.

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Improved InGaAs/GaAsSb MBE Growth of Quantum Cascade Lasers

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The combination of InGaAs quantum wells and GaAsSb barriers was recently demonstrated as a promising material system for mid-infrared (MIR) and THz quantum cascade lasers [1]. Key advantages are the low effective mass in both compounds and the moderate electronic barrier height for THz devices. Both materials are grown lattice-matched to InP substrates using molecular beam epitaxy (MBE). For the growth of the mixed group V ternary, preset fluxes of both group V species are supplied from valved crackers. Switching between the materials is then done by shutter operations only [2]. For further optimization of the growth process, we investigated both interface types in these heterostructures by high-resolution transmission electron microscopy. In addition, the behavior of Si atoms in the $GaAs_{0.51}Sb_{0.49}$ layers was investigated, as Si is a donor in GaAs but an acceptor in GaSb. The obtained conductivity was clearly n-type for doping levels between 1.7e18 and 8.5e15 cm^{-3} [3].

MIR QCLs around 11 µm wavelengths based on InGaAs/GaAsSb heterostructures were first demonstrated using a 3-well active region with an air-waveguide, where a peak optical output power of 20 mW was reached. Based on this a 4-well active region was designed and realized to allow higher optical output power and operation temperatures [4]. This led to an increase of the maximum output power to 1.2 W.

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Optically In-Well Pumped VECSEL Emitting Beyond 3 µm

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In this work, the first optically in-well pumped vertical external cavity surface emitting laser (VECSELs) operating in the wavelength range beyond 3 µm is presented. Mid-IR lasers are especially suitable for spectroscopic sensing applications, since the strong fundamental vibration mode of molecules are lying within the mid-IR. Among others, they are used for environmental monitoring, high speed exhaust gas analysis, chemical reaction control and so on [1]. In contrast to all edge emitting diode lasers, VECSELs are attractive for spectroscopic sensing due to their very small beam divergence (<1°) and nearly perfect circular emission cone [2]–[4]. In addition, VECSELS offers power scalability as a result of their nearly vertical heat flow and are generally optically pumped.

The active structure of our VECSEL is formed by 30 periods of PbTe QWs (each 15 nm thick) and CdTe barriers (each 50 nm thick). All layers are deposited by MBE on a GaAs substrate without any further processing. The barrier material is transparent for our 1.55 µm pump laser. Consequently, all pump power is only absorbed in the QWs (in-well pumping). The bottom Bragg mirror of the VECSEL is realized with 4.5 PbEuTe/EuTe layer pairs to reach a reflectivity of more than 99.9%. The resonant laser cavity is completed with an external curved top mirror situated and consists of 2.5 pairs of $Pb_{0.94}Eu_{0.06}Te$ and BaF_2. Such an arrangement contains a free space region permitting optical pumping directly of the active region and vertical laser emission from the chip surface. We measured spectra of the VECSEL at different temperatures. Pumping is done with 100 ns pulses and 10 kHz repetition frequency. The VECSEL is tunable from 3.7 µm down to 3.2 µm by increasing the temperature from 98 K to 203 K. The absorbed threshold pump power is around 13.5 W and the maximal output power is around 5 mW. By optimizing the quantum well position with respect to the intensity distribution of the laser and pump beam we expect to increase the operation temperature up to RT.

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InAlGaN/AlN GaN-HEMTs with In-Situ SiN Passivation

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We present InAlGaN/AlN GaN high electron mobility transistors (HEMTs) with an optimized MOCVD-grown (metal organic chemical vapor deposition) SiN passivation, compared to the standard PECVD (plasma enhanced CVD)-SiN [1]. Passivating the devices effectively reduces electronically active surface states (traps), which can deteriorate the device performance drastically [2]. SiN is grown in the same run (in-situ) as the InAlGaN/AlN/GaN heterostructure, before the actual processing of the device, what enhances the interface quality by avoiding surface contamination before deposition of the passivation. The analyzed GaN HEMTs are processed on SiC substrate with in-situ and PECVD SiN passivation layers of different thicknesses (5 nm in-situ, 30 nm in-situ, no passivation, 30 nm PECVD).

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$In_{0.53}Ga_{0.47}As/GaAs_{0.51}Sb_{0.49}$ Semiconductor Nanowires: Fabrication and Electrical Characterization

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We present recent results on the top-down fabrication and electrical characterization of $In_{0.53}Ga_{0.47}As/GaAs_{0.51}Sb_{0.49}$ semiconductor heterostructure nanowires. This InP-based material system has already been very successfully used for mid-infrared and THz quantum cascade lasers [1],[2]. It offers a low effective electron mass of 0.043 m_0 and a relatively low conduction band offset of 360 meV which makes it ideal for intersubband devices with high optical transition elements and a high tolerance to growth imperfections

The one-dimensional nature of nanowires makes them especially promising for optoelectronic devices using intersubband transitions like THz quantum-cascade lasers, because electron scattering can in principle be strongly reduced by the additional electron confinement in lateral direction, potentially increasing the maximum operating temperature of devices. The fabrication process uses semiconductor heterostructures grown by standard molecular beam epitaxy and incorporates a highly anisotropic reactive ion etching process. In comparison to bottom-up growth schemes this method naturally yields a very good interface quality and each nanowire can be easily exactly positioned.

Further, we present measurements on nanowire resonant tunneling diodes with diameters down to approximately 100 nanometers. A common problem in the fabrication of semiconductor nanowires is that a large density of surface states can deplete the whole structure from charge carriers. We show with simple double-barrier heterostructures, producing a negative differential resistance region in the current-voltage characteristics, that no significant deteriorations are observed from bulk devices to nanowires with diameters down to 100 nm.

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Self-Assembly and Growth of In-Plane, Prism-Shaped SiGe Nanowires on Rib-Patterned Si (001) Substrates

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Heteroepitaxial growth of Stranski-Kranstanow (SK) quantum dots has been extensively studied in the Ge/Si (001) model system, in which elastic strain relief is provided by three-dimensional (3D), nanoscale islands nucleating on a two-dimensional (2D) wetting-layer.

The interplay between strain relaxation and surface energy minimization leads to the well-defined shape evolution from huts to pyramids, domes, and barns, depending on the coverage and growth conditions.

With the exception of huts, these 3D structures have all the fourfold symmetry of the Si(001) substrate. So far, no reports exist on the formation of self-organized, in-plane, one-dimensional (1D) nanostructures of SiGe on Si (001). One way to produce 1D structures is the use of vicinal surfaces [1], in particular Si (1 1 10), a surface that was intensely studied recently [2], [3]. High index substrates, however, limit the application potential because of the lacking compatibility with standard Si technology. Moreover, so far there is not much work described on the site control of such 1D nanostructures.

In this work, in-plane nanowires were produced during the growth of $Si_{0.8}Ge_{0.2}$ onto rib-patterned Si (001) templates oriented along a [010] direction. Atomic force microscopy reveals that initially hut-shaped SiGe islands on the upper (001) area of the ribs form extended nanowires with lengths up to 10 µm via coalescence and self-alignment to the rib direction. Also, the number of parallel nanowires on the rib top can be controlled. Finite element simulations show that these phenomena can be attributed to the minimization of the surface and strain energy density. This method provides a route towards devices based on in-plane SiGe nanowires.

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X-ray Scattering Studies of SiGe Superlattice Interfaces

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High resolution synchrotron X-ray scattering techniques are used to study micro-/nano-fabricated Si/SiGe superlattices intended to demonstrate integrated on-chip harvesting of thermoelectric energy.

The efficiency of thermoelectric materials is improved by enhancing the electrical conductivity while simultaneously blocking the thermal energy transport [1]. Therefore, nanostructures with a large number of interfaces are designed to introduce barriers for phonon transport, in order to efficiently reduce the thermal transport, while maintaining a good electrical transport.

In 2D multilayers both electrical as well as thermal conductivity are influenced (in a different amount) by interface roughness, dislocations, interdiffusion of Ge and Si, as well as point defects accumulated during growth. Both in lateral and vertical transport designs the interface roughness and its correlation plays an important role in the transport characteristics. X-ray reflectivity (XRR) and grazing-incidence small-angle scattering (GISAXS) methods are employed to characterize this interface roughness and also the roughness correlation. The measured reciprocal space maps are fitted with calculated and optimized ones. By this method the total width of the interfaces, the integral r.m.s. roughness, the Hurst parameter and the lateral and vertical correlation lengths of the interfaces are determined [2].

These studies are correlated with transmission electron microscopy (TEM) studies and electrical and thermal transport measurements. The results are used to optimize growth and design of nanostructures tailored for on-chip thermoelectric energy generators.

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Impact of the ALD Process on the Inversion Capacitance in Ge Based MOS Capacitors

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Due to the aggressive down-scaling of the Metal-Oxide-Semiconductor (MOS) structures, the introduction of new substrate materials like Germanium (Ge) is necessary. Despite of the successful realization of Ge-based MOS field-effect transistors and many improvements of MOS capacitors, the reported device performance is still below theoretical predictions. Here, the real origins for this device performance degradation are not yet completely understood. Capacitance-voltage (C-V) measurements are widely used to characterize MOS capacitors. The appearance of "low frequency" behavior (HF) at high measurement frequencies is not unusual on Ge substrates due to a high intrinsic carrier concentration and a short minority carrier response time.

Here, we investigate the impact of the ALD temperature on the electrical properties of ZrO_2/GeO_2/Ge MOS capacitors. The ZrO_2 dielectrics are grown in a 0.3 Torr ambient from a tetrakis(diethylamino)zirconium $Zr(NEt_2)_4$ precursor and water with a thickness of 7 nm at deposition temperatures of 150 °C and 250 °C. A strong impact on the HF capacitance-voltage curve in inversion is found, as the deposition temperature of ZrO_2 is changed from 150 °C to 250 °C. From our electrical measurements, a shortening of the minority carrier response time is observed by increasing the ALD temperature from 150 °C to 250 °C. The activation energies E_A for generation of minority carriers in inversion at -2V is determined by means of an Arrhenius plot. While E_A = 0.7 eV for 150 °C approximately correspond to the Ge band-gap energy, however E_A = 0.4 eV for capacitors processed at 250 °C indicates a minority carrier generation through mid-gap traps. ToF-SIMS measurements are conducted, which indicated a loss of interfacial GeO in case of high ALD temperatures.

This work is funded by the Austrian Science Fund (FWF), project No. P19787-N14. The Gesellschaft für Mikro- und Nanoelektronik (GMe), as well as the Zentrum für Mikro- und Nanostrukturen (ZMNS), are gratefully acknowledged.

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Application of FIB Induced Sb Nanowires Micro Scale pH Sensor

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The usage of pH sensors is of a great importance in a wide range of industries, particularly in the field of medical diagnostics and biological research. There is variety of methods and devices for its measurement, like bulky, fragile glass bulb electrodes or ion-sensitive field-effect transistors (ISFET-s).

With increasing demand of portable biomedical sensing devices, it is crucial to find a solution to make nano/biointegrated sensors for precise pH determination.

Antimony (Sb) as material for pH electrodes has some practical properties, such as remarkable linear response to the H+ concentration in solutions, chemical resistance, ease of fabrication and availability in pure form. It also withstands hydrofluoric (HF) acid and allows reliable determination of the proton concentration in HF-containing solution in which a glass electrode normally cannot be used. These properties make Sb and in particular Sb nanowires due to the large surface area to volume ratio a suitable material for commercial pH electrodes.

Different approaches for synthesis of antimony nanowires have been reported such as pulsed electrodeposition, micro-wave-assisted growth, and Focused Ion Beam (FIB) induced synthesis.

FIB induced synthesis of antimony nanowires about 25 nm in diameter and several µm long was shown at room temperature without using any additional material source.

We present the formation of a microscale pH sensor using this nanowire network as sensing electrode. We formed the CMOS compatible pH sensor combining well known deposition techniques with FIB sputtering.

An Electromagnetically Actuated Orbiting Sphere Viscometer

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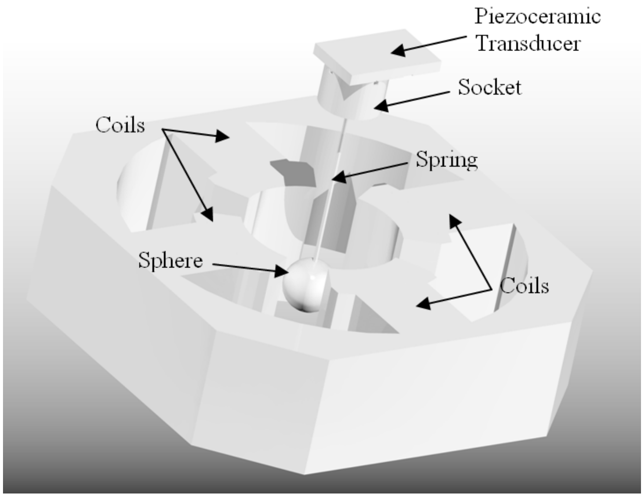
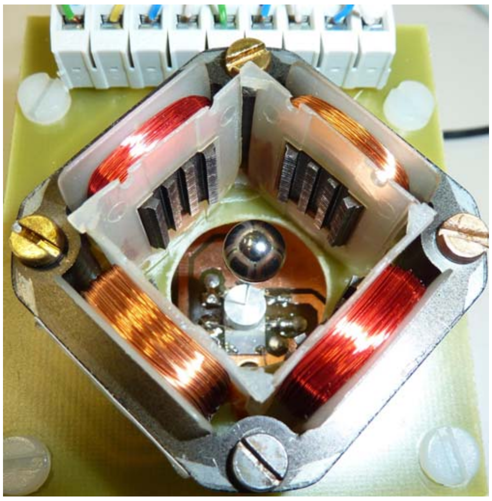
For online monitoring applications involving fluids, the use of miniaturized rheometers or viscosity sensors is near at hand. Miniaturizing classical rheometer principles (such as rotating cylinders or plate-cone arrangements) is often difficult as precision drives and bearings are involved. Oscillating devices have thus been considered which however often vibrate at elevated frequencies such that the probed rheological domain is not comparable to that of established rheometric principles. A simple classical measurement principle is the falling ball viscometer where the motion of a ball (driven by gravitation) through a sample liquid is monitored.

We present a related viscosity sensor principle which uses a circling metal sphere attached to a wire acting as mechanical spring. The circulation is excited electromagnetically using four actuation coils. The arrangement of the coils allows a slow circular motion if they are driven accordingly. The circular motion causes a constant speed of the sphere and thus a stationary flow around the sphere, which allows probing a rheological regime comparable to conventional falling ball viscometers.

The motion of the sphere is measured by four piezoceramic transducers. The spring-wire is mounted using a socket on four PZT's, which are arranged in a square. For better common mode rejection, the voltage of two opposite electrodes is measured differentially using two charge amplifiers and an instrumentation amplifier. The output voltages of the instrumentation amplifiers are used to determine the position of the sphere.



(a)



(b)

Fig. 1: (a) Sensor setup; (b) first prototype of the measurement setup.

Mid-Infrared Optoelectronic Sensors

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Sensor research has experienced an intensive growth in the recent years. As the number of areas of sensor applications is expanding, the challenges for the sensor devices become more complex. Among those challenges are the miniaturization of the sensors, their compatibility to Si-based technology and the integration as single platform devices.

For infrared absorption sensors, a possible approach to these calls is a sensor based on a Si waveguide (WG). A conventional IR-absorption sensor includes three components: a source, an interaction volume and a detector. We are investigating a sensor whose interaction volume is a single-mode Si WG on low refractive index substrate. The single-mode requirement for the WG is needed to avoid losses due to imperfections on the WG walls causing redistribution of the carried energy among the different modes. This consideration prompts WG dimensions of 2 µm width and 600 nm height for an operation wavelength of $\lambda = 5$ µm. The dimensions are verified by 3D simulations using the beam propagation method. For those parameters, the WG will support one transverse electric (TE) mode and one transverse magnetic (TM) mode. The emitter of the electromagnetic field can be a thermal source, which is placed in the plane of the WG. It might be placed also out of the plane of the WG. In this case, the coupling of the emitted electromagnetic field is carried out by a grating coupler on the WG surface. The detector is to be placed at the output of the interaction region between the propagating wave and the sample.

The sensor can be made compatible to the Si technology. In this case it is possible to realize a system as a single platform device.

Droplet and Particle Manipulation in Emulsions and Suspensions Using 3D Electro-Osmotic Micropumps

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This contribution presents investigations on droplet and particle manipulation in microfluidic channels realized in SU-8/glass technology, which is based on a competitive interplay of viscous drag, gravitational, buoyancy and dielectrophoretic forces. The latter are induced by alternating current (AC) driven three-dimensional (3D) stepped electrode arrays in the microfluidic channel, enabling so called 3D AC electro-osmotic pumping. Due to size- and density-dependent differences in polarizability, targeted particles respectively droplets in the fluid stream can be slowed down or even pinned above the electrode structures by adjusting the operation parameters of the pump. Moreover, specific designs of the electrode array at the channel bottom can be used to realize an additional circumferential flow field in addition to the longitudinal transport flow, which in turn can be utilized for particle separation. Hence the presented pump device can be used for simultaneous pumping and manipulation of droplets and particles in emulsions and suspensions.