GMe Forum 2011

Abstracts of the Invited Presentations

Vienna University of Technology
April 14 and 15, 2011

Society for Micro- and Nanoelectronics
Vienna, 2011

Society for Micro- and Nanoelectronics
c/o Institute of Sensor and Actuator Systems
Vienna University of Technology
Gusshausstrasse 27–29/366
A-1040 Vienna, Austria

Thursday, April 14, 2011

10:00 – 10:30	Welcome, Coffee
10:30 – 11:00	Opening
11:00 – 12:00	**Keynote:** O. HÄBERLEN (Infineon Villach): *Power Semiconductors – Key Enablers for Energy Efficiency*
	Organic Thin Film Solar Cells:
12:00 – 12:45	M.C. SCHARBER (Konarka Austria Linz): *Organic Thin Film Solar Cells*
12:45 – 14:00	Lunch Break
	Sensors:
14:00 – 14:45	R. LUCKLUM (Otto-von-Guericke-University Magdeburg): *Merging the Ultrasonic and Acoustic Sensor Principle*
14:45 – 15:30	J. KASBERGER (RECENDT GmbH, Linz): *An Integrated IR-Sensor for Vibrational IR-Spectroscopy*
15:30 – 16:30	Poster Session & Coffee Break
16:30 – 17:15	P. ERTL (AIT, Wien): *LAB-ON-A-CHIP: Applications to Cell Biology*

Friday, April 15, 2011

	Nanostructures and Nanotechnology:
09:30 – 10:15	H. KOSINA (TU Vienna): *Semiconductor Device Modeling: The last 30 Years*
10:15 – 11:00	A. FONTCUBERTA I MORRAL (EPFL Lausanne): *MBE growth of III-V nanowires and related heterostructures – Application to photovoltaics*
11:00 – 11:30	Coffee Break
11:30 – 12:15	J.P. REITHMAIER (University Kassel): *Next generation of quantum dot devices based on tailored nanostructured materials*
12:15 – 13:00	G. SPRINGHOLZ (JKU Linz): *Mid Infrared Active Quantum Dots*

Power Semiconductors – Key Enablers for Energy Efficiency

Dr. Oliver Häberlen

Senior Principal Technology Development
Infineon Technologies Austria AG

The world wide increase in personal wealth and the growing population is continuously driving the energy consumption and consequently the demand for energy. About a third of the global energy used is based on electricity. Currently huge amounts of energy are still lost along the electrical energy supply chain from generation over distribution to final consumption.

We will have a closer look along this energy supply chain and show how modern power semiconductors cut energy losses at every conversion step. This begins with power generation for example from renewable energy sources like solar and wind power. The generated power has to be transformed from DC or variable frequency AC to the constant frequency of the power grid with high quality. It continues with the transmission of the power since generation and consumption are often quite distant. And it ends in the consumer's world where electricity is being used throughout our daily life spanning from all kinds of electrical motors in industry, transportation, home appliances to lighting and finally consumer electronics.

Every of the previous mentioned conversion steps uses its own adapted power electronics topology which in turn requires specific properties of the power semiconductors. It will be shown how IGBT technologies are addressing the needs of high power conversion with variable low frequencies and how progress in semiconductor technology triggers new packaging technologies by continuously increasing power density. The example of a switched mode power supply will finally be used to demonstrate how modern silicon power MOS technologies combined with silicon carbide based devices have tremendously improved the energy efficiency from 60% to well above 90% within the last decade.

Thin Film Organic Solar Cells: Power Plastic Converting Light to Energy – Anywhere

Markus Scharber

Konarka Austria, Altenbergerstrasse 69, 4040 Linz, Austria
www.konarka.com

Achieving efficient solar energy conversion at both large scale and low cost is one of the most important technological challenges for the near future. In this respect solution-processed thin film organic solar cells have gained serious attention during the last few years. Among all the photovoltaic technologies, organic solar cells are outstanding in their potential as a true low cost photovoltaic technology because of their compatibility to conventional, large volume printing and coating processes.

World wide research in organic solar cells has started around 10 years ago. Since then the number of scientific publications is growing exponentially indicating the enormous interest in this technology. In 2006, about 10 % of the scientific publications in the field of photovoltaics reported on organic solar cells. At the same time the performance of organic solar cells was improving gradually from 1 % in the year 2000 to over 8 % in 2011.

Konarka Technologies is leading the development and commercialization of thin film organic solar cells and launched the first solution-processed thin film organic solar cell product in 2009. The company is currently developing large scale production capabilities and is exploring new materials and components for next generation products with improved performance.

In the presentation the basic concepts and advantages of thin film organic solar cells are discussed. Realized and potential applications of thin film organic solar cells will be described and an outlook on the future development of the technology is given.

Merging the Ultrasonic and Microacoustic Sensor Principle

Ralf Lucklum

Institute of Micro and Sensor Systems, Otto-von-Guericke-University, Magdeburg, Germany

Ultrasonic sensors and acoustic (resonant) microsensors are well accepted devices in many application fields. Both principles are based on acoustic wave propagation in a way that the value of interest perturbs wave propagation in a distinct manner. The sensing capabilities of ultrasonic sensors rely on time of flight measurement of an ultrasonic burst traveling through the object of interest. This value can be determined with high accuracy. Similarly, the impressive sensing capabilities of resonant microsensors result from the high Q-factor of the resonator and precise determination of the resonant frequency. Both principles face however, severe limitation in size and integration into microsystems.

Acoustic band gap materials, so-called phononic crystals, provide a new platform for sensing material properties in small cavities. Phononic crystals are periodic composite materials with spatial modulation of acoustically relevant parameters like elasticity, mass density and longitudinal and transverse velocities of elastic waves. Their most exiting feature is the existence of acoustic band gaps, i.e. a frequency range where (ultra)sound cannot propagate through the structure. The sensor concept just recently introduced employs specific transmission windows within the band gap. In this application it is most reasonable that the material of interest constitutes one component of the phononic crystal, e.g., a fluid in the holes of a solid plate. If the value of interest, e.g. the concentration of a contaminant in a liquid mixture, changes its acoustic properties, the acoustic properties of the phononic crystal will change as well.

Transmission or reflection coefficients are appropriate parameters for measurement and used to find a characteristic feature of the phononic crystal. For a sensor application, a transmission peak within the band gap or a transmission dip outside the band gap is the most favorable feature since the respective frequency of maximum/minimum transmission is easy to determine. The sensor scheme therefore relies on the determination of the frequency dependence of maximum/minimum transmission on the physical or chemical value of interest. The transmission peaks can be considered as being based on resonance-like effects, their examination therefore merges basic features of ultrasonic and acoustic microsensors.

Three realizations of the phononic crystal sensor will be introduced. The simplest version is the parallel arrangement of several layers of metal plates and a liquid in between. The transmission properties can be analytically calculated; the results can serve as proof-of-principle. The sensitivity related to those peaks is in the order of macroscopic sensors. Sensors utilizing 2D phononic crystal have been studied in two basic arrangements, with in-plane excitation and detection of waves and an incidence direction perpendicular to the plate. In both realizations a liquid fills all holes of the phononic crystal plate; in the latter case it also covers both surfaces. In the in-plane arrangement specific peaks could be identified which represent changes in liquid properties. When using normal incidence of waves, the extraordinary transmission peak has been found to be strongly dependent on liquid sound velocity. The effect is more robust and the insertion loss of the device is much lower, an important issue from a practical point of view.

An Integrated IR-Sensor for Vibrational IR-Spectroscopy

Jürgen Kasberger

Research Center for Non Destructive Testing GmbH (RECENDT), 4020 Linz, Austria

The monitoring of chemical processes is a growing discipline in almost any fields of chemical industry like, e.g., petro, pharmaceutical or food industry. Even though the characterization of fluids is prevalent in chemistry, there is also a strong demand in other branches of daily live, where, for example, health care is a representative with requirements on minimum sample volume. Within our research, dedicated to process monitoring, one of our major research targets has been the characterization of specified samples by means of a hand-held sensor. Typically, the physical sensor concepts, utilized for integrated sensors, are not very selective in characterizing the chemical composition. Thus, we have been working on a fully integrated IR-absorption sensor able to determine the quantitative concentration of specified liquids by monitoring the spectral IR finger print. Exploiting the advantages of miniaturized sensor as well as the selectivity of spectroscopic measurements leads to a selective and sensitive sensor.

Our sensor is based on the IR absorption in the evanescent field region of an integrated mono-mode waveguide utilizing thermally generated and detected IR radiation. For the coupling into and out of the waveguide, two grating couplers are employed, which couple broadband thermal IR radiation into the waveguide and the attenuated IR radiation towards a thermal IR detector (array), respectively. To achieve a spectroscopic measurement, we utilize the dispersive feature of the grating coupler, which couples the IR beams out of the waveguide at angles depending on the wavelength.

In this contribution, we provide an overview discussing the device design, the associated modeling and the related experimental results.

LAB-ON-A-CHIP: Applications to Cell Biology

Peter Ertl

Department of Health & Environment/ Nano Systems
AIT Austrian Institute of Technology, GmbH, Vienna Austria

Cell cultures and cell-based assays are an essential tool for drug discovery, tissue engineering and stem cell research. Although studying cell cultures has become an essential tool in cell and molecular biology, medicine and biotechnology, it has fallen far behind in the pace of progress as demonstrated by genome sequencing, imaging probes, and high-throughput testing of biochemicals. One major drawback of employing conventional cell cultures is that they do not consider adequate nutrient supply, fluid mechanical shear forces, waste removal, and constant temperature. It is well known that cell responses are profoundly influenced by the cellular microenvironment or biological niche. Additionally using classical cell-based assays, particularly in combination with prevailing screening technologies, employ immortalized cell lines exhibiting phenotypes that differ significantly from those found in human pathology. Consequently, to gain a deeper biological understanding of the complex cellular interactions with their microenvironment, it is necessary to first make progress in experimental devices and analytical methods.

Microfabrication technology has shown potential for providing the next generation of cell analysis tools where large numbers of single cells or small numbers of cell populations can be tested in a cellular environment that better mimics *in vivo* situations. Microfluidic biochips or lab-on-a-chip systems are vital for cell analysis because they allow spatial and temporal control of growth conditions. An important aspect in cell analysis also relates to the ability to investigate dynamic cell responses to changing external parameters. Consequently, to advance cell based *in vitro* methodologies we have developed lab-on-a-chip systems capable of monitoring cellular dynamics continuously and non-invasively in a nanoliter environment under near-native conditions. The Cell-on-Chip system comprises of external pumping and heating stations, valves, injection ports and the microfluidic biochip containing embedded optical and electrical microsensors. The presented work addresses aspects of chip design and sensor characterization as well as their applications to cell biology including nanotoxicology, tumor invasion studies and personalized medicine. The presented technology could, therefore, provide medicine with a diagnostic tool exhibiting better sensitivity, specificity and reliability.

Semiconductor Device Modeling: The Last 30 Years

Hans Kosina

Institute for Microelectronics, TU Vienna

Numerical simulation of semiconductor devices has evolved to a wide and viable research field over more than three decades. The various subjects considered reflect the tremendous progress in semiconductor technology. The term Technology CAD (TCAD) has been coined to describe classical device simulation, which is based on continuum theory and classical transport theory. By solving the continuity equations for electrons and holes self-consistently with the Poisson equation for the electrostatic potential, the operation of various unipolar and bipolar devices can be well understood, both qualitatively and quantitatively]. The main drivers for TCAD tool development were silicon integrated circuit technology and silicon power devices. According to the scaling rules of CMOS technology, the doping levels and the electric field strengths in the junctions were continuously increased, which eventually resulted in reliability problems due to hot carriers. To study hot carrier effects theoretically, end of the 1980s Monte Carlo simulation including a numerically tabulated electronic band structure has been introduced. The Monte Carlo method solves the classical Boltzmann equation for the charge carriers and is often considered a reference method for the simpler transport models used in TCAD. The continuous reduction of the supply voltage below three Volts, however, alleviated the hot carrier problem significantly. With the advent of strain engineering in the 1990s the electronic band structure was intentionally distorted by imposing appropriate strain conditions. Full-band Monte Carlo calculations helped to quantify the effect of the band structure changes on the electronic transport properties. For the classical TCAD tools new mobility models have been developed taking the strain dependence into account. With continued down-scaling of the oxide thickness the classical TCAD tools needed to be augmented by quantum correction models which approximate the quantum mechanical charge distribution in the channel. Besides silicon main stream technology, a variety of new semiconductor nano-structures and nano-devices came into the focus of device simulation, but also a variety of new materials. Examples are carbon nano-tubes, graphene, and organic semiconductors, to name a few. Device modeling has entered the field of mesoscopic physics, where quantum mechanical effects such as confinement, tunneling, interference and charging effects determine the characteristics of a device. This extended field of research is commonly referred to as Computational Electronics. Mesoscopic physics still uses concepts from continuum theory, such as band structure, band diagrams, and envelope functions which are wave functions where the lattice-periodic part has been factored out. At the small end of mesoscopic structures the tight-binding method is often used, which is an empirical atomistic method for electronic structure calculation. Specific problems need to be considered on an atomistic level and require so-called *ab initio* methods. An example is the degradation of gate insulators, where *ab initio* calculations give insight into the type of field-induced defects and their kinetics. Another important subject of device modeling deals with electrical devices coupled to some non-electric system, as it is the case for optoelectronic devices, including various types of semiconductor lasers, or thermoelectric devices, but also MEMS and sensor devices for various applications. In summary, it can be concluded that device modeling has evolved to a wide multidisciplinary field. Numerical mathematics, computer science, and various fields from physics such as solid state physics, quantum mechanics, and statistical mechanics, are closely interlinked. Today, Computational Electronics provides a multitude of approaches and tools to cope with the ever increasing number of new semiconductor devices and structures, and the new materials being introduced.

MBE Growth of III-V Nanowires and Related Heterostructures – Application to Photovoltaics

A. Fontcuberta i Morral

Ecole Polytechnique Fédérale de Lausanne (EPFL), Switzerland

Nanowires are filamentary crystals with a diameter of few to a hundred of nanometers. Thanks to their dimensions they are the perfect playground for fundamental studies and for improving devices such as solar cells. Nanowires are typically obtained by the vapor-liquid-solid method in which a metal catalyst is used for the gathering of the precursor species and nanowire growth. In most of the cases gold is used, though it has been shown to affect negatively the electronic and optical properties of semiconductors. We obtain ultra-high purity GaAs nanowires by avoiding the use of gold and by the use of molecular beam epitaxy (MBE). MBE offers also the unique possibility of combining an extremely high purity of materials with the possibility of growing with epitaxial quality on the nanowire facets. Prismatic quantum wells and Stranski-Krastanov quantum dots are obtained with a very high quality, as demonstrated by the optical spectroscopy measurements. Finally, we discuss how these nanowires are excellent candidates for the fabrication of solar cells and high mobility transistors by using a modulation doped structure.

Next Generation of Quantum Dot Devices Based on Tailored Nanostructured Materials

Johann Peter Reithmaier

Technische Physik, Institute of Nanostructure Technologies and Analytics (INA), University of Kassel, 34132 Kassel, Germany

By nano-structuring of semiconductors, the macroscopic material properties can be directly controlled by the geometric dimensions of the nano-objects rather than by the chemical composition. However, by using the most commonly applied Stranski-Krastanov growth mode the control of the quantum dot geometry in most cases is suffering by size fluctuations and the statistical distribution of nucleation sites.

This presentation gives an overview about our recent work on developing improved and new growth processes for quantum dot materials, exhibiting an enhanced degree of freedom for tailoring the material properties for specific optoelectronic device applications.

Improvements obtained in quantum dot growth techniques will be discussed in different quantum dot material systems (GaAs and InP based) and by using different growth techniques, like Stranski-Krastanov growth mode, droplet epitaxy and growth on pre-patterned surfaces. Device examples will be given, where this new generation of quantum dot material is used to tailor specific devices properties. This includes, e.g., 920 nm cooler-less high power pump modules based on quantum dot laser arrays with internal temperature compensation, 1060 nm high brightness single mode lasers for frequency doubling based on a tunneling injection design, and new generation of high-gain InP quantum dot material for high-speed lasers and optical amplifiers.

Finally, an outlook will be given on the potential of tailored quantum dot material to realize ultra-fast optoelectronic devices approaching the THz frequency regime.

Mid-Infrared Active Quantum Dots

G. Springholz

Institute of Semiconductor Physics, University of Linz, Austria

In spite of extensive research, mid-infrared emission from self-assembled semiconductor quantum dots produced by the usual heteroepitaxial Stranski-Krastnow growth has remained elusive due to the unfavorable type II band alignments of most narrow band gap material systems. In this talk, I will present an alternative synthesis approach, based on epitaxial PbTe quantum dots (QDs) embedded in a wide band gap CdTe matrix. These materials are practically strain free due to the almost perfect lattice matching but exhibit a huge quantum confinement due to the very large 1.2 eV difference in the band gaps. Our synthesis approach is based on phase separation rather than on lattice-mismatch strain and is driven by the large miscibility gap between IV-VI and II-VI materials due to the difference in lattice structure. As a result, in epitaxial structures phase separation occurs at elevated temperatures, resulting in the formation of well isolated, nearly spherically and wetting-layer free PbTe quantum dots with atomically abrupt interfaces. The quantum dots exhibit intense mid-infrared emission even at room temperature and the dot size can be varied over a wide range by changing the deposited layer thickness or composition or by variation of the growth temperature. Due to the large quantum confinement, mid-infrared emission can be tuned over the whole 1.5 – 4 µm wavelength region. Application of these quantum dots in the form of MID LEDs and microdisk lasers is demonstrated, where the latter represent the first quantum dot lasers emitting at wavelengths longer than 1.6 µm. Potential applications of such devices are in molecular gas analysis, environmental monitoring and medical diagnostics.