

# Nano-scaled Dielectric Barriers (NanoDieB) for CMOS compatible Si-technologies

Dieter Schmeißer<sup>1</sup>, Götz Seibold<sup>2</sup>, Jürgen Reif<sup>3</sup>

<sup>1</sup> Lehrstuhl Angewandte Physik-Sensorik

<sup>2</sup> Juniorprofessur Physik komplexer Systeme

<sup>3</sup> Lehrstuhl Experimentalphysik/Materialwissenschaften

## Kurzfassung

Die Integration von neuartigen nanostrukturierten Materialien und Strukturen mit Größen unterhalb von 10 nm in Silizium-basierten CMOS Technologien ist international ein aktuelles Forschungsthema. Diese Thematik wird auch von einem Team von naturwissenschaftlichen Arbeitsgruppen an der BTU Cottbus bearbeitet. Diese Materialklassen werden mit interdisziplinären Anstrengungen in der Präparation, Charakterisierung und Theorie untersucht. Unser Augenmerk liegt auf neuartigen dielektrischen Barrieren, Nano-Kristall-Wachstum und Selbstorganisation von Nanostrukturen auf Silizium. Elektronische und magnetische Eigenschaften stehen im Fokus des wissenschaftlichen Interesses. Diese Themenstellung ist momentan zwar in Grundlagenbereich angesiedelt, bietet auch eine Grundlage für industrielle Kooperationen.

## Abstract

The challenge of integrating advanced nano-scaled (dimensions < 10 nm) materials and structures into silicon based CMOS technologies is addressed in a joint research activity at the BTU Cottbus. Such complex materials are developed by highly interdisciplinary efforts in preparation, characterization, and theory. We focus on novel dielectric barrier systems, nano-whisker growth, and self-organization of nanostructures on silicon. Electronic and magnetic properties address important scientific and technological goals.

## Introduction

Nano-scaled materials are a very active field of research driven by the demands of Si-technology and initiated by the ever shrinking dimensions in both, logic and memory devices. In particular, while the success of the existing technologies is based on the excellent performance of SiO<sub>2</sub> as a gate insulator material, in coming technologies it should be replaced by materials with even better dielectric properties. As a consequence increasing research on alternative materials has been strengthened in the last years [1, 2]. Those materials include Si-based oxynitrides, Aluminum-oxides, and rare earth based oxides.

However, preparation and implementation of such hetero-materials means extraordinarily high demands for materials science, considering the requirement that the material bulk properties are supposed to be maintained even when being processed on a nanometer scale. This is exactly the challenge for our research. On the one hand these materials require special preparation procedures, on the other hand they have to be thoroughly examined for their physical characteristics. We work to establish novel relevant technology steps to create ultrathin films of such materials as dielectric barriers, find the stability conditions of hetero-phases, and learn about combined mechanical and electrical qualities. Our attempt is to establish novel materials used as storage and logic devices. For the design of such ultrathin films, a particular challenge is the question whether it is possible to maintain their physical properties known from bulk material. This is non trivial. For example, magnetic properties are known to vary with film thickness.

In another attempt we include nano-particles into the dielectric barriers. We focus on the theoretical and experimental properties of individual nano-particles as well as larger arrays of them forming „nano-materials“. Here, the project goals range from production of isolated nano-particles to the analysis of quantum-confinement-structures as well as their self-organization and their periodic assembling on silicon surfaces. Such studies include also the fabrication and characterization of nano-structures such as whiskers and nano wires. Finally, we want to implement the possibility of transiently changing the dielectric properties on a very short dynamic time scale by applying external optical or magnetic fields. Our analytical tools focus on the electrical and mechanical characteristics of these possible new materials. In addition we test, evaluate and calibrate sophisticated spectroscopic methods.

The core competences of the working groups provide solid experiences for a fundamental examination and characterization of functional and non-metallic materials. The joint effort now focuses on oxidic heterosystems including nano-scaled films and particles for future devices. These are hot topics in the area of nano-electronics with the idea to implement novel materials with fascinating properties in nano-electronic and information technologies [1-3].

## Details of the research program

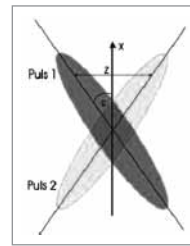
The *transient modification/modulation of the Dielectric Constant* in thin dielectric layers is one of the research projects.

Considering the ever increasing switching speed in electronic devices, on the one hand, and the tendency of implementing optical signal transmission even on the device level, on the other hand, it appears quite attractive to find a way of directly performing – or, at least, triggering – the switching act in a CMOS device by a very short optical pulse. The attraction should be twofold: the direct integration of the optical pulse in the switching mechanism would render unnecessary the use of a detection/conversion element and, second, the possibility of using ultrashort light pulses in the sub-picosecond range might give access to corresponding switching times, orders of magnitude shorter than the application of a gate voltage pulse, presently.

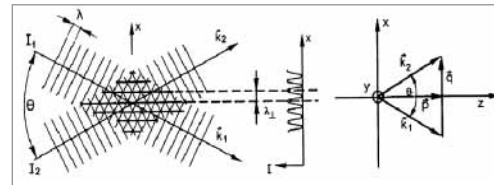
This partial project is aimed to investigate such an approach. It is based on the idea that the switching, i.e. the providing of a sufficient carrier density in the channel between source and drain, is not accomplished by applying an appropriate gate voltage but, instead, by transiently modifying the gate dielectric constant (and/or even the carrier mobility in the channel) by an optical pulse.

The dielectric constant of an insulator can easily be derived from the polarization of the material under the presence of an electric field. In general, the responsible polarizability is a material constant. Correctly speaking, however, this is only true as long as the material response may be considered as harmonic. When the electric field becomes sufficiently large, this assumption is no longer justified: the response becomes anharmonic and can be approximated by a power series in terms of the electric field. Consequently, the polarization contains terms which do longer depend linearly on the field. This can, in turn, be expressed by field-dependent contributions to the polarizability [4, 5]. For optical fields, this situation corresponds to a light-intensity-dependent contribution to the refractive index  $n$ , e.g. the domain of nonlinear optics and multiphoton processes.

In recent experiments [5-12], we have demonstrated that, indeed, it is possible to transiently modify the refractive index substantially – and thus  $k$  – of a dielectric by tightly focusing femtosecond laser pulses at rather moderate energy density of  $\approx 10 \text{ mJ/cm}^2$ , corresponding to an energy of less than a nJ. This is well below the threshold for permanent material modification, even after a very large number of laser pulses. Further, we have shown that the response time is at the order of one optical cycle, i.e.  $\approx 1 \text{ fs}$ , if the optical wavelength is far from a resonance in the dielectric. In particular, applying two overlapping, non-collinear laser pulses, we were able to induce a transient phase grating by transforming the interference pattern into a corresponding index modulation. In these experiments, monitoring for instance the duration of a pulse deflected by this grating, we confirmed the instantaneous, transient nature of the refractive index modification, with a response time at the order of 1 fs [13, 14]. So far, all experiments have been conducted in bulk dielectric materials.



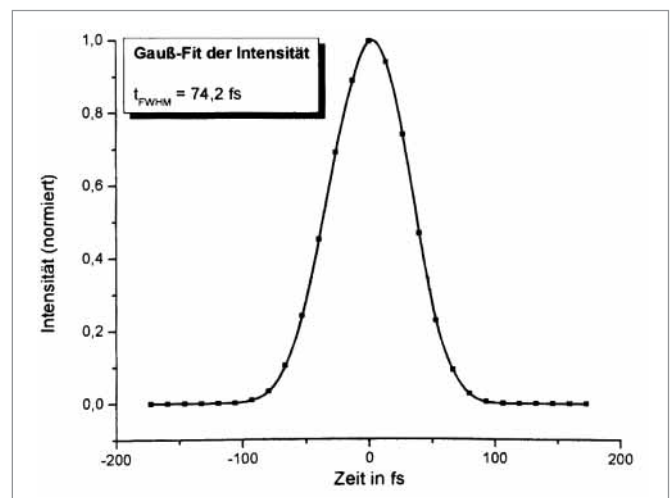
**Figure 1:**  
Schematic of two overlapping ultrashort laser pulses [14]



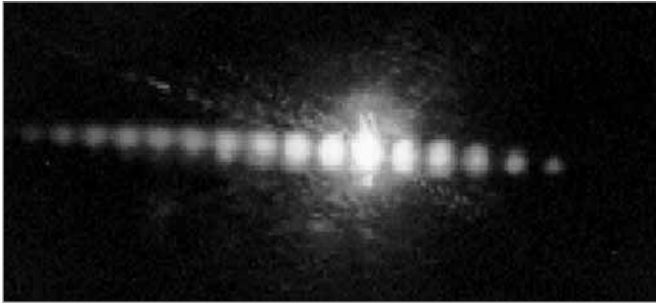
**Figure 2:**  
Resulting Interference pattern [14]

The goal of the present proposal is the transfer of this transient index- (and thus  $k$ -) modification to thin dielectric films, in particular on Si-substrate. Further, the effect of such modified dielectric films has to be explored. In particular, the question has to be addressed whether there is, indeed, an electrically exploitable effect. The role of the dielectric-Si interface, e.g. optical reflection but also seed of Si-photoelectrons into the dielectric, must be studied as well as the possibility of photo-induced permanent material modifications such as interface diffusion.

The possibility of reducing the physical size of the modified area from the optical diffraction limit of  $\approx 1 \mu\text{m}$  to CMOS-relevant 100 nm is another topic to be addressed. Here, the solution could be based on the non-linearity of the light-induced index modification: since it relies on the optical Kerr effect, a third-order non-linearity proportional to the third power of the input intensity, the interaction might be concentrated to only the central part of the incident light spatial profile, a Gaussian. The influence of a larger scale periodic index-modification due to multi-beam interference – similar to that observed in the experiments on dielectric bulk crystals – will constitute a further topic of research. Finally, the question will be tackled of how to integrate future Si-based „internal“ light sources into the scheme.



**Figure 3:**  
Duration of the index modification [14]



**Figure 4:**  
Diffraction pattern of a blue beam from the transient grating

Magnetic nano-particles embedded into oxidic barriers offer a novel access to combine magnetic and electronic properties for future applications in spintronic. These magnetic centers are ideally suited for candidates in spin-injection devices and ternary logic. The physical understanding of these nanoscaled objects is the main barrier to overcome before applications in CMOS technology are possible. This new degree of freedom based on the spin of the stored electrons leads to fantastic new possibilities in storage devices apart from recent flash-memories.

The possibilities to integrate small scaled magnetic objects into circuits for industrial applications lead to a tremendous scientific gold-rush in recent times. A lot of groups are working on these nano-magnets to understand the basics behind spin-behavior and they found giant magnetic moments induced from the small metals [15, 16]. This pioneering work has one major drawback it is often limited to exclusive substrates or preparation procedures [17], not suitable for later industrial applications.

In the last years, we have worked on the formation of ordered metal-containing nanostructures in different geometries with sizes below 10 nm [18-20]. By using a self assembling approach of block copolymers on silicon based substrates, several geometries have been developed and successfully characterized [21]. Nanorods and wires of metallic Nickel, Chromium, Titanium and their oxides such as NiO, Cr<sub>2</sub>O<sub>3</sub> and CrO<sub>2</sub> and TiO<sub>2</sub> have been fabricated and investigated.

One mile stone for the integration of magnetic metals into silicon technologies is the availability of ferromagnetism even at room temperature. This goal is hard to reach, because only very few semiconductor materials compatible with silicon are proposed to have ferromagnetic properties around 20 °C when doped with magnetic metals [22]. Among the few there is Cobalt doped ZnO, and we have recently established that there is indeed ferromagnetism at RT [23].

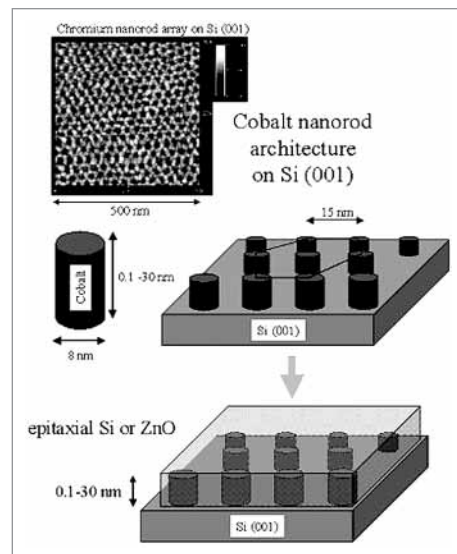
Another possible candidate to exhibit ferromagnetic properties at room temperature when doped with Cobalt is Cerium-oxide. This rare earth element is found to have giant magnetic moments with high dielectric constants ideally suited for industrial applications [24-27].

The studies to be performed in near future here at BTU will follow two different approaches. In a first part, the proposed project focuses on the fabrication and characterization of semiconducting nanoparticles using polymeric templates. Nanoparticles are periodically arranged and

will be deposited on Si(001) surfaces. After deposition (and removal of the template) an protective oxide layer (SiO<sub>2</sub>, ZnO) is deposited. In the second part we focus on ultra-thin dielectric layers of rare earth oxides on Si(001). We dope these films by Co in the range (1%-10%) for which in thicker layers ferromagnetism has been observed.

In a systematic architecture we build arrays of Cobalt nanoparticles onto Si(001). We use Co nanorods with a defined diameter of 8 nm and deposit them by electrochemical deposition through a polymer template. The deposited nanoparticles are arranged in a hexagonal supercell and the nanoparticle-nanoparticle distance is 15 nm. With this procedure [21] silicon substrates and other can be covered with regular metallic nanoparticles over length scales to several centimeters, what corresponds to the size of Si(001) wafers, used for industrial applications. Up to this step, preparation is done under ambient conditions.

After removing the template by solvents, the space between the nanoparticles is filled by some protective oxidic layer in vacuum systems. We will select SiO<sub>2</sub> (Silicon deposition followed by oxidation in N<sub>2</sub>O) because its ease of handling and compatibility to Si technology. Thereby an ordered nanoparticle array with well defined/narrow size distribution is obtained in an oxidic matrix. In Fig. 5 we have displayed the corresponding AFM image of an as-prepared array of free standing Chromium nanorods on Si(001) surfaces.



**Figure 5:**  
Sketch for fabricating magnetic semiconductor compounds with Cobalt nano particles. An AFM image of a Chromium nanorod array on Si(001) is shown on top.

The magnetic moments and electronic properties of these compounds are investigated with special emphasis on the SiO<sub>2</sub> layer thickness and nanoparticle height. A challenge is the understanding of magnetic coupling between Co and SiO<sub>2</sub> and the Co-Co particle distance, feasible with the approach described above.

Long term visions include:

- the large scale preparation on Si-substrates
- discussion of coupled spin systems on Si surfaces
- the spin injection via nano-Schottky-barriers
- to vary the diameter of nanorods down to 1 nm.

In diluted magnetic dielectrics Cobalt is used as a dopant in dielectric thin films on Si(001). We benefit from our experience in preparing high- $k$  dielectric layers on Si(001). Spectroscopic investigations concern the Co oxidation state as to be determined from the satellite peaks in the Co2p core level spectra. In XAS measurements we determine the site of the Co ion by its characteristic pattern of the crystal field splitting. The magnetic properties will be determined by measurements of the linear and circular dichroism.

We focus on Cerioxide layers as the dielectric. This is because of the recent report on the huge magnetic moments and high Curie temperatures and we will start to reproduce these properties in an ultra-thin film of CeO<sub>2</sub> prepared in UHV on Si substrates. The second year is planned for the characterization of the magnetic properties of the Co doped Cer-oxide thin films and to correlate the magnetic moments with the dielectric behavior.

Long term vision:

- Establish ferromagnetism in ultra-thin layers on Si substrates.
- Find out size of the magnetic moments compared to known values for Co:ZnO PLD films.
- Find possible limitation which could hinder an implementation in Si technology.
- Establish and prove the high spin moments reported for Co:CeO<sub>2</sub>.

Beside the preparation of the ferromagnetic layers on Si substrates special notice will be devoted to their spectroscopic characterization:

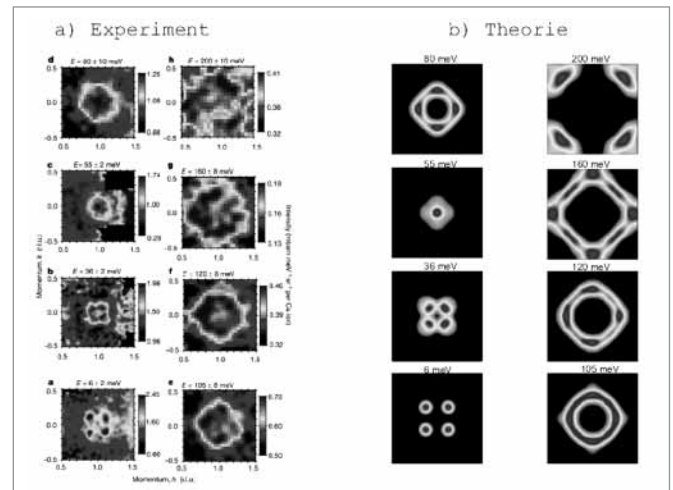
Our group is specialized in photoelectron spectroscopy with synchrotron radiation on functional surfaces and interfaces. We have several UHV systems in the lab and, in addition, use the BTU owned beamline U49/2 PGM 2 at BESSY which delivers linearly polarized synchrotron radiation covering the energy range from 80-1500 eV. It is ideally suited to perform bulk and surface sensitive XPS measurements for materials research as most of the core level and absorption edges are accessible in that energy range. It has ideal conditions to evaluate the chemical state like the oxidation or the interface interactions of the materials mentioned above.

It should be mentioned that the magnetic moments can be determined quantitatively by XMCD. Because of the small film thickness, i.e. the total volume of the magnetic layer is very small, the standard magnetization method via SQUID can not be used for such measurements. Insofar, the spectroscopic characterization is currently the only technique to characterize the magnetic and electronic properties of our ultra-thin films. The use of a XMLD/XMCD system for room temperature studies is reasonable as we deal with the application of systems which have a Curie temperature above 300 K. This means that the data are not influenced by paramagnetic centers as their temperature dependent contribution according to the Brillouin function is significant only at temperatures below 100 K [28, 29].

In a close collaboration the *theoretical description of isolated magnetic nanoparticles* is addressed. Here we are concerned with various aspects of individual magnetic nanoparticles which are prepared and analyzed by the respective experimental groups. Especially we want to investigate the magnetic properties of chromium oxide nanoparti-

cles which as a bulk material is a ferromagnetic half-metal. Magnetism in the bulk is due to double-exchange, i.e. a Hund coupling between localized  $d_{xy}$  states below  $E_F$  and a hybridized  $d_{yz}z^2 - O_{2p}$  band crossing  $E_F$ , which can be modeled by a two-orbital Hubbard model. Due to the importance of correlation effects we are planning to use a slave-boson representation of the Hamiltonian where dynamic properties can be obtained within an expansion of the boson fields up to quadratic order. During the last years, we have developed and well-elaborated this technique [30, 31] which has proven to give a very good description of the static and dynamic properties of inhomogeneous electronic states in cuprate high- $T_c$  superconductors [32-34]. As an example, we show in Fig. 6 the magnetic excitation spectra in LBCO measured with inelastic neutron scattering [35] and our computations within the time-dependent Gutzwiller approximation [34]. We find excellent agreement with respect to both energy and momentum dependency of magnetic excitations which are calculated for a striped electronic ground state.

Recently we have also applied this scheme to the investigation of ferromagnetism in Hubbard-type models [36] where it turned out to be comparable with exact techniques.



**Figure 6:**

*Magnetic excitations in the LBCO superconductor at doping  $x=1/8$ . The left panel shows the experimentally determined spin fluctuations in the magnetic Brillouin zone at selected energies (from Ref. [35]). The right panel displays the theoretical spectra at the same energies calculated from a stripe model.*

In connection with the applied project, the questions to be asked are: How does magnetism in this model evolve upon reducing the system size, i.e. when the surface to bulk ratio increases? What are the consequences of the discreteness of energy levels on collective excitations (spectrum and lifetime) in small double exchange systems? The microscopic calculation can also serve for a determination of parameters for additional micromagnetic calculations of nanoparticles within the Landau-Lifschitz Gilbert model. The latter approach is used for the determination of magnetization reversal processes dependent on shape and size of the nanoparticles. Furthermore, since the nanoparticles under considerations are embedded in polymer materials, we have to ask whether the coupling to the environment is relevant for a proper description of irreversibility and relaxation processes.

Finally it should be mentioned that there are still some further group contributing to the research initiative on nanoscaled dielectric barriers. One team is from the IHP-microelectronics (FFO) dealing with the epitaxial growth of Praseodymium-oxide layers on Si substrates. The advantage of epitaxial films is in their structural stabilities. Another group is from theory department and deals with transport mechanisms in nanostructured devices.

Further activities around the research initiative deal with the formation of nanoscaled structures in Silicon surfaces by employing self organization mechanisms. This is a rather new development which involves experimental and theoretical studies. The goal is to achieve nanostructured Si surfaces with feature size below 10 nm. This method then is thought to be an elegant alternative for nanostructuring of device features instead of using the expensive nano-lithography used nowadays.

## Summary and perspectives

Dielectric barrier systems for Si-based CMOS technology are in the focus of replacing the traditional high-quality Si-SiO<sub>2</sub> interface by material alternatives. The International Technology Roadmap for Semiconductors [37] addresses the demand for the search of high-*k* dielectrics which enable lower leakage currents (reduced tunneling currents) of the gate insulator. Among the candidates currently under contention, rare earth oxides are attractive due to their high thermodynamic stability and their usually large conduction band offsets. Specifically promising are oxides such as Pr<sub>2</sub>O<sub>3</sub> and HfO<sub>2</sub> as inferred from our long term experience. We optimize the preparation conditions in order to reduce lattice mismatch, interface state densities and increase the dielectric properties while aggressively reducing the thickness.

Research on modification of oxidic barriers in order to introduce novel physical phenomena like the spin moments of incorporated transition metals for spintronic applications contributes to the long term technological tasks. The working groups and partners in this cooperation are organized so that they are complementary to each other and perfectly accomplish the experimental and theoretical methods and techniques. Because of this, the expertise spans from structural properties to mechanical, electronic, thermal, electrical and chemical properties and includes even transient material modification on a fsec time scale.

Another particular activity of the BTU is in the collaboration with the BESSY synchrotron source. The equipment which is operated by both partners is dedicated for analytical spectroscopy and microscopy in the study of semiconductor interfaces and reactions. The spectroscopic characterization represents an outstanding contribution in which we test, develop, validate and apply analytic methods based on fsec laser spectroscopy and synchrotron radiation based X-ray spectroscopies. Both groups provide highly sensitive elemental, structural, and chemical analyses. Although such techniques are far from becoming routine methods in CMOS technologies, they yield excellent information for the implementation of nano structured materials as their information depth is matching the nano scale of the materials. In addition, a series of conventional testing equipments such as the scanning atomic force

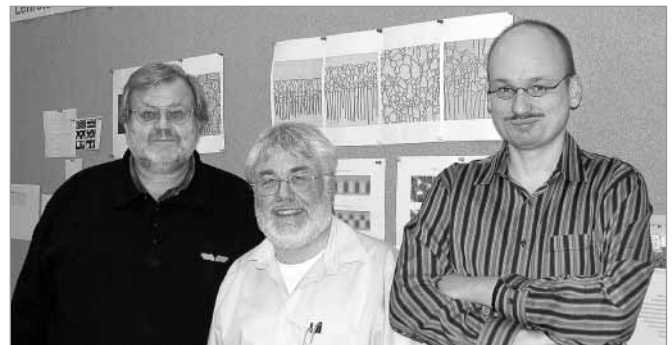
and Kelvin-AFM microprobes will be essential because of their ability to image nano scaled structures with high resolution.

We are proud to have a close collaboration with theoretical groups to enable both, materials modeling and ab-initio calculations of selected properties. The theoretical activities may be separated in two groups concerning the properties of nanoparticles and the transport mechanisms in nano scaled systems. In the former group topics include the origin and coupling of magnetic moments and the description of non linear and dynamic coupling in self organization mechanism. The ballistic transport properties are the focus of the latter group which is applied to CMOS compatible quantum barrier system.

## References

- [1] **WASER, R. (HRSG), 2003:** Nanoelectronics and Information Technology-Advanced Electronic Materials and Novel Devices. WileyVCH, Weinheim, ISBN 3-527-40363-9.
- [2] **LURYI, XU AND ZASLAVSKY, 2004:** Future Trends in Microelectronics – The Nano Millennium, Wiley & Sons Inc.
- [3] **ZSCHECH, WHELAN, MIKOLAJICK (EDS.), 2005:** Materials for Information Technology, Devices, Interconnects and Packaging”, Series: Engineering Materials and Processes, Springer.
- [4] **MARRÉ, D.; TUMINO, A.; BELLINGERI, E.; PALLECCHI, I.; PELLEGRINO, L. AND SIRI, A. S.; (2003):** Strontium titanate resistance modulation by ferroelectric field effect; J.Phys.D: Appl.Phys.36 896–900.
- [5] **SCHNEIDER, T.; WOLFFRAMM, D.; MITZNER, R.; REIF, J.; (1999):** Ultrafast optical switching by instantaneous laser-induced grating formation and self-diffraction in barium fluoride; Appl.Phys.B 68, S.749-751.
- [6] **SCHNEIDER, T.; WOLFFRAMM, D.; REIF, J.; (1999):** Highly Efficient, Ultrafast Laser Beam Manipulation by Laser Induced Index Grating in Barium Fluoride; in: P. E. Andersen, P. M. Johansen, H. C. Pedersen, P. M. Petersen, M. Saffman, eds.: Advances in Photo-refractive Materials, Effects, and Devices; OSA Tops 27, S. 306
- [7] **SCHNEIDER, T.; WOLFFRAMM, D.; MITZNER, R.; REIF, J.; (1999):** Ultrafast Transient Grating in Barium Fluoride; p.145 in: G. Leuchs et al., eds.: Novel Lasers and Devices. Basic Aspects; OSA Technical Digest
- [8] **SCHNEIDER, T.; WOLFFRAMM, D.; REIF, J.; (2000):** Ultrafast laser-induced index grating in transparent insulators; Nucl.Instr.Meth.B S.166-167, S.809-814.
- [9] **SCHMID, R. P.; SCHNEIDER, T.; REIF, J.; ULTRAFAST TRANSIENT GRATING IN BARIUM FLUORIDE (2001):** Efficient Instantaneous Optical Switching, Frequency Conversion and Simple Logic Operations on a Femtosecond Time Scale, in: Ultrafast Electronics and Optoelectronics, Y-K. Chen, Wayne Knox, and Mark Rodwell, eds., OSA Trends in Optics and Photonics 49 S. 111.
- [10] **SCHNEIDER, T.; REIF, J.; (2002):** Influence of an ultrafast transient refractive index grating on nonlinear optical phenomena; Phys.Rev.A 65, 023801.
- [11] **SCHMID, R. P.; SCHNEIDER, T.; REIF, J.; (2002):** Femtosecond All-optical Wavelength- and Time-Demultiplexer for OTDM/WDM Systems; Appl.Phys.B 74, S.205.

- [12] SCHMID, R. P.; SCHNEIDER, T.; REIF, J.; (2002): Optical Processing on a Femtosecond Time Scale; Opt.Comm.207, S. 155-160.
- [13] FAHR, M.; (2004): „Optische Frequenzverdrehung an einem transienten Brechungsindexgitter“, Diplomarbeit BTU Cottbus (LS Experimentalphysik II).
- [14] HÄNEL, M.; (2006): Diplomarbeit BTU Cottbus (LS Experimentalphysik II).
- [15] GAMBARDILLA, P.; (2003): Giant magnetic anisotropy of single cobalt atoms and nanoparticles, et al. Science 300, 1130.
- [16] GETZLAFF, M.; BANSMANN, J.; BULUT, F.; GEBHARDT, R. K.; KLEIBERT, A. AND MEIWES-BROER, K.-H.; 2006: Appl.Phys. A, (82) 95; J. Bansmann and A. Kleibert (2005), Appl.Phys. A 80 957., Structure, composition and magnetic properties of size-selected FeCo alloy clusters on surfaces
- [17] WIEDWALD, U.; CERCHEZ, M.; FARLE, M.; FAUTH, K.; SCHÜTZ, G.; ZÜRN, K.; BOYEN, H. G.; ZIEMANN, P.; (2004): Effective exchange in quasi two-dimensional self-assembled nanoparticle array, Phys. Rev. B 70, 214412.
- [18] SEIFARTH, O.; 2006: Properties of Chromium, Cobalt and Nickel Nanoparticles embedded into ordered block copolymers and conducting polymers, Phd Thesis, BTU Cottbus.
- [19] SEIFARTH, O.; KRENEK, R.; TOKAREV, I.; BURKOV, Y.; SIDORENKO, A.; MINKO, S.; STAMM, M.; SCHMEIBER, D.: Thin Solid Films, accepted. Metallic Nickel Nanorod Arrays Embedded into Ordered Block Copolymer Templates,
- [20] SEIFARTH, O.; SCHMEIBER, D.; KRENEK, R.; SIDORENKO, A.; STAMM, M.; (2006): Electron Spectroscopy and Microscopy on Chromium Oxide Nanowires on Templated Block Copolymers, Progress in Solid State Chemistry 34, S. 111.
- [21] TOKAREV, I.; KRENEK, R.; BURKOV, Y.; SCHMEISSER, D.; SIDORENKO, A.; MINKO, S.; STAMM, M.; 2005: Microphase Separation in Thin Films of Poly(styrene-block-4-Vinylpyridine) Copolymer-2-(4'-Hydroxybenzeneazo)benzoic Acid Assembly, Macromolecules, (38) 507-516.
- [22] DIETL, T. OHNO, H. MATSUKURA, F. CIBERT, J. AND FERRAND, D.; (2001): Zener Model Description of Ferromagnetism in Zinc-Blende Magnetic Semiconductors, Science 287, 1019.
- [23] NIELSEN, K.-W.; BAUER, S.; GOENNENWEIN, S. T. B.; OPEL, M.; GROSS, R.; CEZAR, J. C.; SCHMEIBER, D.: Room-Temperature Ferromagnetism in Cobalt-Doped ZnO Detected by X-ray Magnetic Circular Dichroism, APL, submitted.
- [24] TIWARI, A.; BHOSLE, V. M.; RAMACHANDRAN, S.; SUDHAKAR, N.; NARAYAN, J.; BUDAK, S. AND GUPTA, A.; (2006): Ferromagnetism in Co doped CeO<sub>2</sub>: Observation of a Giant Magnetic Moment with a High Curie Temperature, Applied Physics Letters 88 142511.
- [25] SCHMEIBER, D.; DABROWSKI, J.; MÜSSIG, H.-J.; (2003): The Pr<sub>2</sub>O<sub>3</sub>/Si(001) interface: a mixed Si-Pr oxide, MRS San Francisco Meeting, E-MRS 2003 Spring Meeting, Journal of Applied Physics, MRS Proceedings Volume 765, D3.24.
- [26] SCHMEIBER, D.; ZHENG, F.; HIMPSEL, F.; ENGELMANN, H.-J.; ZSCHECH, E.; (2006): Silicate Formation at the Interface of high-k dielectrics and Si(001) Surfaces, MRS Proceedings 917 E10-02
- [27] HENKEL, K.; TORCHE, M.; SOHAL, R.; SCHWIERTZ, C.; HOFFMANN, P.; SCHMEIBER, D.; (2006): Pr-O-N Dielectrics for MIS Stacks on Silicon and Silicon Carbide Surfaces, MRS Proceedings 911 B11.
- [28] VENKATESAN, M.; FITZGERALD, C. B.; COEY, J. M. D.; (2004): Unexpected magnetism in a dielectric oxide, NATURE 430, 630.
- [29] BERKELEY/USA: Advanced Light Source, Projekt No ALS-01597.
- [30] SEIBOLD, G. UND LORENZANA, J.; (2001): Time-dependent Gutzwiller approximation for the Hubbard model. Phys. Rev. Lett. 86, 2605.
- [31] SEIBOLD, G. BECCA, F.; RUBIN, P.; LORENZANA, J.; (2004): Time-dependent Gutzwiller theory of magnetic excitations in the Hubbard model. Phys. Rev. B 69, 155113.
- [32] LORENZANA, J. UND SEIBOLD, G.; (2002): Metallic mean-field stripes, incommensurability and chemical potential for cuprates. Phys. Rev. Lett. 89, 136401.
- [33] LORENZANA, J. UND SEIBOLD, G.; (2003): Dynamics of metallic stripes in cuprates. Phys. Rev. Lett. 90, 66404.
- [34] SEIBOLD, G. UND LORENZANA, J.; (2005): Magnetic fluctuations of stripes in the high-temperature superconductors. Phys. Rev. Lett. 94, 107006.
- [35] TRANQUADA, J. M. ET AL.; (2004): Nature (London) 429, 534.
- [36] GÜNTHER, F. SEIBOLD G. UND LORENZANA, J.: Lifshitz point in the infinite dimensional Hubbard model. submitted Phys. Rev. B.
- [37] SEMICONDUCTOR INDUSTRY ASSOCIATION: International Technology Roadmap for Semiconductors, 4300 Stevens Suite Blvd, Suite 271, San Jose, CA, 95129, USA



v. l. n. r.: Dieter Schmeißer, Jürgen Reif, Götz Seibold

**Prof. Dr. rer. nat. habil. Dieter Schmeißer** studierte in Erlangen Physik. Seine Promotion schloss er am Fritz-Haber-Institut Berlin ab. Auslandsaufenthalte führten ihn zu IBM, Yorktown Heights und an die University of Philadelphia. Habilitation wurde er an der Universität Tübingen. Seit 1996 ist er an der Brandenburgischen Technischen Universität Cottbus Leiter des Lehrstuhles Angewandte Physik/Sensorik. Er ist Mitglied im Vorstand der Deutschen Materialwissenschaftlichen Gesellschaft (DeMaWiG) sowie im wissenschaftlichen Beirat des Kunststoffkompetenzzentrums Schwarzheide. In der DGM leitet er den Arbeitskreis „Materialien für logische Devices“ im Fachausschuss „Materialien für elektronische Anwendungen“.

**Prof. Dr. Götz Seibold** studierte Physik an der Universität in Stuttgart. Nach seiner Promotion im Jahr 1995 und einem Auslandsaufenthalt an der Universität „La Sapienza“ in Rom wechselte er an die BTU Cottbus. Er wurde 2003 zum Juniorprofessor für „Physik komplexer Systeme“ ernannt und hat zudem am Institut für Physik und Chemie habilitiert.

**Prof. Dr. rer. nat. habil. Jürgen Reif** studierte in Köln und München Physik. Er arbeitete als wissenschaftlicher Mitarbeiter am Max-Planck-Institut für Quantenoptik (Garching), der Ludwig-Maximilians-Universität (München), am Forschungszentrum Saclay (Paris) und als Assistent an der FU Berlin, wo er 1991 seine Habilitation abschloss. Forschungsaufenthalte absolvierte er an der Vanderbilt University, Nashville, TE (USA), der Chalmers University of Technology, Göteborg (Schweden), dem Centre d'Études Nucléaires, Saclay (Frankreich) sowie der University of Wales, Swansea (Großbritannien). Seit 1996 ist er an BTU Cottbus und leitet den Lehrstuhl Experimentalphysik/Materialwissenschaften. Seit 2005 ist er Dekan der Fakultät Mathematik, Naturwissenschaften und Informatik.