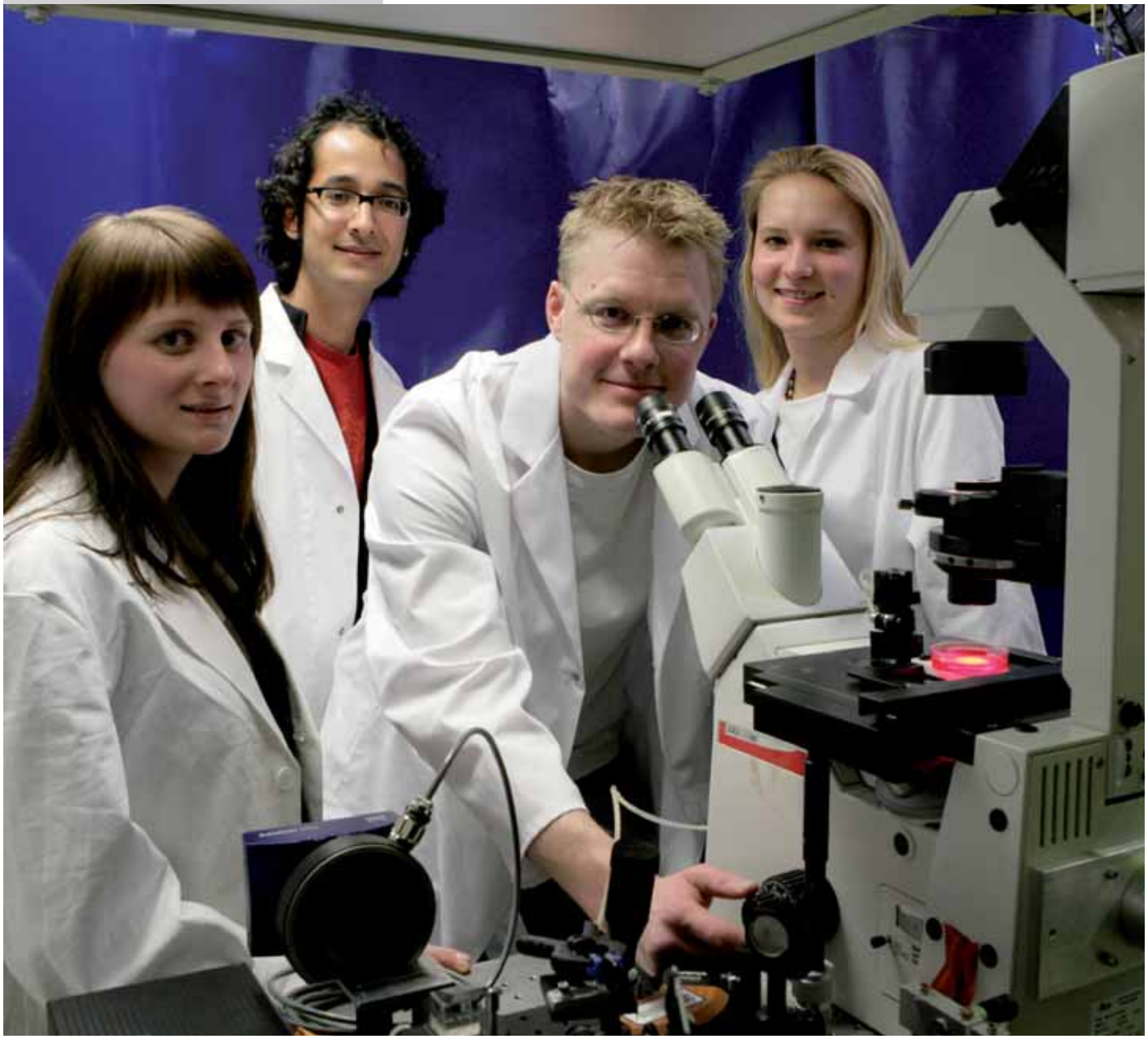
UNIVERSITÄT LEIPZIG

Graduate School

Leipzig School of Natural Sciences – Building with Molecules and Nano-objects

BuildMoNa



Doctoral candidates from chemistry (Carolin Limburg), physics (Jose Alvarado and Björn Stuhrmann) and biochemistry (Cornelia Walther) performing and discussing an experiment that uses optical cell guidance to interface neurons with nano-structures that are used to stabilize and monitor controlled neuronal network architectures.

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CONTENTS

1 KEY DATA

1.1 Principal investigators

Surname, first name, academic title	Institute	Research area
Beck-Sickinger, Annette G., Prof. Dr.	Institute of Biochemistry	Bioorganic Chemistry, Biochemistry
Berger, Stefan, Prof. Dr.	Institute of Analytical Chemistry	Structural Analytical Chemistry
Buchmeiser, Michael, Prof. Dr.	Institute of Technical Chemistry Leibniz-Institute of Surface Modification (IOM)	Macromolecular Chemistry
Butz, Tilman, Prof. Dr.	Institute of Experimental Physics II	Ion Beam Analysis and Modification
Esquinazi, Pablo D., Prof. Dr.	Institute of Experimental Physics II	Solid State Physics
Grundmann, Marius, Prof. Dr.	Institute of Experimental Physics II	Semiconductor Nanostructures
Haase, Jürgen, Prof. Dr.	Institute of Experimental Physics II	Correlated Matter
Hey-Hawkins, Evamarie, Prof. Dr.	Institute of Inorganic Chemistry	Organometallic Chemistry
Janke, Wolfhard, Prof. Dr.	Institute of Theoretical Physics	Statistical Physics
Käs, Josef Alfons, Prof. Dr.	Institute of Experimental Physics I	Laser Physics, Biological and Soft-matter Physics
Kersting, Berthold, Prof. Dr.	Institute of Inorganic Chemistry	Supramolecular Chemistry
Keyser, Ulrich Felix, Dr.	Institute of Experimental Physics I	Biological and Soft-matter Physics
Kopinke, Frank-Dieter, Prof. Dr.	Helmholtz-Center for Environmental Research (UFZ)	Environmental Chemistry
Krautscheid, Harald, Prof. Dr.	Institute of Inorganic Chemistry	Solid State Chemistry
Kremer, Friedrich, Prof. Dr.	Institute of Experimental Physics I	Polymerphysics
Kroy, Klaus, Prof. Dr.	Institute of Theoretical Physics	Soft and Biological Matter
Morgner, Harald, Prof. Dr.	Wilhelm Ostwald-Institute of Physical and Theoretical Chemistry	Solid and Fluid Interfaces
Müller, Stefan, Prof. Dr.	Max Planck Institute for Mathematics in the Sciences	Applied Mathematics
Rauschenbach, Bernd, Prof. Dr.	Institute of Experimental Physics II Leibniz-Institute of Surface Modification (IOM)	Nanophysics and Nanotechnology
Robitzki, Andrea A., Prof. Dr.	Institute of Biochemistry Center for Biotechnology and Biomedicine	Bioelectronic Assays
Schirmer, Kristin, Dr.	Helmholtz-Center for Environmental Research (UFZ)	Cell Biology and Toxicology

1.2 Participating institutions and cooperation partners

Institutes and institutions of the Universität Leipzig	Location
Faculty of Bioscience, Pharmacy and Psychology Institute of Biochemistry	Leipzig
Faculty of Chemistry and Mineralogy Institute of Analytical Chemistry Institute of Inorganic Chemistry Wilhelm Ostwald Institute of Physical and Theoretical Chemistry Institute of Technical Chemistry	Leipzig
Faculty of Mathematics and Computer Science Mathematical Institute	Leipzig
Faculty of Physics and Earth Science Institute of Theoretical Physics Institute of Experimental Physics I Institute of Experimental Physics II	Leipzig
Center for Biotechnology and Biomedicine	Leipzig
Integrated non-university institutions	**Location**
Leibniz-Institute of Surface Modification	Leipzig
Max Planck Institute for Mathematics in the Sciences	Leipzig
Helmholtz-Center for Environmental Research	Leipzig
Associated cooperation partners (industrial partners)	**Location**
Aixtron AG	Aachen
BDF Beiersdorf	Hamburg
Bauer Umwelt GmbH	Schrobenhausen
Bruker BioSpin GmbH	Rheinstetten
Carl Zeiss MicroImaging GmbH	Jena
Chemilia	Huddinge, Sweden
Convertex	Bitterfeld
Dr. Gerhard Schmidt GmbH	Neunkirchen
Euroderm biotech & aesthetics	Leipzig
EverQ	Thalheim
Evotec technologies	Hamburg
FEI Company Tools for Nanotech	Eindhoven, The Netherlands
Freiberger Compounds Materials GmbH	Freiberg
HiTec Zang GmbH	Herzogenrath
ikfe	Mainz
Industrial Research Limited	Lower Hutt, New Zealand
Inotec FEG mbH	Markkleeberg
JPK instruments	Berlin
Karl-Winnacker-Institut der DECHEMA	Frankfurt am Main

KeyNeurotek AG	Magdeburg
Namos GmbH	Dresden
NMR Service	Erfurt
novamass	Oulu, Finnland
Novocontrol Technologies GmbH	Hundsangen
OSRAM Opto Semiconductor GmbH	Regensburg
Pharmacelsus GmbH	Saarbrücken
ProBioGen AG	Berlin
Toshiba Research Europe Limited	Cambridge, UK

1.3 Estimated number of participating doctoral candidates

For the Graduate School "Leipzig School of Natural Sciences – Building with Molecules and Nano-objects (BuildMoNa)" a total enrollment of 90 to 100 doctoral candidates is envisaged, 30 of whom will be funded by scholarships provided by the Graduate School, at least 30-40 by third-party funding, and up to 30 scholarships will be provided by the Universität Leipzig and the Saxon Ministry of Science and the Fine Arts (SMWK), respectively. Suitable students will be admitted until the total number is reached. New doctoral candidates will be continuously incorporated to replace those finishing their doctoral degrees. In general, the duration for a doctoral thesis is expected to be limited to 3 years.

1.4 Brief summary

Die Graduiertenschule „Leipziger Schule der Naturwissenschaften – Bauen mit Molekülen und Nano-objekten (BuildMoNa)" an der Research Academy Leipzig (RAL) konzentriert sich auf die interdisziplinäre Ausbildung von jungen Nachwuchswissenschaftlern, basierend auf fachübergreifender, exzellenter Forschung. Diese folgt der „bottom-up"-Strategie bei der Entwicklung neuer Materialien: Aus geeigneten Bausteinen, wie Nanopartikeln, veränderbaren Molekülen, Polymergerüsten, Peptiden und Proteinen, werden vorzugsweise über Mechanismen der Selbstorganisation neue Materialien hergestellt, die intelligent, anpassungsfähig, umweltfreundlich und kostengünstig sind und lebender Materie ähneln. Dieser Paradigmenwechsel von homogenen, ausgedehnten Materialien hin zu multifunktionalen Materialen, welche auf intelligenter Kombination oben genannter Bausteine basieren, wird zukünftig den Wissenstransfer zwischen Grundlagenforschung und angewandten Wissenschaften wesentlich bestimmen.

Die wissenschaftliche Strategie ist das „Bauen mit Molekülen und Nano-objekten (BuildMoNa)". Diese Aktivitäten spiegeln sich in der interdisziplinären *Forschung*, der Anwendung und Entwicklung neuartiger *Methoden* sowie der fachübergreifenden *Ausbildung* wider.

In der *Forschung* werden „harte" (Atome, Moleküle) oder/und „weiche" Bausteine (Polymere, Biomoleküle) so miteinander verknüpft oder an Gerüsten angebracht, dass neuartige Strukturen entstehen, die auf Grund von neuen Eigenschaften innovative Anwendungen versprechen. Beim Bau sowie bei der Charakterisierung der neuen Strukturen spielen *Methoden* und ihre Entwicklung eine besondere Rolle. Die *Ausbildung* hat das Ziel, den fachübergreifenden Austausch in den Naturwissenschaften zu fördern und fundiertes, material- und methoden-orientiertes Wissen zu vermitteln. Darüber hinaus werden Zusatzqualifikationen angeboten, die der Vorbereitung auf eine weitere international ausgerichtete berufliche Entwicklung dienen.

Die etablierten Kooperationen mit internationalen Wissenschafts- und Industriepartnern werden genutzt werden, um das Konzept der Graduiertenschule durch zusätzliche Expertise im Bereich der Materialforschung sinnvoll zu komplementieren.

Diese Graduiertenschule richtet sich an motivierte und exzellente Bewerber aus dem In- und Ausland mit Bachelor-, Master- oder äquivalenten Abschlüssen und soll ihnen durch

ausgezeichnete Rahmenbedingungen neuartige Ansätze in der Materialforschung und eine weitere Karriere in der Wissenschaft und Industrie ermöglichen.

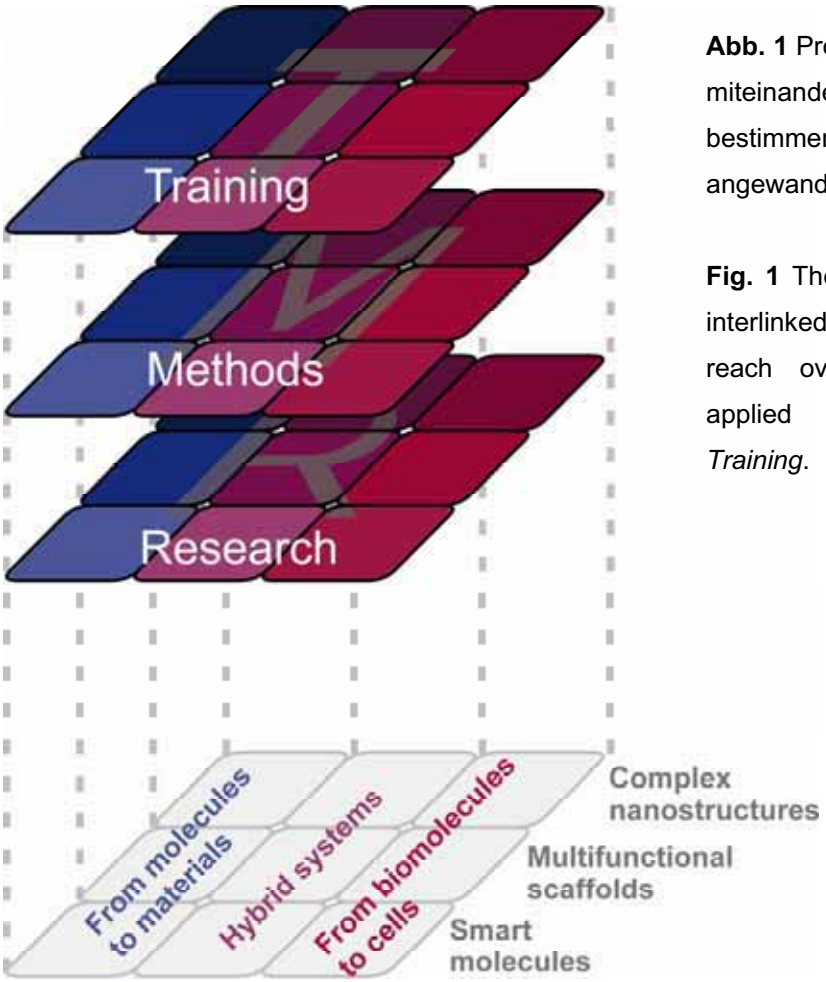


Abb. 1 Profil der Graduiertenschule. Sechs miteinander verzahnte Forschungsthemen bestimmen die Ebenen *Forschung*, angewandte *Methoden* sowie *Ausbildung.*

Fig. 1 The Graduate School's Profile. Six interlinked, synergistic research themes reach over the envisioned *Research*, applied *Methods*, and corresponding *Training*.

The Graduate School "Leipzig School of Natural Sciences – Building with Molecules and Nano-objects (BuildMoNa)" focuses on interdisciplinary graduate education through top-level, synergistic research. Our materials research concept is based on a "bottom-up" approach. Progressive building blocks, such as nano-objects, smart molecules, polymeric scaffolds, peptides, and active proteins, will be combined – preferentially by self-organization – to create fundamentally new classes of materials that are inspired by active, adaptive living matter, and that are environmentally friendly, highly efficient, low-cost devices serving multifunctional purposes for a steadily more diversified modern society. The paradigm shift from uniform bulk materials towards nanostructured multifunctional materials that emerge from combinations of smart molecules, proteins, and nano-objects is essential for the future knowledge transfer from fundamental to applied sciences.

The Graduate School's main objective is "Building with Molecules and Nano-objects (BuildMoNa)". The central themes will connect interdisciplinary, fundamental *Research*, the use and development of suitable, novel *Methods*, and interdisciplinary graduate *Training*.

In our *Research*, "hard" (synthetic molecules and crystalline nanostructures) and/or "soft"

(polymers, biomolecules) building blocks will be directly connected or organized to complex structures by scaffolds to reveal new building principles and to produce new, desired materials with innovative applications.

For the success of such research the development of novel *Methods* for building and characterization of new materials is essential.

Recognizing the need for a new generation of interdisciplinary scientists the *Training* program aims at promoting interdisciplinary exchange in the natural sciences by high-quality education in material- and method-oriented subjects.

The cooperation with international scientific and industrial partners, as well as other research institutions in the Leipzig area will complement and broaden the school's expertise and outreach by establishing a unique research and training network for the doctoral candidates.

The school aims to attract highly motivated and excellent applicants with BSc, MSc or equivalent degrees from around the world to engage in top-level research and high-quality training which will propel them into important positions in academia and industry.

2 ACADEMIC PROFILE

2.1 Academic aims

Current research in chemistry, biology, and physics rapidly gains an understanding of objects on the molecular and nano-scale. Nano-objects, proteins, and macromolecules become more and more readily available. Interdisciplinary approaches that combine these building blocks from biology, chemistry, and physics will create new materials. Thereby it will be the particular challenge to develop building principles for materials that are more than the simple sum of the properties of their nano-constituents. It is our aim to develop the basic principles to make active or smart, complex, multifunctional materials. Biological cells exemplify that such materials can be created. The human genome projects illustrate what is waiting for nanosciences. Knowing all genes, i.e. the biological building blocks, does not mean that it is understood how proteins interact to achieve a certain biological function. Equally the combination of nano-objects to complex materials does not solely require a knowledge of the building blocks, it also requires an understanding of the building principles.

Functional materials with an industrial relevance typically require operation at ambient temperatures which is also perfectly suited to create and use hybrids from biomimetic and synthetic compounds. The properties of materials at these temperatures are particularly rich on the nanometer scale as shown in Fig. 2, where an electron constrained by a nanoscale diameter box becomes sensitive to ambient thermal energy variations (blue line). On the other hand, the thermal energy contained in a nanoscale object approaches that of a chemical bond so that fluctuations on the nanoscale are capable of breaking bonds, causing the objects to spontaneously reassemble. Consequently we expect an intricate interplay of chemical and electronic properties for nanoscale systems. While the high-energy quantum structures of

atoms, molecules and solids (to the left of the crossing lines in Fig. 2) are well explored, and powerful concepts exist for the behavior of classical systems (to the right of the crossing lines in Fig. 2), the understanding of materials with nanoscale structures (below the crossing lines, highlighted in red) is still rather poor. While nature works and builds optimal solutions in "nanospace" driven by evolution, chemistry and physics only begin to exploit the potential for such an endeavor. Biology can teach us how structures associated with weak binding energies (a few k_BT) influenced by thermal noise and self-organization far from thermal equilibrium lead to highly dynamic, complex materials.

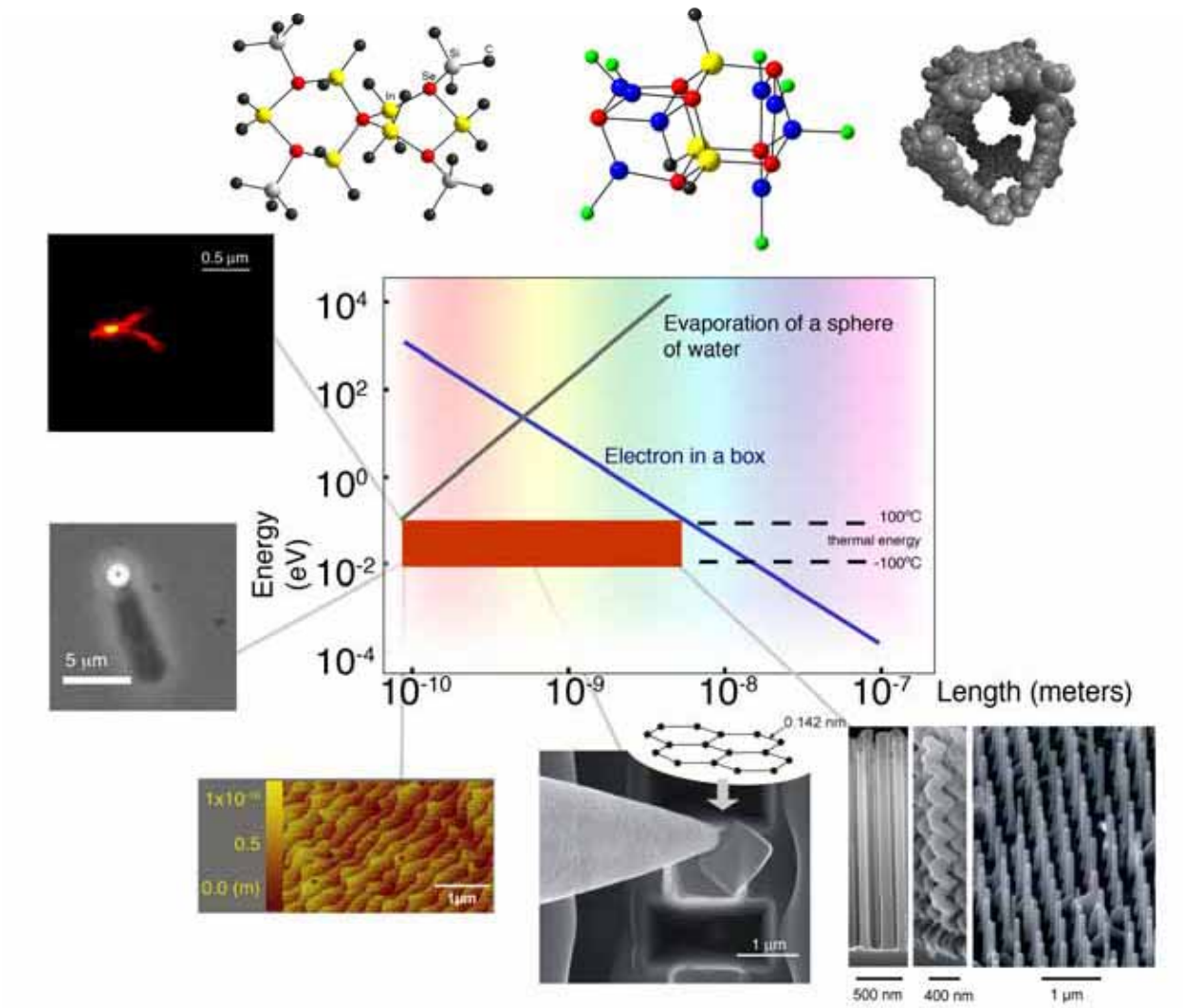


Fig. 2 Convergence of energy and length scales in new materials combining hard and soft building blocks (inspired by an article from Stephen Quake in Physics Today).

It is also worth pointing out that conventional "top-down" approaches are problematic in understanding or manufacturing complex nano- and microscale structures. The knowledge of the bulk materials will not suffice in predicting their properties when utilized at the nanoscale,

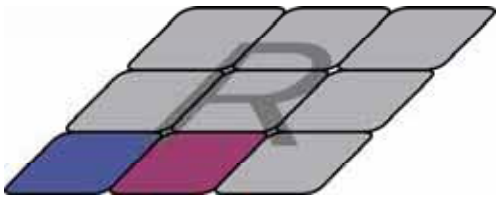
and the successive manipulation of a macroscopic material to create nanoscale structures is often prohibitively costly in an economic sense and in some cases impossible. Therefore, when dealing with complex, multicomponent, nanostructured materials, one has to choose a “bottom-up” approach, where nanoscale objects are constructed from individual molecules. Finally, a clear distinction between chemical and electronic structure fails at the nanoscale.

Consequentially, at the Universität Leipzig we propose to engage in an interdisciplinary “bottom-up” approach to modern materials. Establishing a Graduate School “Leipzig School of Natural Sciences – Building with Molecules and Nano-objects (BuildMoNa)” is the key element for pursuing our goal, since successful interdisciplinary research will be greatly facilitated by an interdisciplinary education of young talented doctoral candidates enabling them to move unconstrained across the borders of scientific disciplines. Such an effort promises to greatly advance materials science in the area of intelligent, adaptive, and living forms of matter.

Our new graduate program has several distinct, forward-looking features (details of the training program are given in chapter 3). Profound training in nanosciences, i.e. in mesoscopic physics, macromolecular chemistry, and nanobiology, will be provided with a post-nano-perspective in mind. Therefore, our program stresses the assembling of nano-sized objects to materials that are more than the simple sum of the individual objects’ properties. This problem will become increasingly important when more and more nano-objects become readily available. Furthermore, the interdisciplinary connection between chemistry and biology or between physics and biology has become an obvious driving force of nanosciences since proteins in cells teach us how to assemble smart and multifunctional materials. However, these initiatives occur often without a sufficient connection between physics and chemistry leading to redundant efforts. In the design of our Graduate School we have paid attention to a strong link between these two fundamental sciences.

2.1.1 Smart molecules

In this area we focus on the specific modification and synthesis of molecules as precursors for materials with optimized catalytic activity and adjustable magnetic, electronic, or optical properties. The preparation, characterization, and investigation of such molecules are tackled by combinations of chemical, physical, and biological techniques (hybrid techniques). The following classes of smart molecules are of particular research interest.



Small molecules, clusters and polynuclear compounds

[Buchmeiser, Grundmann, Haase, Hey-Hawkins, Kersting, Krautscheid]

Small molecules, such as organometallic compounds and main group metal or transition metal complexes, are important as homogeneous catalysts or as precursors for the preparation of

solid-state materials.

New macromolecules (organic, inorganic or biological) will become available from corresponding molecular precursors employing novel catalysts, such as i) heterobi- or heterooligometallic transition metal complexes (for synergistic or successive activation of different organic, inorganic or biological substrates), ii) Ru- and Mo-based initiators for the stereoselective Ring-Opening Metathesis Polymerization (ROMP) or cyclopolymerization, iii) catalysts for the polymerization or copolymerization of monomer units for “intelligent” or biodegradable polymers.

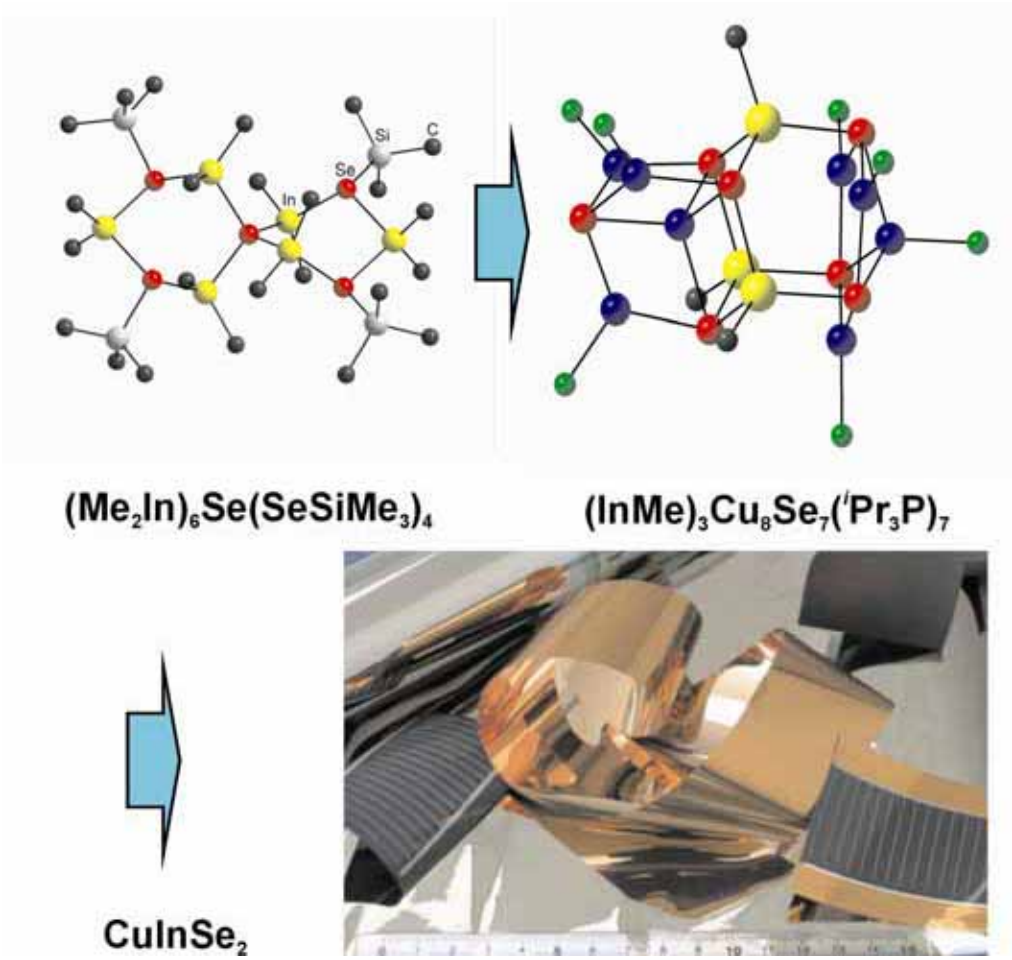


Fig. 3 Metal-chalcogenide cluster molecules as precursors for semiconductor materials such as $CuInSe_2$, used in thin-film (second generation) solar cells (here shown: ZnO/$CuInSe_2$/Mo on flexible polymer substrate, Solarion).

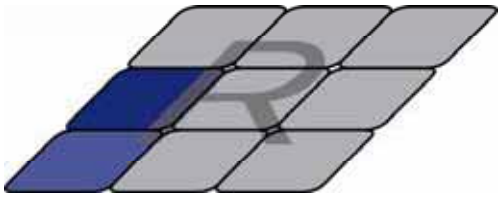
Special attention is devoted to the immobilization of these mononuclear or heterooligonuclear transition metal complexes, since they act as catalysts for highly selective reactions, such as Pd-, Ru-, or Fe-mediated C-C and C-X coupling reactions, on polymeric carriers including monolithic and micellar ones, linking this area to “Multifunctional Scaffolds”.

Metal-Organic Frameworks (MOFs) are a new class of materials in which polyfunctional ligands link metal ions or small metal clusters to form highly porous coordination polymers. Molecular building blocks for MOFs are prepared selectively for interdisciplinary applications with different

coordination polymers, e.g., for gas (H_2, CH_4) storage or separation, as heterogeneous catalysts with precise selectivity, or as sensors, linking this area also to “Multifunctional Scaffolds”.

Volatile molecular precursors will be used for the preparation of solid-state materials by Metal Organic Vapor-Phase Epitaxy (MOVPE). Research interests include unprecedented thermally labile phosphorus-rich transition metal complexes, precursors for binary (or ternary) metal phosphides MP_x (or MM'_yP_x), organometallic compounds of group 13 metals (Al, Ga, In), and group 15 elements focusing on novel As, P, and N precursors. Polynuclear molecular compounds are of interest since they can be regarded as links between mononuclear complexes and the corresponding solid-state phase. Compounds under investigation include oligonuclear and polymeric main group element clusters with chalcogen ligands. Future work will also include thermally labile polynuclear clusters with (Ga,Al,In)(O,N,S) groups having well-defined covalent bonds and composition as precursors for the fabrication of atomically designed thin films, nanostructures and binary or ternary nanoparticles, thus linking this area to “Complex Nanostructures”. In molecular magnetism, one of the major objectives is the development and preparation of molecular multispin systems with tailored magnetic properties. Various paramagnetic metallated container molecules with bowl-shaped supporting ligands or bioctahedral metal complexes with conjugated bridging ligands are investigated for the construction of polynuclear complexes with high-spin ground states.

These synthetic molecular building blocks are complemented by proteins and peptides. Peptides can be modified with chelators for metals or quantum dots to act as mediators of function. They allow specific addressing, i.e., control the interaction with surfaces and the orientation of molecules, and thus act as building blocks for larger units.



Quantum-electronic structures

[Butz, Esquinazi, Grundmann, Haase, Hey-Hawkins, Kersting, Krautscheid]

Extended quantum-electronic structures can be formed when building blocks with loosely bound outer electrons are linked together. The interaction/exchange between itinerant electrons or between itinerant and weakly localized electrons or their interactions with the ion cores of the material can produce unconventional conductivity, superconductivity, and magnetism. At the nanoscale one can find extraordinarily rich electron physics. Materials with low carrier densities, and nodes in the orbital angular momentum of the involved electrons are prone to such behavior. Order or disorder in electronic structure parameters can emerge as a function of chemical composition, temperature, electromagnetic field, or pressure. Local or global phase transitions between different forms of electronic matter can be initiated that change the macroscopic material properties in distinct ways. The richness of electronic quantum structures

can be compared with that of biological systems.

Building complex electronic structures with small molecules (organometallic compounds and transition metal complexes) enables the study of the size-dependent properties of quantum structures including emerging new properties ("bottom-up" approach). By variation of the chemical structure, electronic instabilities can trigger new effects. This can be tested by the variation of external parameters such as high magnetic fields. In such experiments, modern concepts like quantum-criticality will be investigated. Such studies require specific chemical synthesis performed in the small molecules area of research.

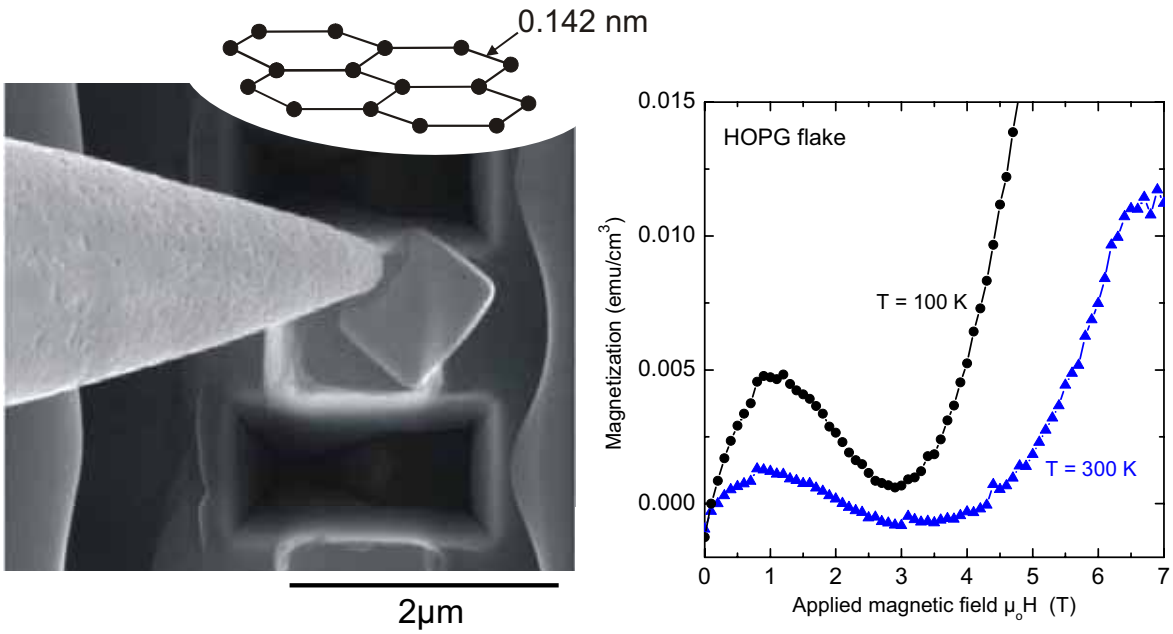


Fig. 4 Left: Preparation of µm^2-size graphite flake. Right: Persistence of de Haas-van Alphen quantum oscillations in highly ordered pyrolitic graphite (HOPG) up to room temperature.

The electronic spin degrees of freedom are linked to orbital degrees of freedom by the Pauli principle and spin-orbit coupling for heavier atoms. The classical example is that of a Fermi liquid that explains why only certain electrons (those at the Fermi surface) are involved in a material's low-energy physical properties such as conduction of current and heat. Consequently, if we influence the electronic spin states by magnetic fields we can change the low-energy properties of the material. This is the area of spin-based electronics, "spintronics", where the electronic spin's manipulation leads to changes in electronic conduction. In modern materials science, spintronics is an important strategy although mainly restricted to "top-down" approaches. Spintronics devices, however, can also be manufactured in more efficient "bottom-up" approaches. Magnetoresistive devices will be created and analyzed by building new structures with clusters of itinerant and magnetic systems.

We pursue selected systems that offer the possibility to extend quantum electronic effects up to

room temperature. Our work on highly ordered pyrolitic graphite, a material built up by weakly coupled graphene sheets, shows such effects in magneto-transport experiments. Also the electron physics involving massless and massive fermions is tremendously rich. Other systems with room temperature quantum coherence include our oxide microcavities that are built up from multiple dielectric layers. They exhibit strong coupling of light and matter at room temperature. It may also be possible to extend Bose-Einstein condensation of quasi-particles in the form of cavity-polaritons.

The very high superconducting transition temperature and unconventional electronic properties of the cuprate superconductors have challenged our understanding of such systems. Even after 20 years of intense research, there is no widely accepted theory for the behavior of the charge carriers in those systems. Experimental facts and fundamental considerations suggest that, e.g., nanoscale electronic structures (regular or inhomogeneous forms of electronic self-organization) can occur in these materials and may be intimately related to their unusual properties. Other systems with astonishing properties are superconducting $Ca_{2-x}Na_xCuO_2Cl_2$, Na_xCoO_2 + y H_2O, MgB_2, the heavy fermion materials, or manganites. These materials have surprised the community in the past few years. These examples prove that we can expect intricate relations of physical parameters (conductivity, superconductivity, magnetism) to chemical (high-energy) composition, or to external parameters. In a “bottom-up”, interdisciplinary approach many more such systems with great potential for science and technology will emerge. By building materials with tailored nanoscale chemical disorder, the interplay between chemical and electronic structure can be investigated.

Biorganics, peptides and biocatalysts

[Beck-Sickinger, Buchmeiser, Hey-Hawkins, Robitzki]

Recently, a significant advance in peptide synthesis and ligation strategies has been achieved that now permits the production of chemically modified peptides and proteins. Peptide synthesis allows the incorporation of non-natural building blocks, e.g., chelators for metals, fluorescent dyes including quantum dots, or immobilization tags.

Native Chemical Ligation (NCL) can create larger peptides from multiple smaller synthetic unprotected peptides by using the chemoselective reaction between a C-terminal thioester and an N-terminal cysteine residue, resulting in a native peptide bond. Besides the rapid isolation of highly pure recombinant proteins, intein technologies enable the production of polypeptides with the reactive groups necessary for NCL. Expressed Protein Ligation (EPL) extends NCL’s scope by overcoming the size limitation of target proteins which are accessible to synthesis. The intein splicing and EPL have been proven to be useful for protein semisynthesis.

Thus, now all non-natural building blocks can be introduced in proteins, as well. The approach has been applied to produce selectively labeled enzymes, such as aldoketoreductase that was selectively modified with biotin and immobilized for bioelectronic applications. Furthermore, this approach can be used to immobilize peptides and proteins on 3D microcavities for the development of biosensors, to produce chemically modified proteins such as fluorescent proteins or peptides/proteins containing heterobimetallic segments. The necessary interdisciplinary approach to this area, which includes linking molecules to solid-state materials and the synthesis and characterization of desired materials properties, can be perfectly tackled in the proposed Graduate School's interdisciplinary environment.

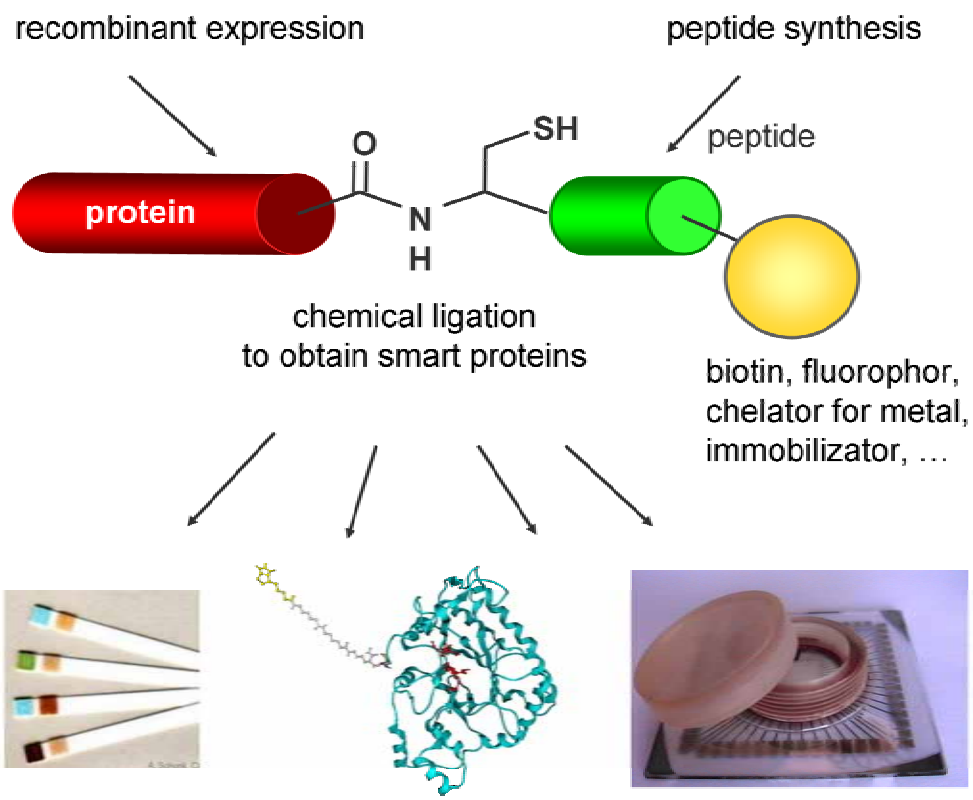


Fig. 5 Proteins expressed by recombinant techniques combined with specific peptides form a versatile class of building blocks as artificially modified proteins.

2.1.2 Multifunctional scaffolds

In this area we focus on the building of active materials or machines by organizing smart molecules and complex nanostructures in polymeric scaffolds, liquid crystalline films or solid surfaces. The cytoskeleton of biological cells serves as a prototypical example and as an inspiration for the desired structures. Furthermore, functionalized polymers are investigated with respect to their application as semiconductors, superconductors, in optoelectronics and as supports for catalysts. Accordingly, within the framework of hybrid techniques, immobilized enzymes will be used as catalysts for synthesis as well as for diagnostic purposes.

From biological cells to biomimetic molecular and nano-systems

[Butz, Käs, Kroy, Müller, Robitzki]

Recent scientific progress has generated a variety of smart nano-objects and provided a detailed understanding of active biological macromolecules. Nature can teach us how to build novel machines from the aforementioned nano-objects and macromolecules, which entails more than simply adding together these building blocks.

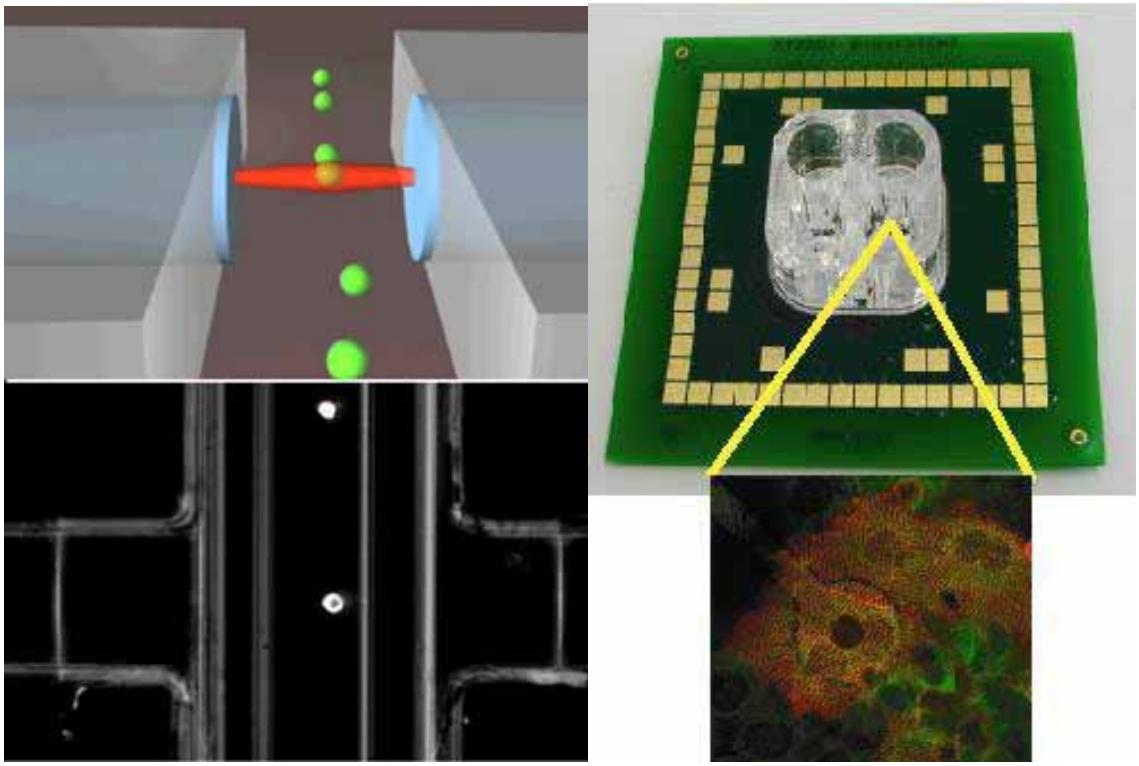
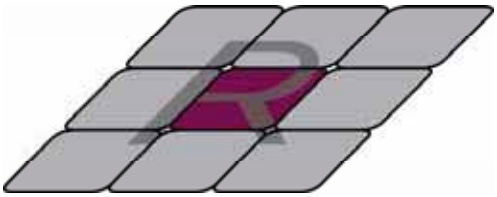


Fig. 6 The Optical Stretcher (left side) uses cell elasticity as a novel cell marker to diagnose and isolate different cell types such as metastatic cancer cells or progenitor cells. Cardiac cells interfaced with a semiconductor chip (right side) serve as screening tool in the development of new reagents against cardiac diseases.

From a materials perspective biological cells can be considered as an array of active and passive nano-sized objects (i.e. proteins) that are organized by polymeric scaffolds (i.e. the cell's cytoskeleton) to build a multifunctional, adaptable machine. Biological cells move on their own, generate forces, sense their environment, and independently produce new macromolecules. However, some 25,000 genes encode the information of human life, and their subsequent transcription and translation add to the complexity of molecular interactions resulting in an astronomical combinatorial number of relations that are to decipher and to understand. Nevertheless, two synergistic approaches will be used for the challenging

knowledge transfer from cells to new materials. *In vitro* studies of cells' reconstituted elements identified as independent functional modules – such as the cytoskeletal elements mentioned in the section on hard-soft hybrid materials – will be complemented by research that utilizes whole cells to create smart materials. Eventually, after clarifying the salient features contributed by the cells, the cells could be replaced by a biomimetic solution which replicates these contributions in a highly controllable fashion.

Novel high throughput and high content cytological techniques facilitated the new era of cellomics. Cutting-edge molecular biology, microarray techniques, and microfluidics will be combined with unique laser manipulation tools to isolate and to manipulate often rare cells with unique functions or desired intracellular components. Among these techniques is the molecular marker-free cell elasticity based isolation of cells with the Optical Stretcher, the optomolecular control of cell growth, and the laser beam based dissection of cells and cell organelles. Building on the Universität Leipzig's track record, hybrid, biomedical sensors that emerge from the synthesis of cells and semiconductor chips as well as the biomimetic reconstruction of the eye's retina will be a focus of these efforts. Moreover, cellular motion, force generation, and cellular mechanosensitivity will be analyzed with scanning force microscopy, optical traps, and multiphoton microscopy of motile cells transfected with GFP (green fluorescent protein)-constructs of various cytoskeletal elements to understand how nano-sized active elements in a polymer matrix act as mechanical machines. When a material and/or an application is established that integrates specific cells as functional elements, in a second step, as mentioned, the cells will be replaced by a minimal reconstituted system of cellular components and ultimately a stable biomimetic system will be derived.



Hard-soft hybrid systems

[Beck-Sickinger, Käs, Keyser, Kremer, Kroy, Müller, Robitzki]

By identifying cellular subunits acting as independent functional modules a biological cell's complexity becomes tractable and the fundamental physical principles of these modules can be studied. A typical example for such a module is the intracellular scaffold known as the cytoskeleton. Nano- and microparticles can be ideally organized in reconstituted cytoskeletal elements as soft scaffolds.

On the other hand, isolated cytoskeletal structures can be perfectly confined and coupled to solid-state and synthetic polymer micro- and nanostructures. The cytoskeleton is the key structural element in cellular organization. It is a compound of highly dynamic polymers and active nano-elements inside biological cells that mechanically senses a cell's environment. The cytoskeleton generates cellular motion and forces sufficiently strong to push rigid AFM

cantilevers out of the way. These forces are generated by molecular motor-based nano-muscles and by polymerization through mechanisms similar to Feynman's hypothetical thermal ratchet. Further, the nano-sized motors overcome the inherently slow, often glass-like Brownian polymer dynamics. The interaction between cytoskeletal polymeric scaffolds and molecular motors results in novel self-organization, rapid switching between fluid and solid states, and transitions between ordered and unordered states.

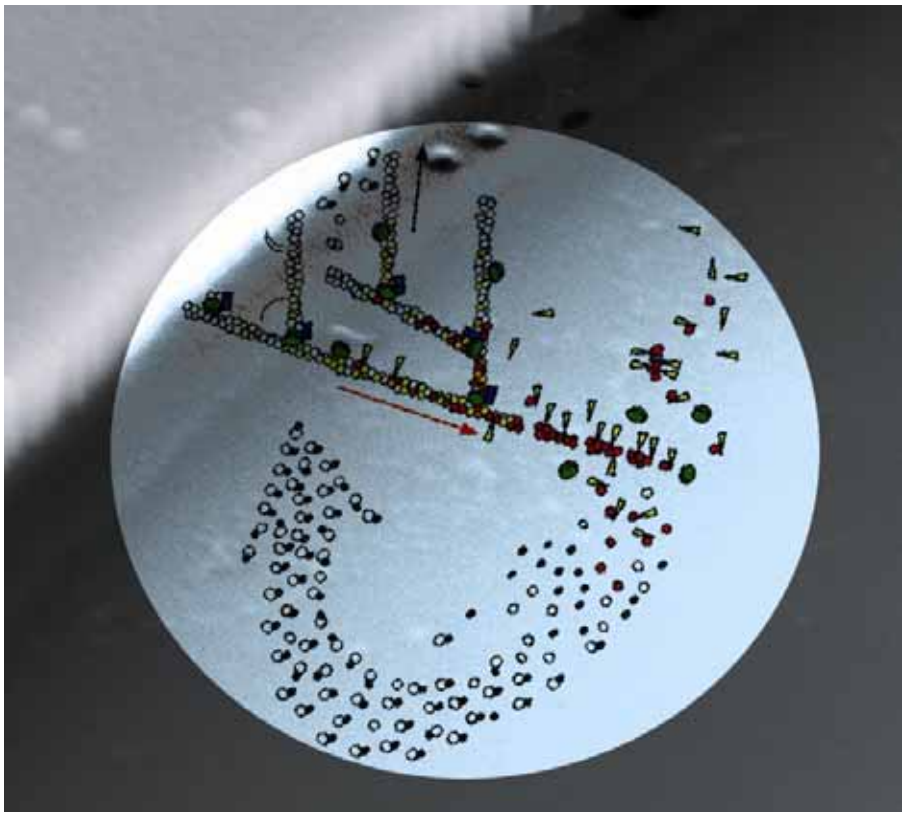


Fig. 7 The polymerization of actin filaments at the nano-well's walls and consequential cross-linking pushes the generated network away from the wall. Further away the network is depolymerized and the monomers are transported back by diffusion to the walls. This generates a steady-state.

Similar to the lamellipodia found in cells, biomimetic thin active polymeric films can be created which move on nano- and microstructured surfaces by polymerization, and nano-muscles created from polymers and molecular motors can exert forces in nanostructured environments.
Reconstituted cytoskeletal elements (similarly used in bead motility assays) can be confined in nano- and microstructured hard wells to form self-sustaining polymer films that move driven by polymerization in a tread milling fashion and that are ideally suited to transport nano-objects.
Furthermore, nanopores – initially formed in soft membrane systems, but ultimately fabricated in hard structures – are ideally suited to obtain information about the molecular properties of DNA when the DNA is sliding through these pores.

Functionalized polymers and porous materials
[Buchmeiser, Esquinazi, Hey-Hawkins, Krautscheid, Kremer]

Despite the large number of known polymers, polymer synthesis and modification remain key issues in building novel, smart materials. Fully conjugated polymers based on polyenes and related structures represent interesting materials for organic field effect transistors, diodes, polymer grid triodes, light-emitting electrochemical cells, or opto-couplers. These polymers are believed to balance sufficient stability versus moisture and oxygen with their ability to decompose. Furthermore, nano-reactors built from soluble block-copolymers (e.g., prepared by the 'living' ring-opening polymerization of 2-oxazolines) are under investigation. They are perfectly suited for both organic and inorganic polymer synthesis, allowing for rapid reactions in environmentally friendly media such as water.

Aliphatic polyesters are extensively used as commodity thermoplastics and have significant biomedical applications. Ring-opening polymerization of cyclic esters is a particularly convenient method for the synthesis of polyesters. A special interest is devoted to poly(ε-caprolactone) (PCL) and poly(3-hydroxybutyrate) (PHB), which is due to its miscibility with different commercial polymers, its biodegradability and biocompatibility, its adhesive properties at low temperatures, and its ability to disperse pigments. PHB occurs naturally as an isotactic, highly crystalline polymer. This stereoregular polymer is produced in nature by microorganisms, but it has low thermostability, and melt processing is therefore difficult. However, copolymerization with other lactones has produced polymers with improved thermal stability and better processability.

Nanostructured materials built from degradable polymers are anticipated to be key elements in future tissue engineering and regenerative medicine. The appropriate nanostructured surfaces might be used for stem cell differentiation, and degradable polymers might replace polyethyleneglycol (PEG) to improve bioavailability, stability, and uptake kinetics of macromolecular drugs. Testing can be easily performed by conjugation of PHB to bioactive peptides and proteins. Considering the recently discovered magnetic ordering in carbon, research will also focus on the magnetic properties of metal-free carbon-based polymers, such as polymers with C-H-N-O chains, or Kapton, another metal-free polymer that can show magnetic ordering at room temperature. A special emphasis will be given to the study of the effects of ion irradiation on the magnetic properties of polymers. Polymeric carriers including monolithic and micellar ones will be used for the immobilization of mononuclear or heterooligonuclear transition metal complexes to combine the advantages of homogeneous catalysis with those of heterogeneous catalysis.

A novel class of highly porous coordination polymers, Metal-Organic Frameworks (MOFs), can

be obtained selectively in organic solvents by self-assembly of suitable molecular building blocks, i.e. metal salts or complexes and the corresponding linkers. Due to the large variety of possible organic linkers with different sizes and different connectivities, MOFs allow for a wider variability of pore volumes and architectures compared to the conventional zeolites and zeolite-like materials and are thus ideally suited for gas storage or separation. Furthermore, by using functionalized linkers, catalytically active metal complex fragments can be integrated into the framework which will then be employed as highly selective heterogeneous catalysts.

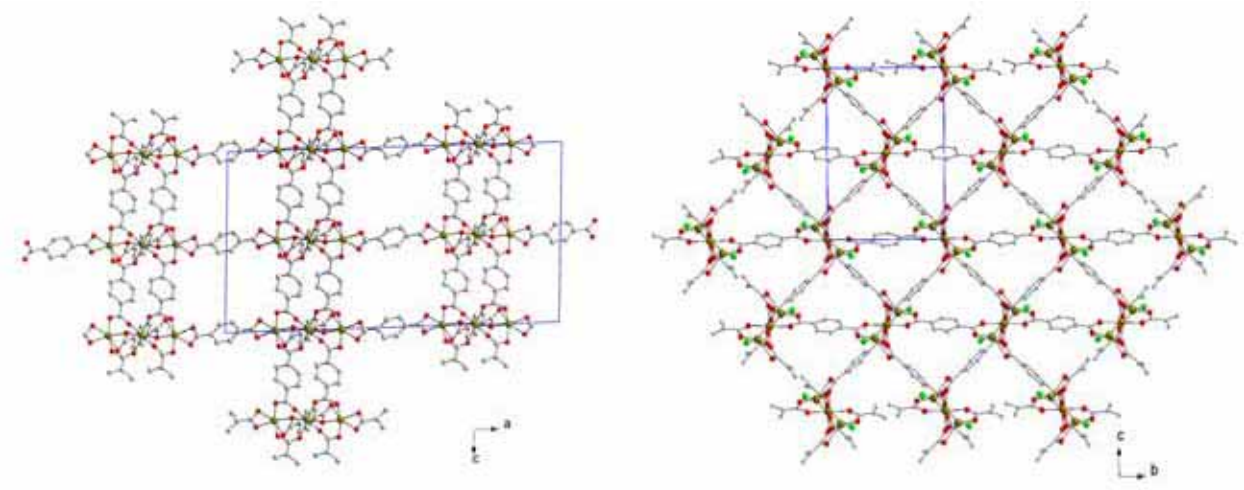
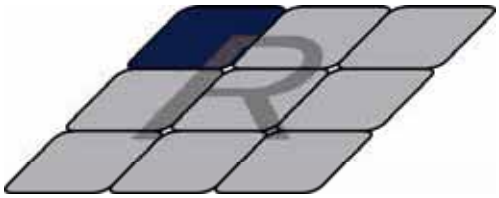


Fig. 8 Selective formation of three- ($[Fe_3L_4]^{2-}$ with L = $C_8H_4O_4^{2-}$, left) or two-dimensional networks ($[Fe_3Cl_2L_3]^{2-}$, right) depending on the co-ligands (Fe: dark olive, O: red, Cl: green, C: gray, H: not shown).

2.1.3 Complex nanostructures

Research focuses on the realization of nanoscale materials using assembly processes of atoms, molecules, and larger building blocks. Assembly, self-assembly and directed self-assembly enable the building of complex nanostructures that cannot be fabricated with other methods. Complex nanostructures include nanowires, quantum dots, textured thin films, surface structures, polymer networks, and biomimetic assembly lines for a factory-on-a-chip.



Inorganic nanostructures

[Butz, Esquinazi, Grundmann, Haase, Janke, Kopinke, Krautscheid, Rauschenbach, Schirmer]

Current research in inorganic nanostructures focuses on three-dimensional structures such as wool-, grass- and whisker-like shapes and sculptured thin films. Self-assembly is used to fabricate such structures with physical and chemical methods. ZnO, GaAs, and InP and their related compounds, such as (Mg,Cd,Zn)O, (Al,Ga,In)(As,P,N), are the materials from which nanowires doped with various elements for n- and p-type conductivity are fabricated. The

sculptured thin films are synthesized in SiO_2, TiO_2, and Si. The oxides are transparent in the visible and offer particularly interesting prospects, such as intensity and phase (polarization) management of visible light, as well as biocompatibility. The particular geometries permit new degrees of freedom in design, choice of substrates, substrate compliance, strain relaxation, chemical composition, crystal structure, and shape (including curvature and chirality and topology). We plan to extend nanostructured self-assembled growth to ferroelectric and superconductive perovskite-type materials.

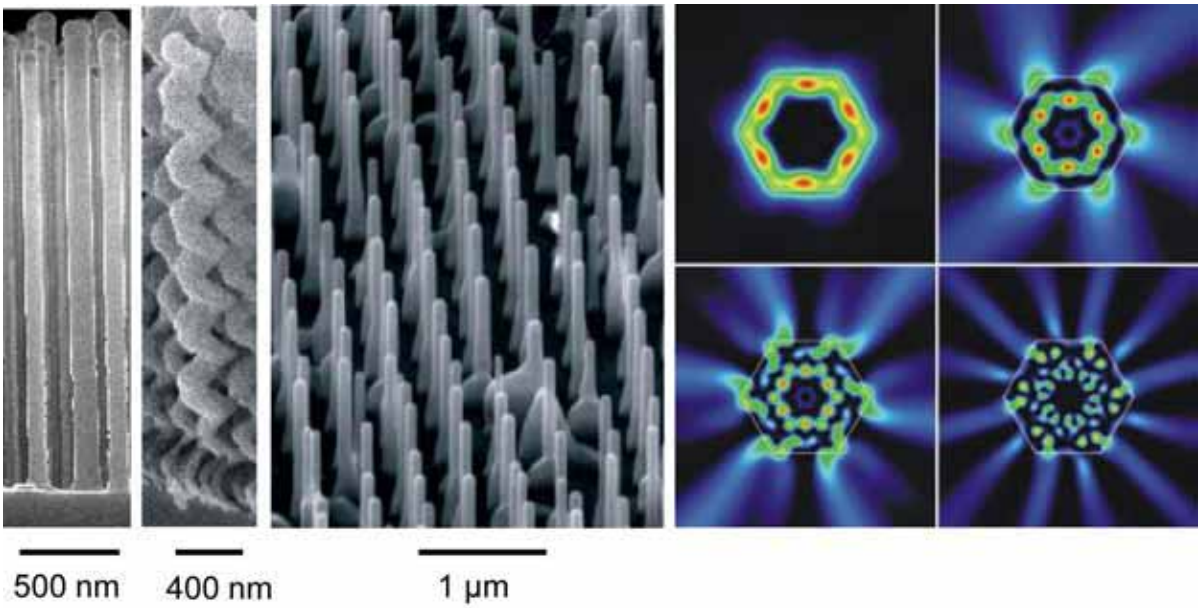


Fig. 9 From left to right: GaAs nanopillars, Si nanospirals and ZnO nanopillars fabricated using directed self-assembly. Far right: Light intensity in various whispering gallery modes in a ZnO nanopillar with hexagonal cross-section.

An example of a chemically more complex material studied is the cylinder-shaped mixed-metal sulfide $FePb_4Sn_3Sb_2S_{14}$. The investigated structures are building blocks for diverse, emerging applications in electronics, photonics, nanomechanics, and sensing. The possibility to interface neuronal networks with these structures is explored and depends on the geometry, macroscopic patterning, non-toxicity, and electronic properties of the nanostructures. The advantages are obvious since the transparency permits light microscopy simultaneously with nanomechanical measurements of neuronal growth cone motility and neuron stimulation as well as electrophysiological measurements of firing neurons.

Quantum dots (Fig. 10) are quasi zero-dimensional systems and serve formidably as containers for charge carriers. The specifics of their interaction with light enables quantum optic phenomena such as entangled photon generation or their use as markers in stable tissue dyes or for time-domain imaging of transport phenomena in fluids. Apart from that they provide a high surface to volume ratio. They can be synthesized and used as separate entities quasi as a nanopowder (see below on nanoparticles), embedded in more or less bulk-like thin films or

embedded in more complex environments such as networks for controlled electronic coupling or optical resonators for photonic applications.

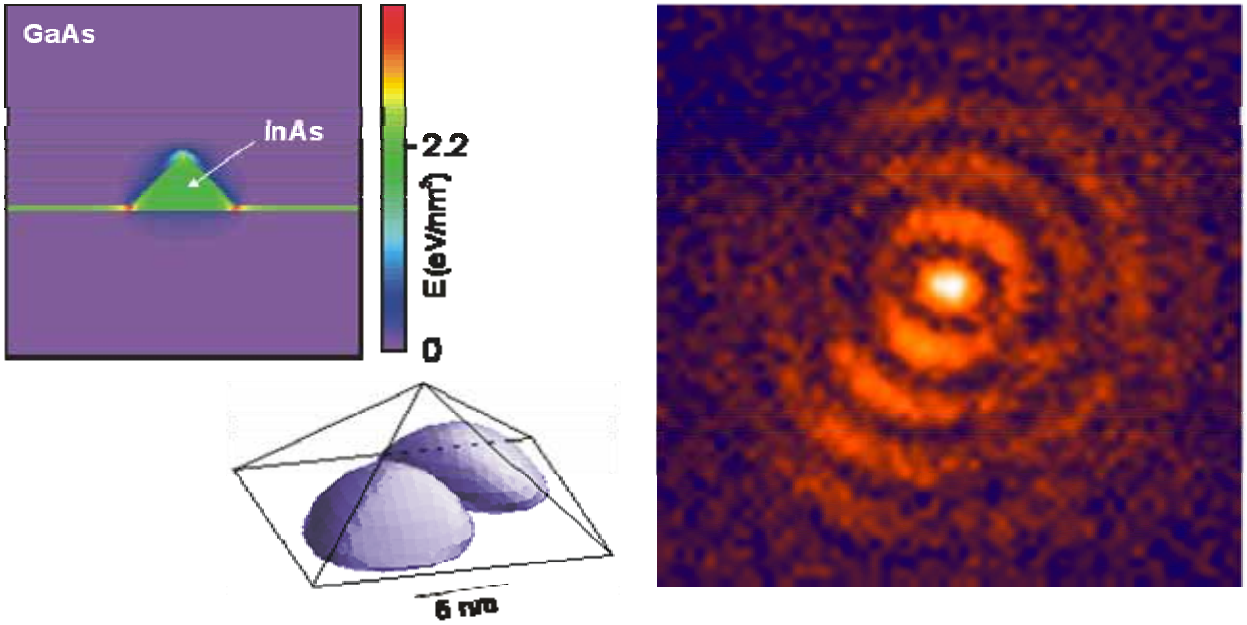
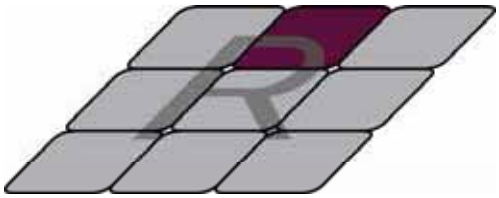


Fig 10 Left: Strain energy and electron wavefunction in an epitaxial InAs/GaAs quantum dot. Right: Defocused fluorescence image (diffraction pattern) of a single colloidal CdSe/ZnS quantum dot.

Inorganic nanoparticles containing zero-valent iron (nZVI) as the reductant of chlorinated compounds are regarded to be a promising tool for *in-situ* cleaning of contaminated groundwater. In particular, the modification of the iron with a trace of Pd and the deposition of the Pd/Fe on microscale activated carbon particles will be investigated.

Human and environmental health risks of nano-sized materials are still not well known and are studied *in vitro* in cell cultures of different origin, primary cells and cell cultures. Cells will be particularly studied from organs of primary contact or up-take, i.e from lung, gill, intestine, and epidermis. These cells are characterized in response to nano-sized materials with regard to altered cell function and viability, e.g., stress response, membrane integrity, genotoxicity, and proliferation.



Surfaces

[Beck-Sickinger, Buchmeiser, Esquinazi, Grundmann, Hey-Hawkins, Janke, Morgner, Keyser, Kopinke, Krautscheid, Kremer, Rauschenbach, Robitzki]

Polymeric surfaces are intensively studied in heterogeneous and biphasic catalysis, since they can serve as “vessels” for nanoparticles and catalysts preventing agglomeration. In this context, the synthesis of block-copolymers suitable for micellar catalysis is of great interest. Furthermore, the interaction of functional solid-state materials with organic and bioorganic

molecules is of high relevance for self-organization mechanisms, molecular recognition, biological markers, and sensors.

Solid-state surfaces play the key role for epitaxial processes and molecule attachment and determine the formation of self-assembled inorganic nanostructures and hard/soft hybrids via their corrugation, steps/kinks, reconstruction/dangling bonds, catalytic activity, and strain state. The variety of phenomena explored in the Graduate School reaches from two-dimensional growth of functional materials and surfaces on monoatomically flat substrates to surfaces facilitating synthesis of structures leading to extreme corrugation in the form of nanowhiskers with height/diameter aspect ratios close to 100:1. We investigate a rich variety of chemical combinations reaching from homoepitaxy (e.g., growing a material on itself) and heteroepitaxy (e.g., growing similar ($Mg_xZn_{1-x}O/ZnO$) or dissimilar ($ZnO/BaTiO_3$) materials on top of each other) to functionalization of surfaces with organic molecules. The surface itself can serve as functional nanostructure, e.g., for the management of light reflection via impedance matching of air (index of refraction n=1) and solid material (typically n=2-4). Those surfaces can be used to selectively attach biomolecules, both for biosensors or immobilized nano-catalysts. This might be enzymes, proteins of the cytoskeleton, selective antibodies or proteins of the extracellular matrix for application in medical materials. The interaction of peptides with semiconductor structures is studied with respect to chemical and conformational properties, self-assembly, and selective attachment.

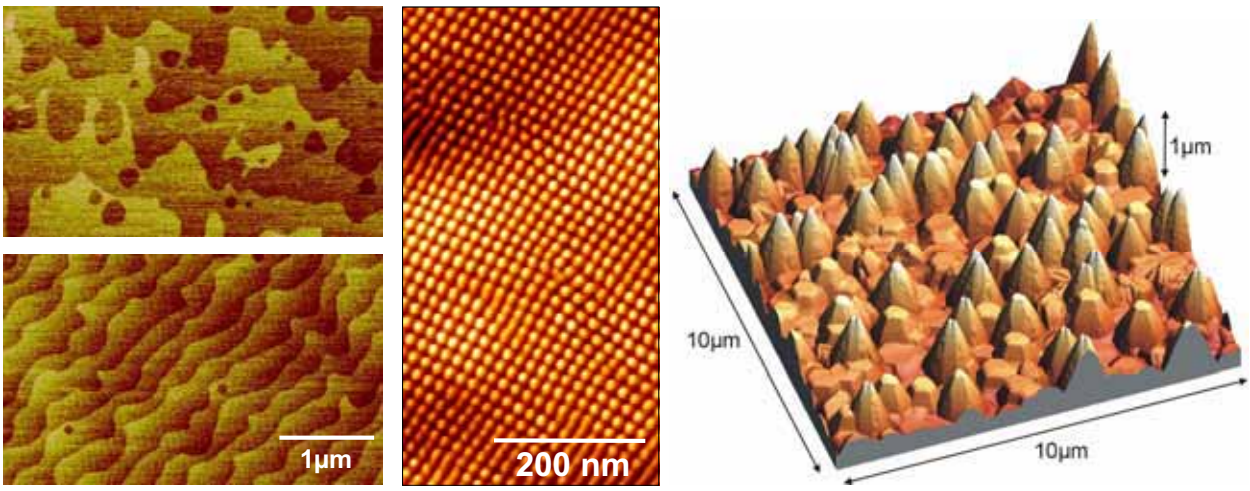


Fig. 11 Left: Atomic-force microscope images of atomically flat, monolayer terraced, (0001) ZnO surfaces (with different off-cut) in air. Center: Nanoscopically corrugated GaSb surface for optimized light transmission (moth eye effect). Right: Microscopically corrugated ZnO surface for optimized light transmission.

Furthermore, nanoporous monolithic media are synthesized that serve as excellent separation media for various analytes including DNA and proteins. They can be also used in heterogeneous catalytic reactions, such as enantioselective metathesis reactions or the complementary use of nano-sized metal particles immobilized within porous monolithic systems.

Sensor-molecule-cell interfaces in biosensors can be optimized by nanostructured microelectrodes. Nanocolumnar electrode surfaces for an intensified and more physiologic cellular membrane contact can be created via chemical edging. Moreover, peptides and proteins can be immobilized on electrode surfaces for an improved cellular contact. The surface-mediated positioning of biological cells and tissues can be realized by treatment with various silanes to generate hydrophilic and hydrophobic areas. Transistors will be developed as autonomous micro-implant structures for *in vivo* biomonitoring. Bio-functionalized colloidal inorganic quantum dots can contribute unique optical or magnetic properties. With optical tweezers *single colloids* can be positioned in 3D space to synthesize rigid one-dimensional wires via copolymerization and to measure their mechanical properties on the level of *single* polymer chains. This would open completely new nanofabrication routes by combining polymer synthesis with nano-physics. Furthermore, by conjugating quantum dots to peptides or proteins, biooligomerization processes can be used to place functionality in a specific manner.

Another aim is the controlled crystallization of magnetic nanoparticles in confined microenvironments. These particles will be assembled from paramagnetic transition metal ions and multifunctional spacer molecules. The intention is to use viruses, storage proteins, micelles, and other self-assembled architectures as crystallization compartments.

The inner surfaces of inorganic materials with nanosize pores, e.g., silicates such as zeolites, are of great interest, as well. While they play an important role in catalysis, their use in connection with physical and/or biological guest-host systems opens interesting research possibilities. In particular the implementation of molecules with low-energy electronic excitations promises rich quantum-electronic physics in such materials due to confinement and tunable electronic exchange mechanisms.

Molecular motors

[Beck-Sickinger, Käs, Kremer, Kroy]

The lab-on-a-chip has become an up-and-coming technology made possible by modern nanosciences and microfluidics. The next step is the development of a nano-factory-on-a-chip. This requires well-controlled transport and precise spatiotemporal localization of nanoscale objects to construct assembly lines on the chip. The molecular motor-based transport along intracellular protein scaffolds, or precise intracellular signaling through diffusion of second messengers in cell membranes point to biomimetic designs for these assembly lines. Furthermore, these two transport systems permit a contrasting comparison of passive and active transport solutions. Inhomogeneous liquid crystalline lipid films, such as cell membranes, use interactions induced and varied in strength and range by lipid nano- and microdomains to

control dimensionality and confinement of diffusive transport. In contrast, molecular motors actively carry nanoloads, such as ribosomes, or transport vesicles through the cell. A molecular motor spends a certain fraction of its time (which depends on the motor's degree of processivity) walking along a filament towards one of its polar ends, while the remaining time the motor diffuses until it encounters another filament. The dependence of motor-based transport in a reconstituted protein scaffold on network architecture, motor density ("traffic jams"), and processivity will be tested using single molecule techniques.

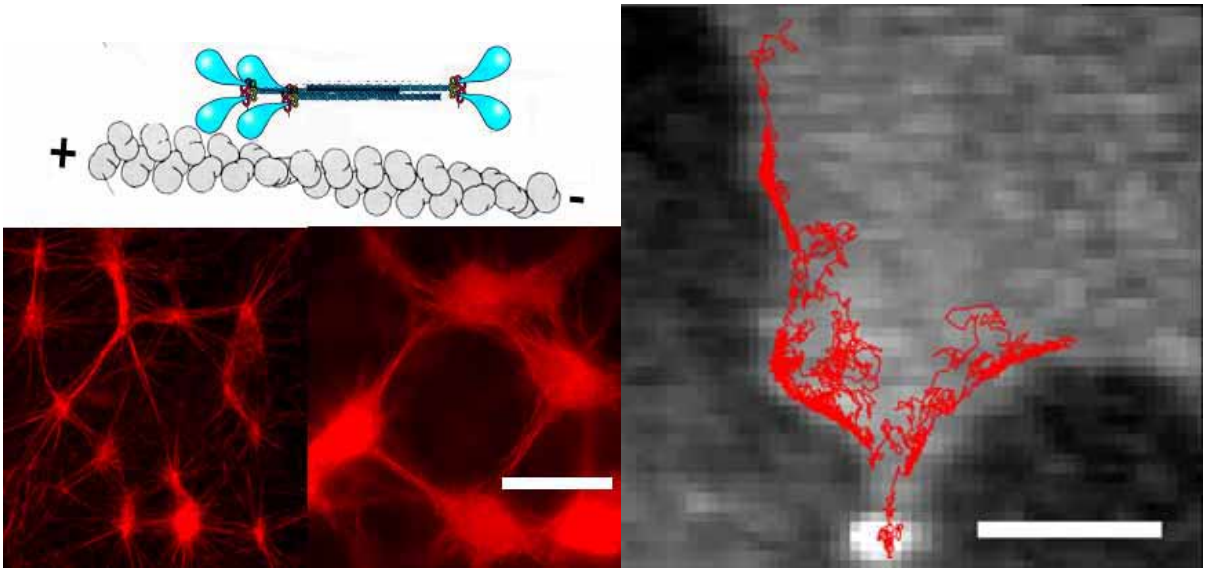


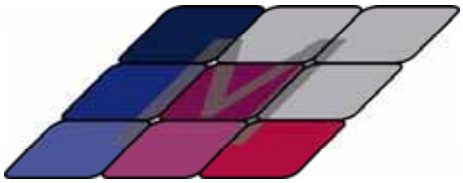
Fig. 12 Myosin minifilaments, a cluster of molecular motors, crawl along actin filaments towards their barbed end (left side, upper part). Self-organized actin scaffolds can serve as transport highways for the molecular motors (left side, lower part). Diffusive track of a quantum dot confined to the boundary of a lipid domain by dipole-dipole interactions (right side). (scale bars = 5 µm)

Molecular motor-based transport of nano-loads has on first sight obvious advantages compared to diffusive transport in liquid crystalline films since it is directed and engulfs no randomness. However, this is only half the truth. Motor-based transport along a polar biopolymer is only reliably directional until the motor detaches either due to the motor's limited processivity or due to the limitation that the biopolymer ends and the motor has to attach to another biopolymer. This problem can be partially solved by the use of highly processive motors. However, the length of a biopolymer is considerable (~20 µm) but not infinite. Furthermore, the transport of loads by motors is one-by-one. This can cause traffic jams and is inefficient when the transported load is a molecule that should feed a chemical reaction. For chemical reactions nano-structured liquid crystalline films seem to be more advantageous. The two dimensionality increases significantly the collision probability in reaction-diffusion-systems, yet it permits much higher mass flows than a one-dimensional system, which allows only one-by-one transport.

The expected results (for the transport in lipid films and the motor-based transport) will provide ground rules for how to employ active transport and Brownian motion of molecular nano-objects

in a constructive manner when they propagate through nanostructured environments. The resulting assembly lines will be ultimately combined with functional elements, which will be developed in parallel.

2.1.4 Expertise in methods



Synthesis, making of new building blocks
[Beck-Sickinger, Grundmann, Hey-Hawkins, Käs, Kersting, Krautscheid, Rauschenbach, Robitzki]

The basis of multifunctional, smart materials is the combination of a rich multitude of building blocks, such as inorganic and organic molecules, nanoparticles, proteins, and nano- and micro-structured surfaces. In the synthesis of organometallic compounds and transition metal complexes modern techniques will be employed, such as state-of-the-art synthesis and handling of air- and moisture-sensitive samples (Schlenk-line techniques).
Chemical vapor deposition of molecular precursors (CVD, MOVPE) and physical epitaxial methods are used for the preparation of thin-film nanostructures.
Self-assembly of metal salts or complexes with corresponding linkers in organic solvents also allows the selective and high-yield synthesis of inorganic-organic hybrid materials (so-called Metal-Organic Frameworks (MOFs)), when the reaction partners and conditions are correctly chosen. The diversity of possible linkers and metal ions or metal clusters as building units is the basis for the variety in structural topologies with corresponding special properties of these polymeric coordination networks.
For biomolecules basic methods, such as robot-assisted parallel bioorganic synthesis of peptides and peptidomimetics, protein expression, modification, and biochemical characterization, as well as novel concepts, such as native chemical ligation (NCL) and expressed protein ligation (EPL), will be used. Special attention will be paid to the synthesis of chemically modified peptides and proteins. This includes peptides that contain chelators to attach metal ions, covalent linkage of peptides and proteins to quantum dots, and strategies for side specific modification by side chain protection strategies. For all types of molecules strategies for their purification and characterization are employed. For bioorganic molecules this includes analytical and preparative HPLC, modern mass spectrometry (FT-ICR, Maldi-TOF/TOF, nano-HPLC-ESI-Q3), Edman-sequencing with sub-pmol-sensitivity, circular dichroism spectrometry, solution and solid-state NMR spectroscopy, up to 700 MHz and 750 MHz, respectively.
Physical and chemical methods will be employed for the fabrication of insulating, metallic, semiconducting and polymeric films. Low-energetic ions, electrons, plasmas as well as VUV and UV photons are utilized in micro- and nanostructuring with beam techniques. These

techniques are complemented by lithography.

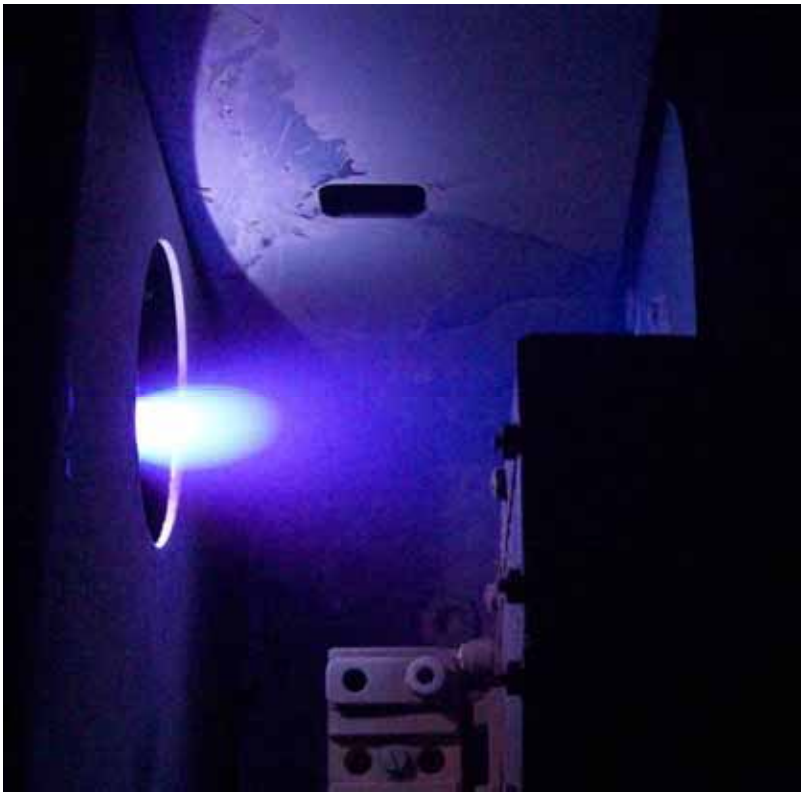


Fig. 13 Plasma plume during Pulsed Laser Deposition of ZnO-based whisker-like nanostructures.

Thus, for chip structuring the following processes are realized: (i) lithography mask design, (ii) mask manufacturing, (iii) standard substrate cleaning, (iv) lithography using photo resist deposition, exposure and development, (v) metal layer sequence (subtractive or additive metal structuring, Ti, Au, etc.), (vi) reinforcement of the contact pads at the interface, (vii) deposition of a passivation layer (PECVD of Si_3N_4 in a plasma reactor, etc.), (viii) a second photo lithography for electrical contact areas, (ix) reactive ion etching of the passivation layer to excavate electrodes in the vicinity of, e.g., cavities and external connection areas, (x) contact area reinforcement of the electrodes (current-based electroplating of gold), and (xi) dicing the 6” substrate into the required MTB format (modified standard wafer dicing).

Nano- and micromanipulations

[Käs, Keyser, Kremer, Rauschenbach, Robitzki]

Self-assembly and self-organization will be the key building principles. Nevertheless, nano- and micro-manipulation techniques will have a central role in probing the spatially inhomogeneous newly created materials. Laser-based techniques are particularly well-established in Leipzig.

Besides state-of-the-art optical tweezers to probe single molecules and laser microbeam devices to dissect and cut on the submicron level, new optical trapping methods, such as the Optical Stretcher to determine the mechanical properties of soft dielectrics, optical cell guidance that locally manipulates intracellular (as well as *in vivo*) biochemical reactions, and the cell rotator for the controlled rotation of microscopic objects, have been developed. The Optical Stretcher and optical cell guidance have found world wide acceptance and are applied to a wide range of problems. The Optical Stretcher and the cell rotator are patented techniques that are licensed to Zeiss – commercial devices will be on the market by fall 2008 – and are already successfully used in medical research or by industrial partners such as Beiersdorf. The US based National Cancer Institute has identified the Optical Stretcher has a key nanotechnology in future tumor diagnostics. Furthermore, AFM-based microrheology has been developed to characterize polymeric scaffolds and is now further improved in collaboration with the Berlin based company JPK. Moreover, single nanopores are utilized for the detection and characterization of polymeric molecules in solution. Electrophoreses of polymer molecules through a single nanopore in combination with high-resolution force measurements enables the determination of the local effective charge distribution as well as the size of polymeric molecules.

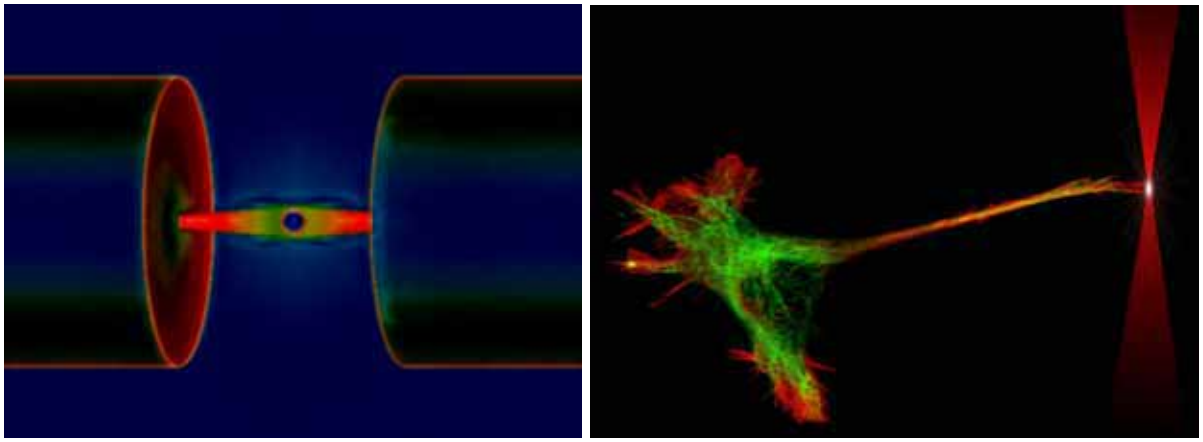


Fig. 14 For the Optical Stretcher technology two counter propagating laser beams emitted from single mode fibers are used for the controlled deformation of soft dielectric materials (left side). The gradient forces exerted by optical tweezers are used to gain optomolecular control over a growing neuron (right side).

Optical tweezers are the perfect fingers to hold and probe contact-free individual objects from the range of single molecules to entire biological cells. Moreover, holographic tweezers or tweezers quickly scanned with acusto-optic-deflectors can generate energy landscapes that produce spatially modulated distributions of dielectric matter. This effect can be explored to gain optomolecular control over chemical reactions. The forces generated by tweezers are weak and thus ideally suited to probe weak interactions, typically found in biological matter. Optical tweezers can be ideally combined with laser microbeams that allow cutting and dissection of

objects. The mechanical properties of soft dielectrics, in particular biological cells, can be probed with the Optical Stretcher. The Optical Stretcher permits high throughput cell elasticity measurements as novel biological cell marker that does not require expensive and contaminating molecular markers. It can be used to isolate adult stem and progenitor cell as well as other rare cells. In cancer diagnosis it uniquely permits to detect the metastatic potential of tumors without resecting nearby lymph nodes. The cell rotator, a novel device that is based on further development of the Optical Stretcher, can be used for optical tomographic approaches to achieve isotropic high-resolution imaging of suspended objects.

Modular setups that combine optical tweezers, microbeam cutting, and optical cell guidance as well as combinations of Optical Stretcher, microbeam, and cell rotator have been established. An intensive and firm scientific exchange between the groups that work with optical manipulation techniques leads to strongly synergistic and accelerated development of these optical techniques.

Stronger forces, e.g., to pull on a molecule, can be generated by scanning force microscopy (SFM) and spectroscopy. They also provide a better accuracy to position nano-objects. However, the object has to be bonded to the SFM-cantilever. Furthermore, SFM is well-matched to perform micro- and nanorheology of thin polymeric films.

Imaging, spectroscopy, and characterization

[Berger, Butz, Esquinazi, Haase, Grundmann, Käs, Krautscheid, Kremer, Morgner, Robitzki]

The development of new materials relies on their precise characterization. Optical techniques, such as single molecule microscopy and confocal/multiphoton microscopy with an unique home-built supercontinuum laser source, are complemented by dual-beam field-emission electron microscopy, TEM, X-ray diffraction, various scanning probe techniques (STM, AFM, etc.) and surface physics methods (XPS, AES, MIES, LEED, etc.).

Characterization of materials on the nanoscale is performed with respect to the structural, mechanical, optical, electrical, and magnetic properties. A recently acquired dual beam microscope with high-resolution electron backscatter diffraction option allows for a quantitative microstructural analysis of materials with a spatial resolution of better than 20 nm. The 14-quadrant low-voltage transmission electron microscopy sensor recently available for scanning microscopes will be used for further characterization of structures, grain boundaries and texture. Optical and electronic properties of nanostructures can be investigated by a variety of electrical (IV and CV spectroscopy, DLTS, SCM) and optical (MIR-UV ellipsometry and luminescence, FTIR, Raman) methods. The mechanical and vibrational properties of nanostructures are investigated by high-resolution interferometric spectroscopy and ultrasonic techniques.

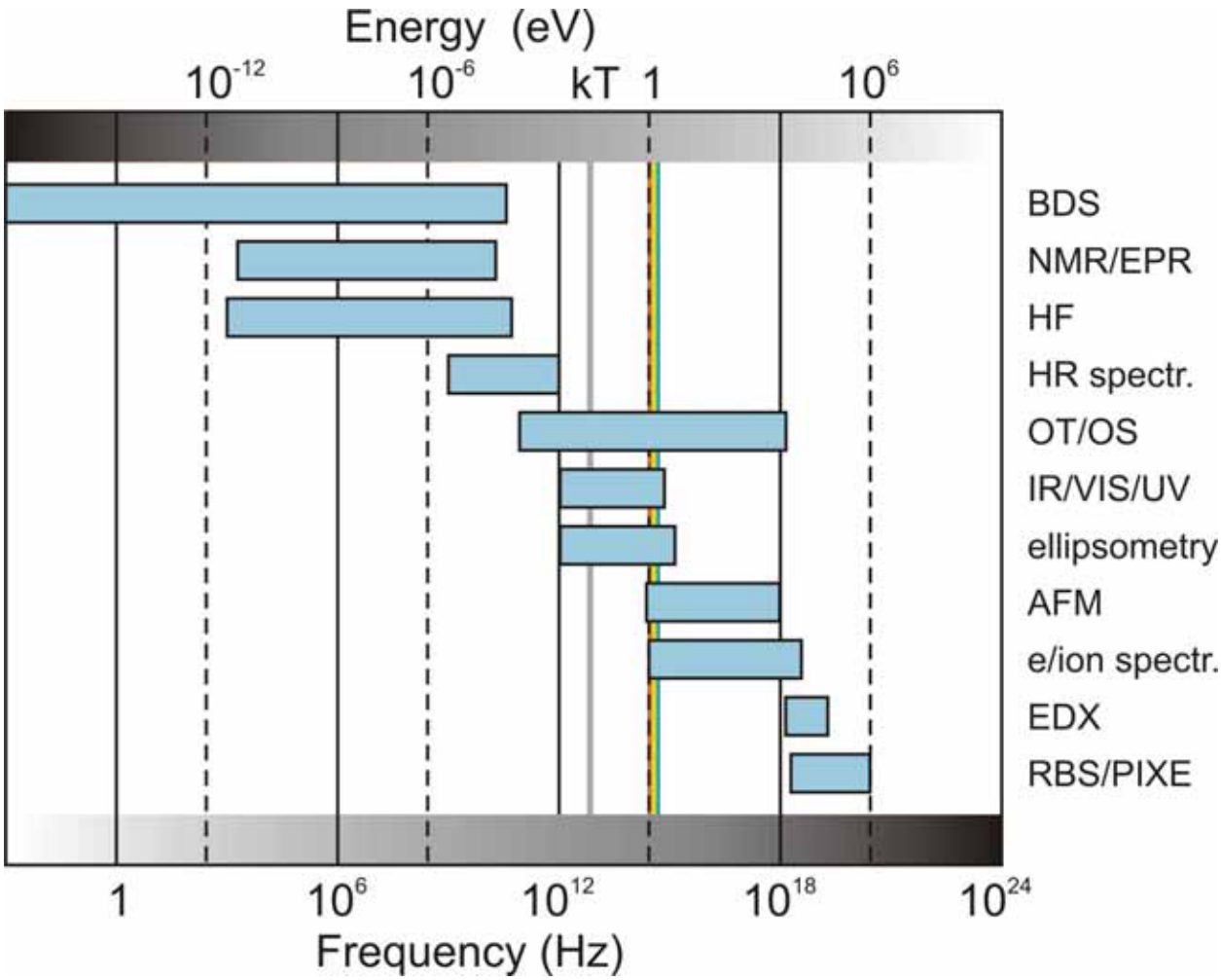
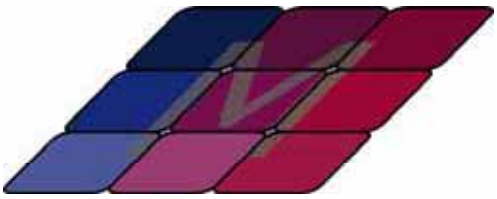


Fig. 15 Selection of experimental methods available in the Graduate School, sorted according to spectral region and/or typical energies or quantum transitions involved.
BDS: broadband dielectric spectroscopy, NMR/EPR: nuclear magnetic resonance, electron paramagnetic resonance, HF: high-frequency electronic characterization, HR spectr.: high-resolution spectroscopy, OT/OS: optical tweezer/optical stretcher, IR/VIS/UV: spectroscopy in the infrared, visible and ultraviolet, AFM: atomic force microscopy, e/ion spectr.: electron and ion spectroscopy, EDX: energy-dispersive X-ray analysis, RBS/PIXE: Rutherford backscattering, particle induced X-ray emission.

Magnetic nanostructures are investigated using magnetic force microscopy and SQUID-based magnetometers. Their transport properties are measured through magnetoresistance and the anomalous Hall effect. Unique strength in several key characterization techniques has been established in Leipzig. The high-energy ion nanoprobe LIPSION is used to reveal morphological as well as compositional information by particle-induced X-ray emission (PIXE), Rutherford backscattering spectrometry (RBS) and scanning transmission ion microscopy (STIM). Molecular and polymer dynamics are investigated by broadband dielectric spectroscopy. Magnetic resonance is one of the major methods for exploring high-, as well as low-energy structures of materials. Unlike surface methods, bulk information with atomic-scale resolution for different points in the unit cell or parts of the molecule can be obtained. The current magnetic

resonance research facilities and equipment available in Leipzig are outstanding and in some respect unique in the world. Magnetic resonance in the highest possible fields (pulsed magnets) is pioneered in Leipzig, many more outstanding techniques (pulsed field gradient NMR, high-resolution liquid and solid-state NMR, ENDOR) are developed and applied to materials science in various laboratories.

Toxicity and biocompatibility is tested by cell- and tissue-based biosensors. Novel 3D microcavity arrays with four electrode configuration for 3D *in vitro* tissue biomonitoring were developed and tested for use as diagnostic modules (tumor diagnosis – characterization of biopsy material for individual cancer therapy). The main aspect of microsystem and sensor system technology is the creation of point-of-need analysis and point-of-care diagnostics. Therefore, portable, efficient, cost-effective manipulation and analytical devices based on self-organizing polymers with integrated detection systems as disposables are in the focus of the research.



Theory

[Janke, Kroy, Müller]

When building with molecules and nano-objects, theory must help to understand not only the constituents, in addition, it has to describe the new emerging systems and their properties that in most cases cannot be anticipated by theory. The reason is that their physical properties and functions cannot be attributed to individual molecules, but arise from the interplay of structures on multiple scales. In this respect, a living biological cell provides a more suitable paradigm for smart materials than textbook examples of solids. Often chemical, mechanical (and biological) aspects cannot easily be studied in isolation and are functionally intertwined. Understanding how the design of these new materials gives rise to desired properties and discovering the general principles that govern their structure, self-organization, and multiscale dynamics, requires a multifaceted toolbox on the theoretical side. We can build on our strong track record in the modeling of the non-equilibrium properties of colloid and protein gels, the viscoelastic mechanics of the cytoskeleton, the non-equilibrium dynamics of DNA molecules under strong external fields, and adsorption properties and structure formation of peptides interacting with solid surfaces. Methods of statistical physics for the exploration of associated free-energy landscapes and characterization of folding channels as well as aggregation properties are other important tools which will be further improved to tackle these challenging topics. Related experimental work is currently in progress in participating groups at Leipzig. A common feature in many of the mentioned problems is the presence of strong fluctuations and stochastic dynamics on the microscale. The emergence of the macroscopic structure and its

(deterministic) dynamics is to be understood.

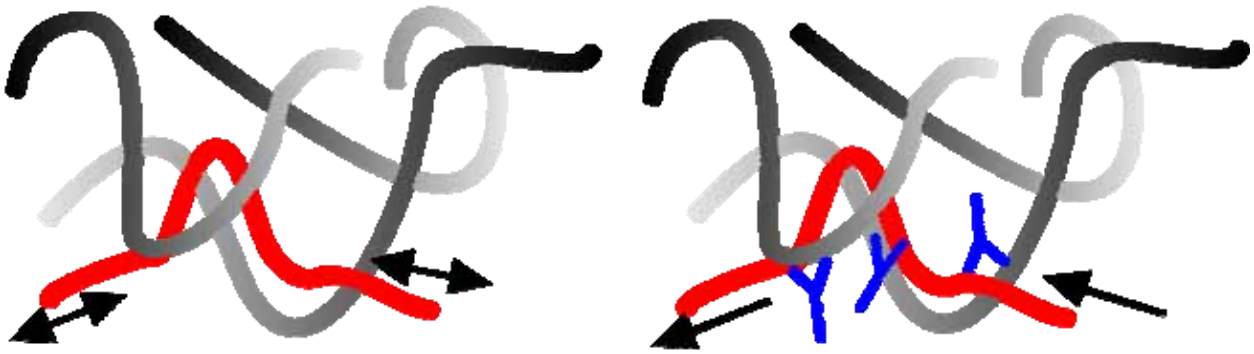


Fig. 16 In active polymer scaffolds (right side) nano-sized molecular motors supersede the polymer chain's Brownian-driven random back and forward motion (left side) and cause directed sliding of the filament and overcome the inherently slow polymer dynamics.

The applied methods range from analytical studies of stochastic integro-differential equations through liquid-state theories, mode-coupling theory, effective hydrodynamic equations, phenomenological modeling, to numerical simulations. For the protein folding problem a multiscale hierarchy of formulations is used, ranging from coarse-grained lattice and off-lattice heteropolymer models to all-atom formulations with varying degrees of resolution. Depending on the level of description, advanced chain-growth algorithms and Markov chain Monte Carlo simulations in generalized ensembles (parallel tempering, multicanonical ensembles, and combinations thereof) are employed. While explorative studies can be performed on local resources, large-scale simulations are run on supercomputers of national research centers (e.g., NIC at FZ Jülich).

On the smallest scale quantum statistical physics will be used, which includes a combination of analytical and numerical techniques. Since in our program nanoscale elements will be organized by polymeric scaffolds, Leipzig's strong expertise in the theoretical analysis of various soft condensed matter systems (such as the cytoskeleton) will be used for the design of these multifunctional scaffolds. The knowledge gained in (quantum) statistical physics and soft matter theory will be integrated in multiscale modeling approaches used at Leipzig's Max Planck Institute for Mathematics in the Sciences to design fundamentally new materials. Non-equilibrium statistical mechanics of the cytoskeleton, interacting stochastic processes, phase boundaries, and multiscale plasticity are central research topics in our Mathematics Department and at the Max Planck Institute for Mathematics in the Sciences as well as in the Top-level Research Area "Mathematical sciences and their application". These subjects will create innovative theoretical approaches that will help to predict and understand the new materials which are the focus of the Graduate School BuildMoNa.

2.1.5 Long-term objectives

The Graduate School "Leipzig School of Natural Sciences" is devoted to the scientific field

"Building with Molecules and Nano-objects" (BuildMoNa). Objects on the nano-scale have fascinating properties and form a natural interface between physics, chemistry, and biology. In a post-nano age the focus of materials science is no longer only on characterization and understanding of these objects. As a wide variety of nano-scale objects will become available as building blocks, the long-term question is how a multitude of different nano-building blocks can be assembled preferentially by self-organization to materials with complex, but predictable properties. Consequentially, it is our aim to prepare our doctoral candidates for this challenge.

The Graduate School BuildMoNa will be established in November 2007. However, already before November the first call for applications will be announced. At the beginning suitable candidates who have already started their doctorate and are currently supported by third-party funding will be enrolled. From January 2008 on, doctoral candidates funded by the Graduate School, the university and the federal state of Saxony will be continuously enrolled until the maximal number of 100 doctoral candidates is reached. In 2011, we will submit an application for extension of funds for our Graduate School until 2017. Continuation of the Graduate School from 2012 on will be pursued independently of the outcome of our application for extension within the Excellence Initiative by the German federal and state governments to promote science and research at German universities.

The Research Academy Leipzig (RAL) provides a stable framework for the Graduate School. The RAL is financed by the Universität Leipzig and encompasses doctoral training within the entire university, not only in natural sciences as focused on in this application. The RAL has been set up for internal and external review by the Universität Leipzig's Vice Rector of Research to continuously monitor and optimize its efficiency. We expect that the high quality of our interdisciplinary research and the attractiveness of the training program will enable us to successfully acquire funds to continuously enroll highly qualified young researchers. The scientific program laid out in this application is innovative and provides scientific challenges for many years to come. Nevertheless, in the long-term the Graduate School BuildMoNa will critically review its visions and research aims and dynamically adjust its research agenda to the most relevant and challenging questions and to the most promising applications. It will also adapt to the inevitable change of personnel in the groups of the PIs, e.g., due to retirement, and strive to recruit further outstanding academic teachers and researchers. Therefore, the structure established through this application is durable, yet dynamic and will be sustained beyond the initial funding period. The Graduate School BuildMoNa will be the nucleus of the Universität Leipzig's vision in the natural sciences and will trigger further initiatives and applications for third-party funding.

2.1.6 Technology transfer

[Beck-Sickinger, Berger, Esquinazi, Grundmann, Käs, Rauschenbach, Robitzki]

The profound expertise and track record in the development and improvement of cutting-edge

technologies has resulted in intensive relations with industry that use or commercialize these novel techniques. A long-standing cooperation with Bruker assures that Leipzig's advances in magnetic resonance become available in the newest NMR machines. Novel optical micro- and nano-manipulation techniques such as the Optical Stretcher will be commercialized by Zeiss. Zeiss is also interested in applications in cancer diagnostics and the isolation of adult stem cells. Biomedical applications of cell-based biosensors are pursued together with Chemilia AB, Pharmacelsus GmbH, and KeyNeurotek AG. Optical cell manipulation techniques for tissue engineering are tested together with Beiersdorf and Euroderm. In addition, a wide variety of scanning probe techniques is also significantly improved. For example, magnetic polymers as well as magnetic structures will be used as dielectric coats for cantilevers to test their use in magnetic force microscopy studies. AFM-based cell rheology will be integrated in the AFMs produced by JPK. In another key area, nanoparticles used as reactants or catalysts are among the most promising new tools for *in-situ* cleaning of contaminated groundwater and aquifers (Bauer Umwelt GmbH). Testing under field conditions is possible in the UFZ research program SAFIRA and its facilities. Close, formalized cooperations on current topics of semiconductor device research, production and supply products exists with various German and European companies (FCM, OSRAM Opto Semiconductor GmbH, AIXTRON).

2.2 Contribution to the university's strategic planning

Materials science has shifted from a pure engineering discipline towards fundamental contributions from natural sciences, thereby crossing the borders between chemistry, physics, biosciences, and mathematics. Based on previous excellent collaborative research activities fundamental interdisciplinary research in materials science represents one of the Universität Leipzig's Top-Level Research Areas ("Profilbildender Forschungsbereich", PbF 1), which predominantly covers the research fields of nano- and microdimensional compound semiconductors, molecules interacting with fluid and solid interfaces, polymer nanostructures, molecular precursors, and active polymer scaffolds in biological cells. Accordingly, the DFG Research Units FOR 522 "Architecture of Nano- and Microdimensional Building Blocks", FOR 404 "Oxidic Interfaces", FOR 365 "Particle Beam Stimulated Ultra-Precision Surface Processing" and the Collaborative Research Center SFB 610 "Variation in Protein Conformation: Cellbiological and Pathological Relevance" have successfully contributed to the university's profile and the establishment of interdisciplinary collaborative research. Furthermore, the participating PIs and faculties have been involved in European collaborative research activities, such as the EU Network of Excellence: SANDiE "Self-Assembled Semiconductor Nanostructures for New Devices in Photonics and Electronics"; EU STRePs: NANDOS "Nanophotonic and Nanoelectronic Devices from Oxide Semiconductors", FERROCARBON "Room Temperature Ferromagnetism in Graphite and Fullerenes", ACTIVE BIOMICS "Active Biomimetic Systems"; EU RTN: ENRAGE "Random Geometry and Random Matrices: Quantum Gravity to Econophysics", and CELLION "Studies on Cellular Response to

Targeted Single Ions Using Nanotechnology". Moreover, the Universität Leipzig has gained fundamental experience in the training of young researchers within well-structured graduate programs such as the International Postgraduate Program (IPP) "Research at the Frontiers of Chemistry", the Research Training Groups "Mechanisms and Applications of Non-conventional Oxidation Reactions" and "InterNeuro", the International Research Training Group "Diffusion in Porous Materials", and the previous Marie-Curie Training Site "Design of Homogeneous and Heterogeneous Catalysts".

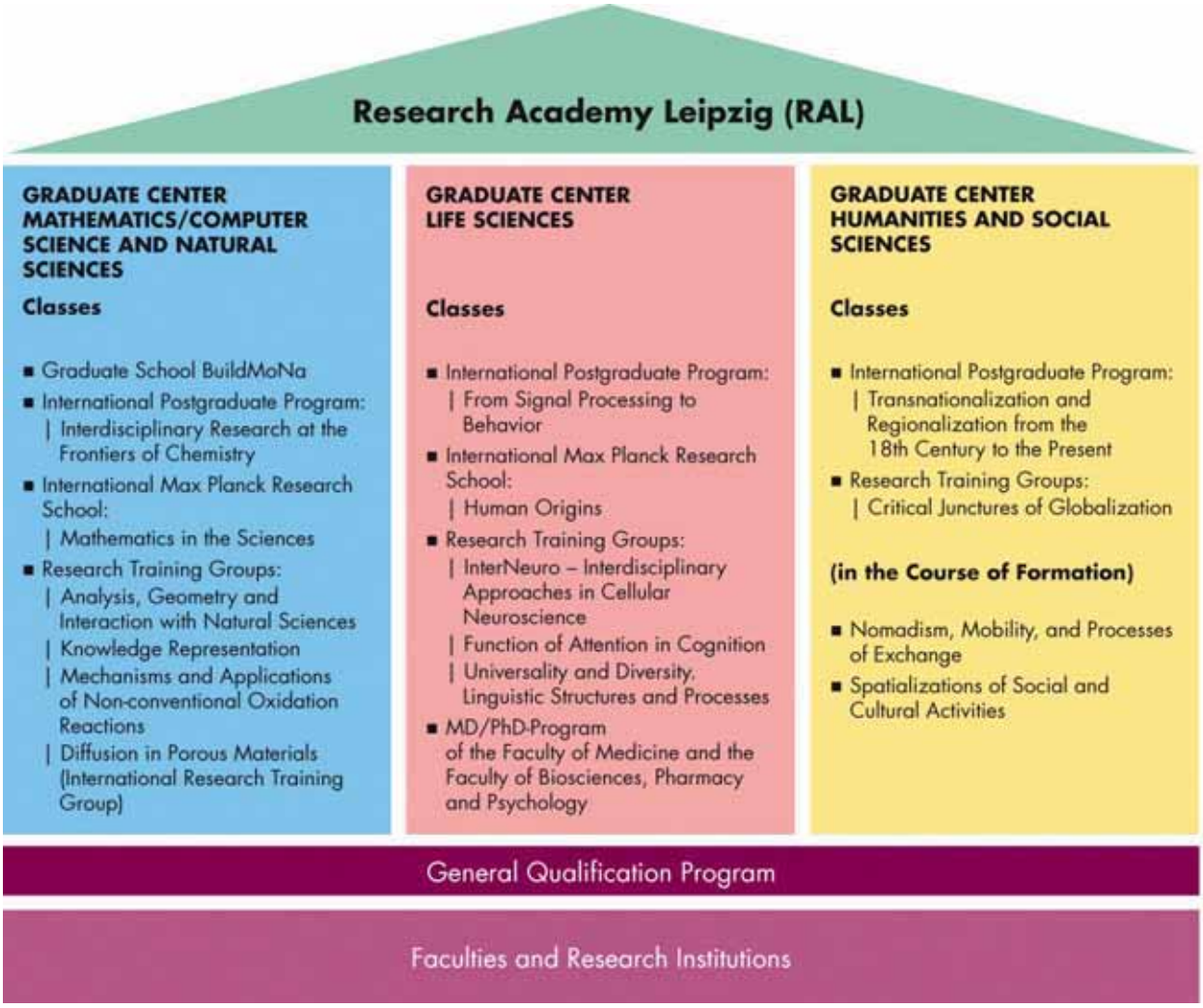


Fig. 17 Research Academy Leipzig (RAL) with three Graduate Centers and their respective Classes.

To meet future challenges in research and in training of young researchers the Universität Leipzig has established the "Research Academy Leipzig" (RAL) which interlinks both doctoral training programs and the university's Top-Level Research Areas. The RAL is organized in the three Graduate Centers "Mathematics/Computer Science and Natural Sciences", "Life Sciences", and "Humanities and Social Sciences" (Fig. 17). The RAL aims at the organization of well-structured training programs, the Classes, and provides the infrastructure for innovative research. Thus, tasks of the RAL include the establishment of graduate schools, the recruitment

and training of excellent doctoral candidates, as well as networking and internationalization. To strengthen research and to promote innovative projects, the RAL will also enable strategic appointments, guest professorships, and flexible seed funding. The proposed Graduate School will be an integral part of the RAL and will represent one of its classes. Within the RAL framework the Graduate Centers, the University's Rectorate, the Career Center, and the Science Support Center cooperate.

Furthermore, the Universität Leipzig and the Saxon Ministry of Science and the Fine Arts (SMWK) will facilitate and support the implementation of the Graduate School BuildMoNa by providing additional scholarships, financial support, and additional funds for the purchase of instrumentation to ensure a state-of-the-art research infrastructure for the Graduate School (as outlined in 5.1.3). Furthermore, more expensive and larger instrumentation will be acquired from the appropriate research funds of the university, whereby the requirements of the Graduate School BuildMoNa are granted highest priority.

The Graduate School‘s research will benefit from the further development of the Top-Level Research Area 1 (PbF 1). This is part of a mutual agreement of the PbF and the university's rectorate. Thus, the PbF 1 will further strengthen its research profile by the application for and the establishment of additional DFG Research Units and Collaborative Research Centers. Future plans also include at least one early senior faculty appointment in “Chemical Vapor Deposition” as one of PbF 1's key areas, timely replacement of retiring principal investigators, establishment of up to three junior professorships, and the purchase of major cutting-edge equipment (e.g., MOVPE for semiconductor nano-heterostructures, high-resolution cryoTEM for structural and chemical analysis of materials).

Furthermore, our plans include the creation of a new materials science center “Laboratory for Interdisciplinary Studies and Applications” (LISA), to better facilitate the Graduate School's objectives. It will be home to the Graduate School's techniques and will offer a platform for collaborations with industrial partners and technology transfer. It will be divided into five sections: micro- and nanostructures, laboratory for tomography, catalyst testing laboratory, biological core facility, and an NMR/EPR platform. Especially young researchers and doctoral candidates will benefit from this excellent scientific and technological infrastructure. In addition to the mentioned Top-Level Research Area 1 (PbF 1) the Graduate School will also interact with PbF 2 “Mathematical Sciences” (by applying mathematics from the areas “Quantum Structures” and “Complex Systems: Mathematical Methods, Computional Tools, Biological Models”), PbF 3 “Molecular and Cellular Communication: Biotechnology, Bioinformatics and Biomedical Sciences in Therapy and Diagnostics” (in the areas “Nanobioelectronics” and “Bioorganic and Bioanalytical Techniques”), and with PbF 4 “Brain, Cognition and Language” (e.g., in the area “Analysis of Neuronal Networks”) (see Fig. 18 and www.uni-leipzig.de/profil), which is quintessential for our interdisciplinary research concept. In particular, within the Top-Level Research Area “Mathematical sciences and their application", the Graduate School BuildMoNa

will be an ideal partner providing inspiration and validation for the center's mathematical modeling efforts.

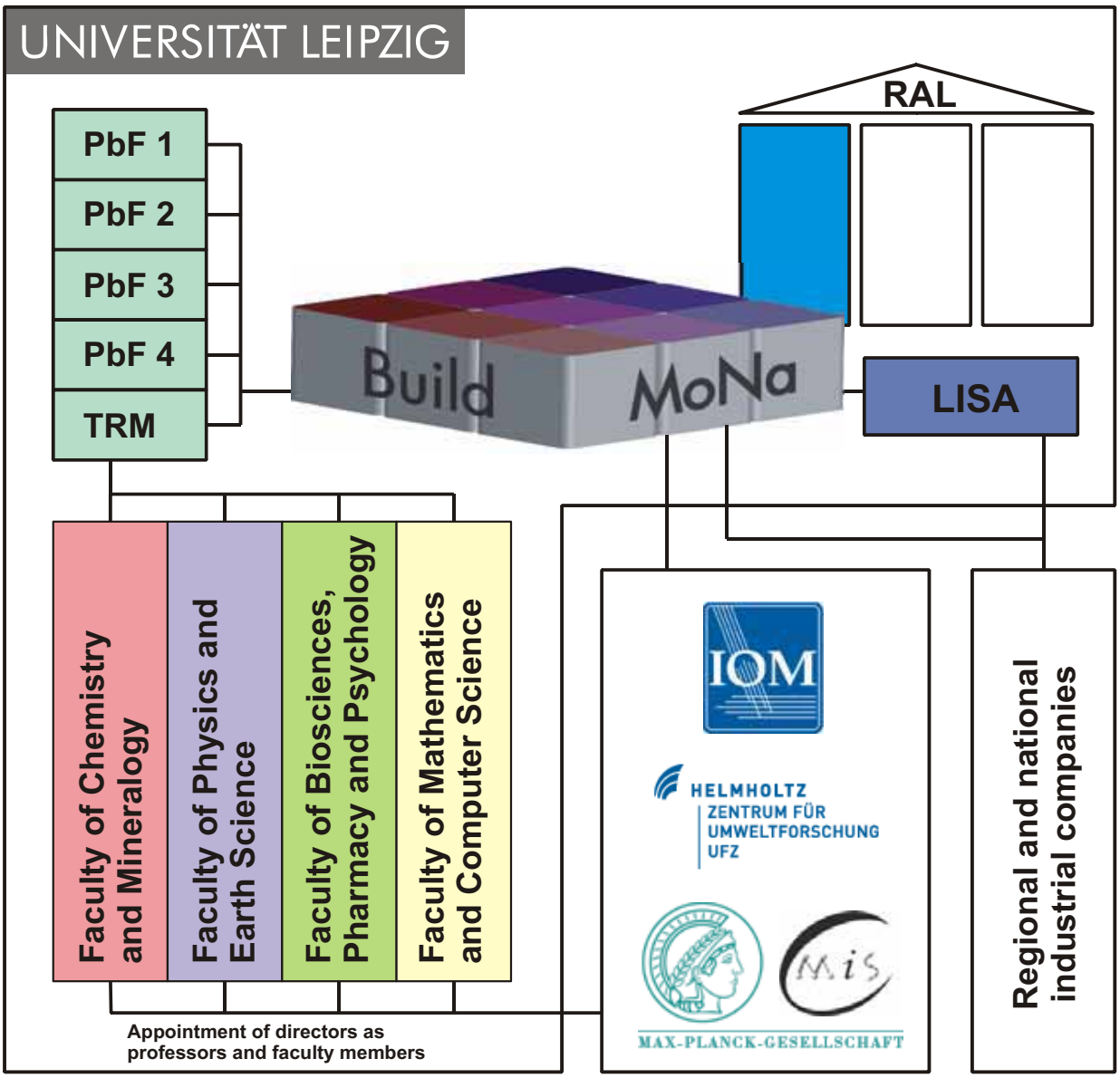


Fig. 18 Strategic planning and interaction of the Graduate School BuildMoNa with the university's Top-Level Research Areas (PbFs).

PbF 1: Multifunctional Materials and Processes from Molecules and Nanodevices, PbF 2: Mathematical Sciences, PbF 3: Molecular and Cellular Communication: Biotechnology, Bioinformatics and Biomedical Sciences in Therapy and Diagnostics, PbF 4: Brain, Cognition and Language, LISA: Laboratory for Interdisciplinary Studies and Applications, TRM: Translational Center for Regenerative Medicine

In 2006 the BMBF granted the Universität Leipzig funding for the Translational Center for Regenerative Medicine (TRM) (annual budget of 4 Mio € for up to 12 years with re-evaluation every four years; www.trm.uni-leipzig.de). Application of novel materials in medicine will be investigated in the TRM, and a close collaboration with the Graduate School BuildMoNa is planned. Three out of four research areas of the TRM are directly linked to the Graduate School

BuildMoNa and are headed by PIs of our Graduate School (TEMAT (headed by Rauschenbach): Tissue Engineering and Materials Science; REMOD (headed by Beck-Sickinger): Regulatory Molecules and Delivery Systems; IMONIT (headed by Robitzki): Imaging, Modeling and Monitoring of Regeneration) and this will assure the transfer of results from basic research to application. Joint workshops and meetings of TRM and the Graduate School BuildMoNa are planned.

2.3 Partnerships and collaborations

The long-standing cooperation with local external academic institutions, such as the Leibniz-Institute of Surface Modification (IOM), the Max Planck Institute for Mathematics in the Sciences (MPI-MiS), and the Helmholtz-Center for Environmental Research Leipzig-Halle (UFZ) (part of the Helmholtz Association), continues to be very lively and highly productive. The directors of the IOM and MPI-MiS as well as researchers of the UFZ are appointed as full professors at the appropriate faculties (Faculty of Chemistry and Mineralogy, Faculty of Physics and Earth Science, Faculty of Biosciences, Pharmacy and Psychology, Faculty of Mathematics and Computer Science, etc.) of the Universität Leipzig. These local external academic institutions and the principal investigators of the Graduate School BuildMoNa are currently involved in numerous joint cooperatively funded international research initiatives (e.g., EU STReP FERROCARBON, RTN ENRAGE, etc.).

Furthermore, world-renowned scientists with additional expertise in materials science are also involved in the Graduate School, both in the training of doctoral candidates (as guest lecturers and with joint research activities) and in offering the use of research facilities (e.g. Cavendish Laboratories at the University of Cambridge, Institute Curie in Paris, Harvard Medical School in Boston) abroad. Among these partners are European, American, and other international leading academic institutions, such as the Institute Curie, ESPCI, various laboratories of the CNRS, the University of Cambridge, St. Petersburg University/Ioffe Institute, the Consejo Superior de Investigaciones Cientificas (CSIC, Madrid), the University of Milan, Harvard University, Stanford University, Princeton University, University of Texas at Austin, University of Pennsylvania, University of Edmonton, ETH Zürich, and the Australian National University. The Universität Leipzig's active role as a member of the "Institute for Complex Adaptive Matter" (ICAM) enhances our worldwide contacts, visibility and engagement in excellent research and education. The Graduate School's spirit also aligns with some of ICAM's goals such as interdisciplinary "bottom-up" research and focus on the education of young researchers. Moreover, doctoral candidates are eligible for ICAM funding that includes participation in ICAM-brand workshops, visits at ICAM-node partners, or even fellowships for extended stays at the partners.

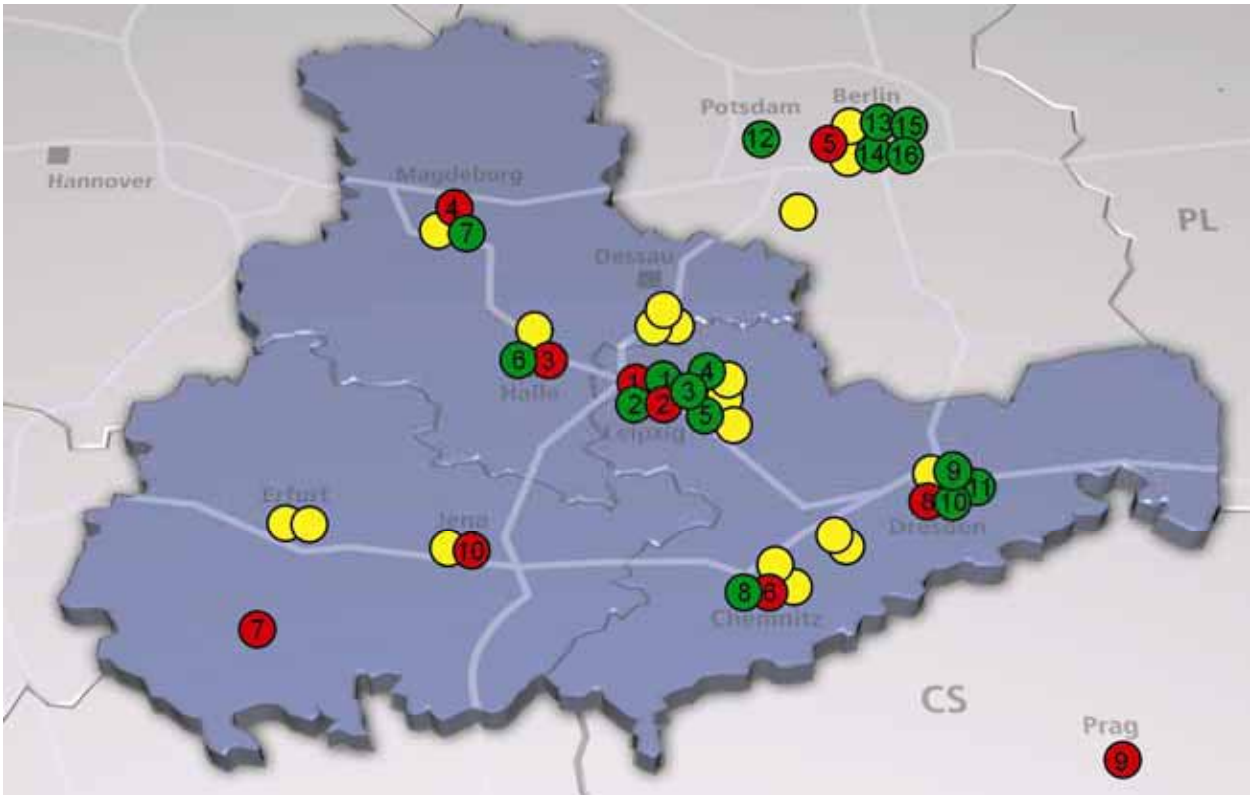


Fig. 19 Partnerships and collaborations of the Graduate School BuildMoNa in the region

Universities: 1 Universität Leipzig, 2 HTWK Leipzig, 3 Martin-Luther Universität Halle, 4 Otto-von-Guericke Universität Magdeburg, 5 TU Berlin, 6 TU Chemnitz, 7 TU Ilmenau, 8 TU Dresden, 9 University of Prague, 10 Friedrich-Schiller-Universität Jena

Research Facilities: 1 Leibniz-Institute of Surface Modification (IOM), 2 Max Planck Institute for Mathematics in the Sciences (MPI-MiS), 3 Helmholtz-Center for Environmental Research (UFZ), 4 Institute of Non-classical Chemistry (INC), 5 Institute for Isotope Research (IIF), 6 Max Planck Institute for Physics of Microstructures, 7 Fraunhofer Institute for Factory Operation and Automation, 8 Fraunhofer IZM Assembly and Packaging Technologies for Microsystems, 9 Forschungszentrum Dresden Rossendorf, 10 MPI for the Physics of Complex Systems, 11 MPI for Cell Biology and Genetics, 12 MPI of Colloids and Interfaces, Potsdam, 13 Physikalisch Technische Bundesanstalt Berlin, 14 Fraunhofer IZM Branch Lab Micro Devices and Equipment, 15 Fritz-Haber Institute Berlin, 16 Hahn-Meitner Institut Berlin

Companies, SMEs

Multinational, global industrial partners are involved in the Graduate School through technology transfer and joint research projects, through participation as guest lecturers within the training program and by offering industrial internships (see chapter 3.2). These activities are or will be formalized in mutual cooperation agreements. Accordingly, the Graduate School will benefit from these collaborations, but will additionally continue to strengthen the interaction and cooperation with both non-university research institutions and industrial partners in the region. As can be seen from Fig. 19 the Universität Leipzig serves as an anchor for regional companies in various industrial sectors such as photovoltaics, semiconductor industry, biotechnology,

biophysics and biomedicine. The University is regarded by the companies as an important partner for scientific cooperation and for the education and training of future employees. The Universität Leipzig is an essential part of the thriving area “Mitteldeutschland”, with the town of Leipzig currently having the highest growth rate in Germany (Prognos, Zukunftsatlas, 2007).

3 RESEARCH TRAINING, SUPERVISION AND CONDITIONS OF THE DOCTORATE

To meet the increasingly broad skill demands in science and industry the interdisciplinary graduate training includes both research and a well-structured curriculum. The independent research work carried out by doctoral candidates, under thorough supervision, represents a major part of the graduate training. In addition, individual scientific training in key research areas and soft skills (as parts of the Personal Development Plan (PDP)) contributes to a highly valuable and lasting education. Moreover, the training program profits from the involvement of international and industrial partners.

To meet the high-level scientific demand, the Graduate School’s target groups are excellent and highly motivated students with either a BSc, MSc or a diploma degree in natural sciences from all regions of the world. In particular, applicants with outstanding results in a bachelor’s degree (grade A, min. 6 semesters) can be admitted to a “fast track” for a doctoral degree. For these students a preparatory training provides the necessary skills and knowledge for a subsequent doctorate. The regular duration for graduation is foreseen to be three years if the students enter with a MSc or diploma degree. The official language is English. In total a minimum of 20 credit points (CP) has to be acquired within the training program. These credit points can serve as the replacement of the rigorosum[1] in accordance with the Faculties’ Graduation Rules.

At the end of the doctoral training the achieved research results must be presented at a public defence, and the doctoral degree Dr. rer. nat. will be awarded.

3.1 Admission and formal requirements for the doctorate

The basic formal requirements of graduate studies are formulated in the Faculties’ Graduation Rules. These rules have been continuously reformed according to the internationalization and structuring of doctoral studies over the last years. Thus, the four faculties participating in the Graduate School BuildMoNa (Faculty of Chemistry and Mineralogy, Faculty of Physics and Earth Science, Faculty of Biosciences, Pharmacy and Psychology, and Faculty of Mathematics and Computer Science) revised their Graduation Rules to permit the admission of the Graduate School’s doctoral candidates, the recognition of qualifications (credits points) within the Graduate School’s structured doctoral training as replacement of the previous rigorosum, and

[1] Rigorosum means an oral exam in the scientific field of the doctoral theses and neighboring subjects. It takes place after acceptance of the dissertation. Depending on the faculty’s rules, 2–8 examiners are involved.

internationalization (joint doctoral studies called "*cotutelles de thèse*", and the use of foreign languages for their doctoral thesis and examinations).

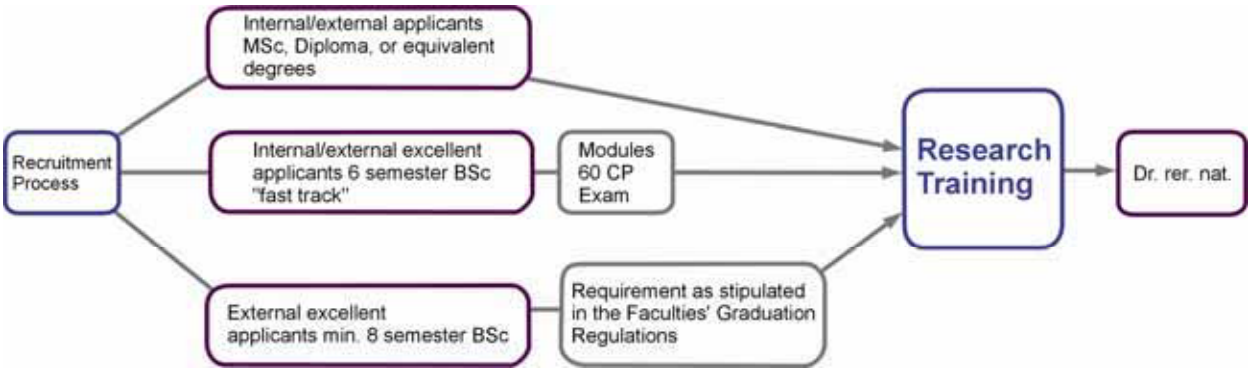


Fig. 20 Admission of applicants with either a BSc, MSc, or diploma degree in natural sciences.

In addition, the Research Academy Leipzig (RAL) provides general guidelines regarding the recruiting of doctoral candidates as well as for the supervision and organization of the training program. On enrollment of the selected applicants, a supervision contract will be signed by the candidate and the two supervisors, and a Personal Development Plan (PDP) will be established (see also chapters 3.3 and 4.3).

The described formal conditions provide the framework for the successful implementation of the Graduate School's general concept, which will further contribute to the reformation of doctoral studies at the Universität Leipzig, and the RAL, and the internationalization of doctoral qualification as recommended in the Bologna Process.

To meet the demand for high-quality researchers, the Graduate School's target groups are excellent and highly motivated students from all regions of the world who have completed either a BSc, MSc, or a diploma degree in natural sciences. The students to be admitted from this pool are selected in a competitive recruitment procedure (see Fig. 20 and chapter 4.3).

According to the applicant's status and the Faculties' Graduation Rules, the selected MSc, and diploma applicants can be admitted directly to the research training program specified in chapter 3.2.

Applicants with outstanding results in a bachelor's degree (grade A, min. 6 semesters) can be admitted to a "fast track" for a doctoral degree (both external and internal students). For these students a preparatory training is available providing the necessary skills and knowledge for subsequent research. According to the Graduate School's profile the preparatory training offers interdisciplinary modules, so that BSc applicants coming from different disciplines (chemistry, physics, biochemistry, and mathematics) can purposefully combine the modules with respect to the subsequent research training. Here, the integration of "fast track" students will be facilitated by scientific assistants provided by the Graduate School or the RAL. Courses amounting to 60 credit points (30 credit points are generally obtained per semester) must be successfully completed (min. grade B) as a requirement to continue graduate studies (see Table 1). In

addition, external applicants coming from a University of Applied Sciences (Fachhochschule) or foreign applicants with outstanding results in a four-year bachelor program are eligible as stipulated in the Faculties' Graduation Rules. For those applicants preparatory courses are also available which, however, have a different focus and time requirement than for applicants with a 6 semester BSc (the decision about the necessary pre-qualifications will be made by the Faculties' Graduation Committees). The Faculties' Graduation Committees will also decide whether the student is admitted based on the acknowledgement of equivalent European and non-European degrees according to the established rules.

Table 1: Preparatory training offered for applicants with a 6 semester BSc degree (fast track).

Chemistry-related modules	**Number of terms**	**CP per module**
ASC-02: NMR Spectroscopy; ASC-03: Optical Spectroscopy; ASC-04: X-ray Diffraction; 13-121-0211: Solid-State Chemistry; 13-122-0221: Inorganic Structure Analysis; 13-122-022: Homogeneous Catalysis in Industry, Synthesis and Nature; 13-1220412: Spectroscopy on Fluid Interfaces; 13-122-0413: Analysis of Solid Surfaces; 13-122-0511: Nanostructured Catalytic Systems; 13-122-0521: Modern Concepts in Catalysis; 13-122-1111: Protein X-ray Crystallography; 13-122-1511: Spectroscopy	1	5
13-122-0212: Advanced Experimental Lab Course on Inorganic Chemistry; 13-122-0213: Advanced Experimental Lab Course on Organometallic Chemistry; 13-122-0215: Advanced Experimental Lab Course on Supramolecular Chemistry; 13-122-0415: Advanced Experimental Lab Course of Fluid and Solid Interfaces; 13-122-0416: Advanced Lab Course on Computer Simulation for the Investigation of Fluid Interfaces; 13-122-0531: Advanced Experimental Lab Course on Structural Characterization of Solid Catalysts	1	10
Physics-related modules	**Number of terms**	**CP per module**
PH-DP-WP1.6: Biophysics; PH-IPSP-W1.2: Superconductivity; PH-IPSP-WP1.4: Theoretical Physics; PH-ISP-WP1.6: Nuclear Probes and Ion Beams	2	10
PH-IPSP-WP1.1: Optoelectronics; PH-IPSP-WP1.5: Spectroscopy	2	5
PH-IPSP-TP5: Quantum Mechanics II/ Statistical Physics II	2	15
PH-IPSP-EP5: Molecular Physics; PH-IPSP-EP6: Solid State Physics; PH-IPSP-TP3: Quantum Mechanics I; PH-IPSP-TP4: Statistical Physics I	1	9

Biochemistry-related modules	**Number of terms**	**CP per module**
11-BCH-0312: Basics in Biochemistry; 11-BCH-0414: Protein Chemistry and Enzymes; 11-BCH-0701: Bioorganic Chemistry; 11-BCH-0703: Molecular Modeling; 11-BCH-0704: Biotechnology and Tissue Engineering;11-BIO-0705: Neurobiology: in Vitro and in Vivo Physiology of Neurons; 09-BCH-080: Physics in Medicine; 11-BCH-0801: Receptor Biochemistry and Signaltransduction; 11-BCH-0802: Biosensors and Biohybrid Technology; 13-BCH-0624: Structural and Inorganic Biochemistry; 11-202-2206; Advanced Methods in Bioinformatics	1	10
Mathematics-related modules	**Number of Terms**	**CP per module**
10-MATHD-5101: Algebra; 10-MATHD-5104: Computational Algebra; 10-MATHD-5203: Advanced Analysis C; 10-MATHD-5203: Advanced Analysis D; 10-MATHD-5402: Mathematical Physics; 10-MATHD-5604: Numerical Mathematics; 10-MATHD-5801: Mathematical Statistics; 10-MATHD-5802: Stochastical Processes	1	5
10-MATHD-5201: Advanced Analysis A; 10-MATHD-5202: Advanced Analysis B	2	10

The regular duration of graduate study is expected to be three years. The official language is English, and the whole review and examination process can be carried out in English. At the end of the doctoral training, the scientific results are summarized in a doctoral thesis. The thesis together with the qualifications and credits (grades) obtained within the doctoral training have to be submitted to the respective Faculties' Graduation Committees. After the thesis has been positively evaluated and graded by 2-3 referees, doctoral candidates have to present their results in a public defense in accordance with the Faculties' Graduation Rules. This presentation is also graded. All grades together (examination results of the training program, doctoral thesis, and public defense) lead to the final grade. Subsequently, the degree Dr. rer. nat. is awarded by the respective faculty. In addition, the doctoral candidate obtains a RAL certificate with a transcript of qualifications acquired within the Graduate School.

3.2 Research training

The research training consists of the research work and a well-structured training program in accordance with the RAL guidelines. Due to the modular structure, the training is individual, flexible in time and efficiency-orientated (see Table 2). Doctoral candidates can choose the training modules based on their individual skills and time management within the three years of graduate studies provided that 20 credit points (CP) are acquired.

The introduction of credit points at the doctoral level is considered a valuable tool in structuring the training. However, to prevent “excessive rules”, the CP system will not be extended to the research work. Doctoral candidates have to gain a minimum of 20 CP (split up as shown in Table 2). 10 CP have to be graded and are recognized as replacement for the conventional *Rigorosum* in agreement with the Faculties’ Graduation Rules and RAL rules (see chapter 3.1). The Personal Development Plan (PDP) is based on the overall training goals and doctoral candidates establish it together with their two supervisors (see also chapter 3.3).

The organizational structures as well as the content of the training modules are summarized in chapters 3.2.1 – 3.2.3.

Table 2 Concept of the doctoral training. This flexible building block system is especially advantageous for young families or doctoral candidates planning a family.

M, **W**, **SY**, **M**: two-day blocks, **S**, **S**: 1-2 hours, **L**, **T**: 2 h per week

R = required, E = elective, R/E = required-elective

TRAINING ACTIVITY			Month (March to February)											
	Type	Min. CP	M	A	M	J	J	A	S	O	N	D	J	F
				summer term						winter term				
Research work	R	-												
Scientific and methods modules	R/E	10	M	M	M	M	M			M	M	M	M	M
Workshop for doctoral students	R								W					
Scientific symposium	R/E		S Y											
Literature seminars	R/E			S		S		S		S		S		S
Guest lectures/ colloquia	E		L	L	L	L	L	L	L	L	L	L	L	L
Tutoring	R/E	5		T	T	T	T			T	T	T	T	
Research stays abroad	E		FLEXIBLE DURING THE WHOLE YEAR (1 week up to a few months)											
Summer/winter schools	E													
Industrial training	E													
Active participation in conferences/workshops	R/E		FLEXIBLE DURING THE WHOLE YEAR (1 up to a few days)											
Transferable (generic) skills	R/E	5		S	S M	S	S M			S	S M	S	S M	

3.2.1 Research work

Doctoral candidates will work on a research topic concerned with the creation and understanding of new materials from molecules and nano-objects under the supervision of in general two professors, coming from two different research areas, taking into consideration the candidates profile and the academic objectives of the Graduate School. The potential supervisors are involved in the recruitment process to allow a clear match between the candidate's research project and the research expertise of the supervisor (see chapter 4.3). The scientific results of the research work are regarded to be the essential part of the doctorate and should be published in international peer-reviewed journals. The dissertation can be submitted in German, or preferably in English.

3.2.2 Scientific and methods modules

The major objective of these modules is interdisciplinary knowledge transfer in important fields of materials science including essential related methods. In total, 6 scientific and 4 methods modules are offered as two-day courses. Doctoral candidates may choose 5 of these modules to obtain a minimum of 10 CP (1 module corresponds to 2 CP). In addition to the principal investigators, international guest lecturers and industrial partners are involved in the courses ensuring the interdisciplinary and international character of the training. Two or three principal investigators will be responsible for each module. In general, the modules are organized as follows:

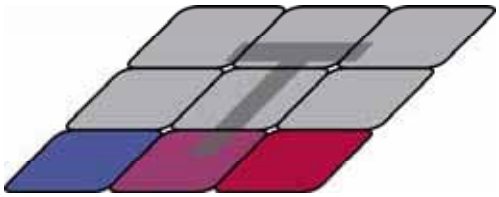
(1) *Preparation phase:* An *e-learning system* providing basic background information, scientific literature, and knowledge tests will help doctoral candidates coming from different disciplines to obtain a basic know-how before participating in the required modules. Therefore different offers will be implemented into the Graduate School's program. In the beginning, e-learning facilities provided by scientific publishers such as WILEY or Pearson will be offered, and each doctoral candidate is eligible for up to two e-learning licenses in the disciplines chemistry, physics, and/or biochemistry as provided by WILEYPlus. For mathematics, the university already has a commercial e-learning platform (w3l), and this system will also be available. The innovative portal "Emiel" (www.fh-augsburg.de/informatik/projekte/mebib/emiel/emiel_fachgebiet.html), provides further teaching modules in a number of scientific fields, and can be used by our doctoral candidates. By implementation of the Graduate School the university's e-learning internet portal will be extended by the import and interactive usage of teaching materials. Besides e-learning, students can participate in modules within the framework of international master courses offered by the participating faculties (i.e. International Physics Studies Program, MSc Biochemistry, MSc Structural Chemistry and Spectroscopy).

(2) *Basics:* The preparation phase, recapitulation of the basics, and the introduction of the

respective scientific area are the main objectives.

(3) *Scientific focus:* The specific knowledge of the research areas is presented and discussed with respect to the academic profile of the Graduate School.

(4) Within the scientific modules, *major related methods* are included. For doctoral candidates who want to broaden and improve their practical skills, an additional elective practical course is offered in terms of a *tandem model* (e.g., a doctoral candidate from physics explains a specific method in nanomanipulations to a student from chemistry; see also *Tutoring*).



Smart molecules

Responsible scientists:

Beck-Sickinger, Haase, Hey-Hawkins

International guest lecturers: Moris S. Eisen (Technion, Haifa), Itamar Willner (Hebrew University, Jerusalem), Kay Johnsson (EPFL, Lausanne), Paul Kamer (University of St. Andrews)

Industrial partners: Convertex, IRL

Basics (For topics marked with an asterisk an e-learning module shall be utilized, the others are covered by lectures from existing master courses):

Organometallic compounds*, transition metal complexes*, quantum-electronic structures, bioorganics, peptides

Aims:

This module aims at linking molecular sciences, as well as topics from solid-state chemistry and physics, homogeneous, heterogeneous and biocatalysis.

Contents:

Specific synthesis, modification and understanding of the changes in the electronic structure of molecules that are precursors for materials with optimized catalytic activity and adjustable magnetic, electronic, and optical properties.

1. Small molecules: organometallic and transition metal complexes, building blocks for metal-organic frameworks (MOFs), precursors for metal organic vapor-phase epitaxy (MOVPE), homogeneous catalysis (principles, examples, applications), immobilization of catalysts (on solid or in liquid supports), electronic structure of active units.

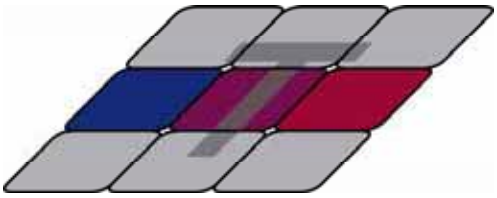
2. Designing and synthesizing smart molecules that contain biological and chemical segments, strategies to introduce metals into biomolecules by selectively introduced chelators, monitoring structural changes.

3. Clusters and polynuclear compounds: links between mononuclear complexes and the corresponding solid-state phase, homo- and heterometallic systems, metallated container molecules, supramolecular chemistry.

4. Supramolecular chemistry, self-assembly (concepts, strategies).

Methods:

Synthesis of new building blocks, characterization of their electronic properties by molecular spectroscopy (IR, NMR, UV-Vis, etc.), structural changes due to interconnection, protein expression, modification and biochemical characterization of enzymes, native chemical ligation (NCL) and expressed protein ligation (EPL).



Multifunctional scaffolds

Responsible scientists: Käs, Kremer, Kroy

International guest lecturers: Jacques Prost (ESPCI), David Weitz (Harvard), Yuri Feldman (Department of Applied Physics, Jerusalem)

Industrial partners: Beiersdorf, Novocontrol

Basics (The topics are covered in biophysics lectures from existing master courses):

Polymer physics, liquid crystal physics, properties and isolation of biopolymers (DNA, actin, intermediate filaments, microtubule), viscoelasticity, statistical physics and thermodynamics of polymer chains

Aims:

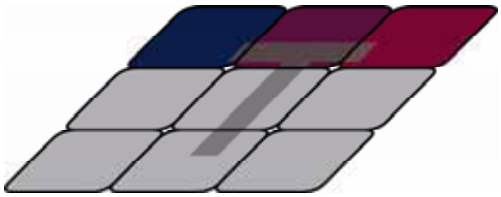
The basic background in soft matter physics and the state of the art knowledge in active and passive biopolymer networks (with a focus on molecular motors) will be taught to enable the students to use highly dynamic polymer scaffolds as an organizing matrix for smart nanoelements and active proteins. A particular focus will be to build mechano-sensing, force-generating, moving, polymeric machines.

Contents:

Different architectures of semiflexible polymer networks, polymer physics of semiflexible polymer chains (individual filaments, entangled and cross linked solutions), liquid crystal physics of lipid membranes (self-assembly, phase diagrams, vesicles, Langmuir monolayers, supported bilayers, thermal ratchets and molecular motors, thermal rachets and polymerization, self-organization in active polymer networks, active and passive filament bundles contractile structures).

Methods:

Rheology and microrheology techniques, single molecule imaging, digital polarization microscopy, confocal/multiphoton microscopy, scanning force spectroscopy of individual polymer chains, dielectric spectroscopy, single particle tracking, soft lithography and microfluidics, biochemistry, recombinant DNA.



Complex nanostructures

Responsible scientists: Esquinazi, Grundmann, Kopinke

International guest lecturers: Lars Samuelson (nm-Consortium, Lund), Nicolas Garcias (CSIC, Madrid), Martin Reinhard (Stanford University)

Industrial partners: FEI Company, OSRAM Opto semiconductor GmbH, FCM

Basics (For topics marked with an asterisk an e-learning module shall be utilized, the others are covered by lectures from existing master courses):

Physics of quantum confinement, classical electrodynamics in dielectric structures and resonators, classical elasticity, light-matter coupling*, physics and chemistry of crystal growth and nucleation, condensed matter aspects of the particularly relevant materials*

Aims:

Deepen the understanding of nanostructures' physical properties (mechanical, electronic, optical) and their relation to shape and geometry as well as energy transfer mechanisms. Understanding networks of nanostructures and related coupling mechanisms.

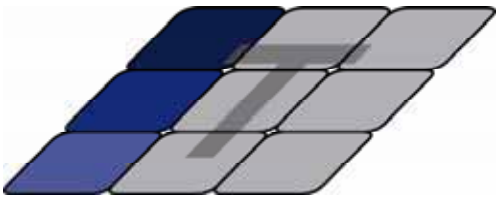
Contents:

1. Functional nanostructures for advanced and novel applications. General: Principles of the formation of self-assembled nanostructures. In the area of photonics: strong interaction of light and matter, Bose-Einstein condensation of cavity polaritons, single photon emitters and related quantum optics, entanglement, quantum communication. In the area of electronics: single charge carrier detection, manipulation and recombination, electronic structure and advanced properties of quantum confinement, nanoscale inhomogeneities, spintronics, orbitronics. In the area of nanomechanics: mechanical properties on the nanoscale, nano-piezoelectricity. In the area of chemistry: nanoparticles and designed porous media for catalysis and photocatalysis.

2. Linking of organic and inorganic building blocks. Principles to attach molecules, peptides, enzymes, and cells on nanostructures and modified surfaces. Charge, momentum and energy transfer in such hybrid systems.

Methods:

Structural analysis with scanning probe techniques, high-resolution electron imaging (TEM, SEM) and chemical analysis. Optical spectroscopy for dielectric function (ellipsometry) and radiative recombination (luminescence) with high spatial resolution. Quantum transport and energy transfer in nanostructures such as tunneling, Förster transfer, radiative transfer, polarization coupling, piezoelectricity (mostly current and capacitance spectroscopy).



From molecules to materials

Responsible scientists: Buchmeiser, Kersting, Morgner

International guest lecturers: Gilbert Nathanson (University of Wisconsin), Greg van Patten (Ohio University)

Industrial partners: EverQ, AIXTRON

Basics:

Molecular precursors, supramolecular chemistry and MOFs: covered in the Module "Smart Molecules", polymers, organic and inorganic nanostructures

Aims:

1. Link molecular sciences and materials science; 2. Understand how materials with optimized catalytic activity and adjustable magnetic, electronic, or optical properties are obtained from molecules; 3. Understand the properties and applications of these materials.

Contents:

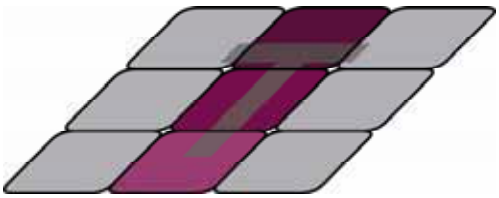
1. Novel materials from "hard" (synthetic molecules and crystalline nanostructures) and/or "soft" (polymers, biomolecules) building blocks, which include: polymers, supramolecular arrangements, proteins and peptides, together with modifications to improve the material qualities (pegylation, lipidisation, glycosylation), metal-organic frameworks (MOFs), metal-binding peptides, thin films and nanostructures, quantum-electronic structures.

2. Properties of these materials: magnetic, electronic, and optical properties, electronic, photonic, and magnetoresistive devices, superconductivity.

3. Application of these materials: in catalysis (immobilized catalysts, MOFs), for gas separation or gas storage (MOFs), as sensors, in electronics, photonics, quantum information technology, spintronics, energy conversion (including solar energy).

Methods:

Immobilization techniques, chemical vapor deposition (CVD, PECVD, MOVPE), physical deposition (PLD), atomic layer deposition (ALD), surface analysis (MIES), device characterization (e.g., IV, CV, S-Parameter).



Hybrid systems

Responsible scientists: Beck-Sickinger, Janke, Rauschenbach

International guest lecturers: Ernest Giralt (Barcelona), Christian LeGrimellec (C.B.S. Montpellier), Anders Irbäck (Lund University), Bernd A. Berg (Florida

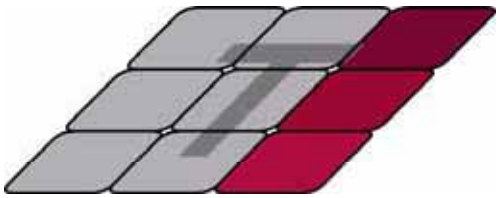
State University), Kay Severin (EPFL Lausanne)
Industrial partner: Zeiss

Basics (For topics marked with an asterisk an e-learning module shall be utilized, the others are covered by lectures from existing master courses):
Chemical synthesis of peptides and carbohydrates, recombinant expression of proteins, protein folding, protein analysis, introduction into surface materials, principles of analysis of surfaces, basics in polymers/macromolecular science*

Aims:
Understanding the principles in preparation and application of hybrid systems, including immobilization of biomolecules and prerequisites for materials to attach biomolecules, as well as possible future application in biomedicine, biotechnology, and informatics.

Contents:
1. Protein expression by specific methods that allow modification and introduction of non proteinogenic amino acids, intein and impact system, modification of tRNA and genetic code expansion, selective chemical modification of proteins, pegylation of proteins, biocompatibility of materials, problems of toxicity and biodegradation.
2. Material aspects, including generation of polymers, surface modification, nanoscaffolds, preparation of building blocks, chemical modification of surfaces.
3. Preparation and analysis of hybrid compounds, ligation strategies, immobilization, application of hybrid materials in biomedical science, for biosensors, and for functional materials.

Methods:
Techniques to obtain modified proteins, side chain protection strategies in peptide synthesis, cell-based assays to study toxicity, biostability and inflammation, analytics will include AFM, solid-state NMR and SIMS (secondary ion mass spectrometry).



From biomolecules to cells
Responsible scientists: Butz, Robitzki, Schirmer
International guest lecturers: Jon Cooper (University of Glasgow), Alberto Corsini (University of Milan), Gregory L. Lowry (Mellon University)
Industrial partners: Eurochem, Evotec, Namos GmbH, Beiersdorf

Basics (The topics are covered by lectures in biochemistry courses from existing bachelor and master courses):
Principles in cell biology, cell compartments, function of the cytoskeleton, DNA transcription

and translation, protein folding

Aims:

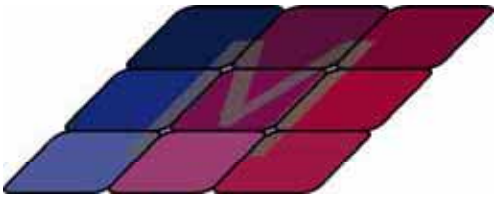
Understanding the biophysics of cells to manipulate them and use them as smallest bioreactors. Combinations of cells with bioelectronics and nano-biotechnological applications shall be deepened. Understanding how the cellular machinery changes when intracellular proteins are changed.

Contents:

1. Cell compartments with their different function: cytoskeleton, cell membrane compartments, different cell types.
2. Biophysical techniques to characterize cells, manipulation of cell growth and orientation with physical and chemical tools, application of cell manipulation in biosensor technology.
3. Eukaryotic expression of proteins in cell culture, 2D and 3D tissue culture, comparison of primary versus tumor cells.

Methods:

Techniques to characterize cells include different microscopic techniques, staining and optical analysis. Transfection studies to create artificial cells with different activities. Impedance spectrometry to characterize modified cells will be included.



Theory

Responsible scientists: Janke, Kroy, Müller

International guest lecturers: David Nelson (Harvard), Jacques Prost (ESPCI)

Basics (The topics are covered by lectures from existing master courses):

Soft matter physics, nonlinear dynamics, self-assembly and self-organization, statistical physics, non-equilibrium physics, quantum mechanics and chemistry

Aims:

Tool box to predict and to inspire complex structures with novel properties built from molecules and nano-objects. Combining a multitude of analytical and computer modeling approaches on multiscales to describe the assembly and operational phase space for smart materials based on polymeric scaffolds organizing active macromolecules and nanodevices.

Contents:

1. Mathematical methods for multiscale modeling
2. Quantum mechanics for mesoscopic, i.e. nanosemiconductor devices
3. Physics of semi-flexible polymer scaffolds
4. Self-organization in active polymer networks

Methods:

Simulation techniques, continuum and molecular theory to describe active and inactive polymer

networks, multiscale modeling.

Magnetic resonance

Responsible scientists: Berger, Haase

International guest lecturer: Andrew G. Webb (Pennsylvania State University), Klaus Koch (University of Stellenbosch)

Industrial partner: BrukerBioSpin

Basics:

Magnetic resonance (NMR and EPR) for the investigation of materials, which are the focus of the Graduate School, and their properties

Aims:

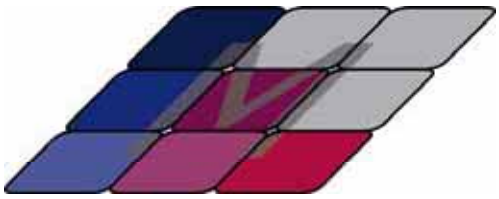
Magnetic resonance, in particular NMR, is one of the very few local probes of bulk matter with applications in almost all natural sciences. Leipzig has a great tradition in applying and developing magnetic resonance in various areas. The powerful spectroscopic insight from magnetic resonance requires, however, a special knowledge of its methods, techniques, and hardware. Therefore, *basic* courses in magnetic resonance will be provided that lay the foundation for its application. Due to the exceptional breadth of applications, *advanced* courses will focus on current research needs.

Contents:

Basic principles of NMR and EPR. NMR of liquids and of solids as basic analytical tool. Advanced methods (e.g., in biological systems, quantum solids, surfaces). Hardware development for special applications (thin films, high fields and frequencies).

Methods:

Given the great expertise in magnetic resonance, interdisciplinary teaching (already practiced in Leipzig) will provide first-hand knowledge from leading experts in various fields. The teaching will also profit from a long-standing experience with GDCh courses where we combine lectures on various subjects with concrete experimental training at instruments, which provides hands-on education in complicated methods.



Synthesis

Responsible scientists: Beck-Sickinger, Grundmann, Krautscheid, Rauschenbach

International guest lecturers: Magnus Willander (Linköping University), Fernando Briones (CSIC), Tom Muir (Rockefeller University)

Industrial partners: OSRAM, AIXTRON AG, FCM

Basics (The topics are covered by lectures in biochemistry or chemistry courses from existing bachelor or master courses):

Principles of crystallography, preparation of crystals, protein folding (*in vitro*), oligomerization, cooperativity methods to analyze this phenomenon, thermodynamics, chemical modification

Aims:

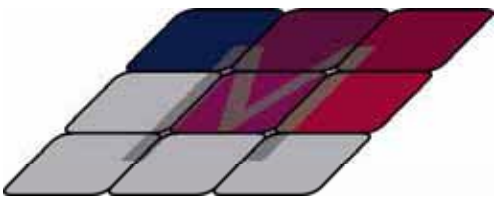
Deepen the understanding of epitaxial growth, growth of two-, one- and zero-dimensional heterostructures, synthesis of new materials via molecular precursors, ion beam methods, alloy formation, macromolecule oligomers, especially understanding and application of the different methods to prepare complex systems and networks from molecules.

Contents:

Understanding the physical and chemical aspects of epitaxial processes for layered and nanostructured materials, self-assembly (experiment), directed self-assembly, production processes of polymeric materials by chemical, biological and physical means. Examples from industrial processes, device fabrication, nanobiotechnology and sensor technology will be included.

Methods:

Introducing the synthetic tools for molecules and materials, especially to prepare complex oligomeric materials, e.g., chemical deposition techniques (CVD, MOVPE, ALD), physical deposition techniques (MBE, PLD, IBAD), biological immobilization, protein production and modification, peptide library synthesis and deconvolution, templates and related growth schemes, preparation and characterization of nanomaterials.



Nanomanipulations

Responsible scientists: Käs, Kremer, Robitzki, Keyser

International guest lecturers: Herman Gaub (LMU), Kishan Dholakia (St. Andrews)

Industrial partners: Zeiss, JPK, Inotec, ikfe

Basics (The topics are covered by biophysics lectures from existing master courses):

Molecular and intermolecular forces, electrostatic forces, magnetic forces, optical forces, mechanical forces, ultrasound, micro- and nanostructures

Aims:

Introducing the building tools for controlled manipulation of nano-objects, macromolecules, proteins, and cells. A particular attention will be paid to basic working principles of the covered nanomanipulation techniques. This will enable the doctoral candidate to create new approaches to nanomanipulation.

Contents:

1. Electromagnetic forces: electric fields and dielectric materials, electrophoresis for molecules,

proteins, and cells, magnetic forces.

2. Optical forces: gradient, scattering, and optical surface forces, Maxwell surface tensor, momentum transfer, transferring angular momentum, holographic tweezers, Mie- vs. Raleigh-regime.

3. Scanning force approaches: Van der Waals forces, inter- and intra-molecular interactions, detection with quadrant diodes.

4. Soft lithography.

Methods:

Optical traps (optical tweezers, optical stretcher, optical cell guidance, optical spanners and rotators, optical sorting and deposition, laser dissection), magnetical tweezers, scanning force microscopy and spectroscopy, dielectrophoretic field cages, lab-on-a-chip.

3.2.3 Further multidisciplinary training activities

Workshop for doctoral candidates

Every year an interdisciplinary workshop for doctoral candidates will be organized. Within the workshop doctoral candidates who finished their first year of graduate studies have to report their scientific progress to an interdisciplinary audience. Inspired by previous experiences in the organization of such events the workshop will take place outside the university's grounds in a separate location close to Leipzig (i.e. at the Wilhelm Ostwald Memorial Conference Center in Großbothen or at Schloss Oppurg) to foster intensive scientific discussion within the interdisciplinary audience and create a scientific atmosphere undisturbed by day-to-day business. Doctoral candidates will obtain 1 CP for their presentation.

Scientific symposium – Annual BuildMoNa Festival

A scientific symposium, the "BuildMoNa Festival", will be organized every year. Its goal is knowledge transfer in specific major research areas of the Graduate School. The symposium is expected to attract world-wide interest in the Graduate School's academic concept. It will comprise lectures held by invited speakers, industrial partners, and Graduate School members (principal investigators and doctoral candidates). Doctoral candidates will obtain 1 CP for their presentation.

Literature seminars

Journal clubs will take place regularly every two weeks and will be organized by the participating PIs according to their scientific panels in the Graduate School BuildMoNa. In conjunction with the seminars, short written tests will be offered twice per semester. Doctoral candidates have to pass in total 4 tests to obtain 1 CP.

Guest lectures/colloquia

In addition to the scientific modules and symposia, guest lectures and colloquia will be organized every week by the Graduate School. These events covering one specific field of

research will take place at the participating faculties and institutes. Attendance of 15 guest lectures or colloquia is acknowledged with 1 CP. Doctoral students are encouraged to participate also in the general lectures at the faculties and the RAL including colloquia of the Institutes of Physics, Institute of Biochemistry, and colloquia of the Faculty of Chemistry and Mineralogy organized together with the German Chemical Society (GDCh). Furthermore, doctoral candidates can benefit from colloquia and scientific events organized by the university's Top-Level Research Areas (PbFs), the TRM, and the "International Institute for Complex Adaptive Matter" (ICAM, http://www.i2cam.org/).

Tutoring

To gain communication and educational skills, doctoral candidates carry out tutoring tasks. These tasks include the tutoring of undergraduate and master students and learning how to impart scientific topics and practical skills. In particular, "fast track" students will obtain tutoring by doctoral candidates as well as scientific assistants. Another area is the practical training of other doctoral candidates in combination with a methods module (*tandem model*). This will especially promote interdisciplinary communication and exchange. 1 CP will be obtained for 30 hours of tutoring (15 h direct tutoring time, 15 h preparation time).

Research stays abroad

A research stay at a foreign collaborating institution can be an essential part of the training. It will offer doctoral candidates an opportunity to work in and thus to integrate into an international scientific environment. Here, the existing Graduate School's international relations and co-operations can be used as an entrance point, and can be extended further. Moreover, such research stays can greatly help to assimilate young researchers into the international community and provide possibilities for their subsequent scientific careers (such as postdoctoral positions). 1 CP will be awarded for a written report on the research activities during a research stay (minimum 2 weeks).

Industrial training

One particular objective of the Graduate School is to enhance the exchange with industrial partners. During industrial training, doctoral candidates will be provided with specific knowledge in materials science not available at the university, and will become familiar with modern industrial business. Doctoral candidates have the opportunity to participate in interdisciplinary trainee programs at several companies: Convertex, OSRAM Opto Semiconductors GmbH, AIXTRON AG, FCM, KeyNeurotek AG, Industrial Research Ltd. (New Zealand), Chemilia AB (Sweden), Namos GmbH, Euroderm, Beiersdorf, Toshiba, Novamass, Pharmacelsus, ProBioGen, ikfe, HiTec, FEI (The Netherlands), Karl-Winnacker-Institut of the DECHEMA, and Zeiss. Up to 1 CP will be awarded (duration min. 2 weeks).

Conferences

Doctoral candidates are expected to actively participate in conferences abroad presenting their

results to an international audience. The participation in conferences also aims towards an improvement of the doctoral candidates' presentation and communication skills, and to promote networking. Activities such as an oral contribution or a poster presentation are acknowledged with 1 CP.

Summer/winter schools

In addition to the scientific training offered by the Graduate School itself, the participation in summer or winter schools is encouraged. Schools of particular interest are held at the Abdus Salam Conference Center for Theoretical Physics, Trieste, at the Institute for Theoretical Physics, UC Santa Barbara, at the Ecole de Physique de Les Houches, at the Boulder School for Condensed Matter and Materials Physics, and at the Aspen Center for Physics. In addition, the Mauterndorfer Winter School on Semiconductors Physics and Nanostructures, the DPG-Physics-Schools and Heraeus Research Schools should be mentioned. Up to 1 CP will be awarded.

Transferable skills

To achieve personal and professional skills and competences a number of courses are offered by the Graduate School itself, and centrally by the RAL. Doctoral candidates can choose the courses according to their own demands and interests (in accordance with the Personal Development Plan (PDP)). In total 5 CP have to be acquired during the three-year program. The courses will be offered as one- or two-day workshops during one semester.

RAL offers can be divided in central courses and scientifically specific modules of the Graduate Centers according to their classes' profiles. Thus, central RAL offers will include language and didactic courses, computer sciences, scientific librarianship, and scientific management courses as well as seminars on business start-ups and specific courses provided by other programs of the RAL. The course program will be published every semester on the RAL internet pages and in the RAL brochure.

In addition, specific offers of the Graduate School will be organized as one- or two-day workshops including the following topics:

(1) Research management (2 modules)
(2) Background information on scientific organizations and funding agencies in Germany and the European Union (2 modules)
(3) Grant writing (2 modules)
(4) Introduction into patents and technology transfer (1 module)
(5) Problem solving (2 modules)
(6) Scientific writing and presentation (2 modules)
(7) Awareness of scientific ethics and intellectual property risks (1 module).

These workshops will be held by professional teachers, who have already been successfully engaged in previous research training programs, by continuously improving/adjusting the level and contents of these modules. According to the research training program two workshops per

semester are offered leading to a total period of three years to complete the whole cycle.

Besides these offers, doctoral candidates will further benefit from specific scientific offers provided by the Graduate Center “Mathematics/Computer Science and Natural Sciences” and its classes (i.e. Max Planck Research School “Mathematics in the Sciences”). In particular, relevant mathematical lectures are offered in the fields nonlinear partial differential equations, the notion of energy in physics, geometry and physics, mathematical methods in biology and neurobiology, and mathematical problems in materials science.

3.3 Supervision and mentoring

A “contract” between two assigned supervisors and the doctoral candidate is one of the major improvements in the training of doctoral candidates with respect to previous programs. One supervisor belongs to the faculty where the doctoral candidate is enrolled, and the other one to a neighboring discipline ensuring the interdisciplinary character of the graduate program. Under certain circumstances (depending on the specific research project and the supervisor’s profile) the number of supervisors can be increased to three. However, this will not be a general rule, to prevent over-regulation. Besides the description of the doctoral candidate’s envisioned research topic, the contract includes the assurance of financial support over the period of three years and the consent with the Personal Development Plan (PDP).

The PDP specifies the training schedule depending on the candidate’s specific scientific and generic needs, and also takes gender aspects into consideration (see also chapter 4.6).

Monitoring and assessment of the doctoral candidate’s progress will follow a clear procedure and are applied for both the doctoral candidates and the PIs. The specific process can be defined as follows:

(1) Monthly meetings between the candidate and the supervisors;
(2) Regular review of the progress (presentation of the research results at the annual workshops and symposia for doctoral candidates, and at meetings of the individual research groups);
(3) Follow-up meetings and seminars according to the PDP;
(4) Feedback from the doctoral candidate concerning the graduate program, training, and supervision in form of questionnaires and assessments;
(5) Possibility of choosing a different supervisor in case of problems. The decision has to be made in accordance with the Graduate School Steering Committee.

3.4 Other activities

Based on the long-standing experience from previous graduate programs such as the International Postgraduate Program (IPP), the Graduate School will provide additional support for the integration of foreign doctoral candidates. Accordingly, doctoral candidates are supported in everyday problems, such as housing, health insurance, visa issues, child care, etc. The Graduate School will intensively collaborate with the RAL and the International Center of the Universität Leipzig. Besides counseling programs cultural activities are offered for the

doctoral candidates of the Graduate School. In spite of using English as scientific language, the Graduate School will host cultural events that incite the interest of the doctoral candidates to learn German so that they can better participate in German social life. German classes at beginners' level (intensive lecture course "Erste Hilfe für ausländische Wissenschaftler in Leipzig") and advanced levels are provided by the Graduate School. These activities will help to facilitate the integration of foreign students into the new cultural environment. Furthermore, a ceremonial welcoming of doctoral candidates and farewell to graduates will take place at an Annual Reception, which will also include the presentation of the annual Graduate School report and the "BuildMoNa Award" to outstanding doctoral candidates for excellence in research (e.g., Dr. rer. nat. "summa cum laude", excellent publication or presentation, etc.).

4 STRUCTURE

4.1 Organization, management and resources

The proposed Graduate School will be integrated as a "class" into the Research Academy Leipzig (RAL), which combines the three Graduate Centers (1) Mathematics/Computer Science and Natural Sciences, (2) Life Sciences, and (3) Humanities and Social Sciences (see also chapter 2.2).

The RAL has been established for a period of five years (in 2006) and will be continued after a positive evaluation in 2011. The RAL is headed by the Universität Leipzig's Vice Rector of Research who is supported by the three Directors of the Graduate Centers (elected for a period of three years, see Fig. 21). The tasks of the RAL Directorate are determined in the RAL rules.

According to the RAL rules, an Advisory Board, consisting of representatives of the RAL, industrial partners, the participating scientific institutions, and representatives of scientific societies in the natural sciences (e.g., Akademie der Wissenschaften zu Leipzig, local representative of the German Chemical Society, etc.), will be established. The Advisory Board will regularly evaluate the scientific activities and will be provided with an annual report from the Graduate Center Directorates.

Each Graduate Center of the RAL is headed by a Graduate Center Directorate consisting of representatives from each class (generally the Speaker/Coordinator and one doctoral candidate). The members of the Graduate Center Directorate are elected according to the classes' rules. The main tasks of the Graduate Center Directorate are to coordinate the scientific programs of the different classes and to administer the university's (RAL) funds provided for doctoral training. These funds include expenses for staff (salaries, offices), expenses for student assistants, travel funds for visiting researchers, travel expenses for doctoral candidates, as well as expenses for marketing/recruiting efforts, for the organization of courses concerning transferable skills, child care, and integration of foreign doctoral candidates. Each Graduate Center is coordinated by a scientific manager who mainly supports the Graduate Center Directorate and who is a staff member of the RAL Office. The RAL Office also

represents the link between the three Graduate Centers including their different classes, the Graduate Studies Committees of the participating faculties, and the university's central administration.

The Graduate School itself will be represented by a Steering Committee consisting of 1-2 representatives from each participating faculty and one elected doctoral candidate as the representative of the Doctoral Candidates Committee. The faculties' representatives will be elected for a period of three years by the PIs. Accordingly, the Graduate School's doctoral candidates will be represented by a Doctoral Candidates Committee consisting of 1-2 elected representatives from each participating faculty. The Doctoral Candidates Committee will represent the doctoral candidates' interests.

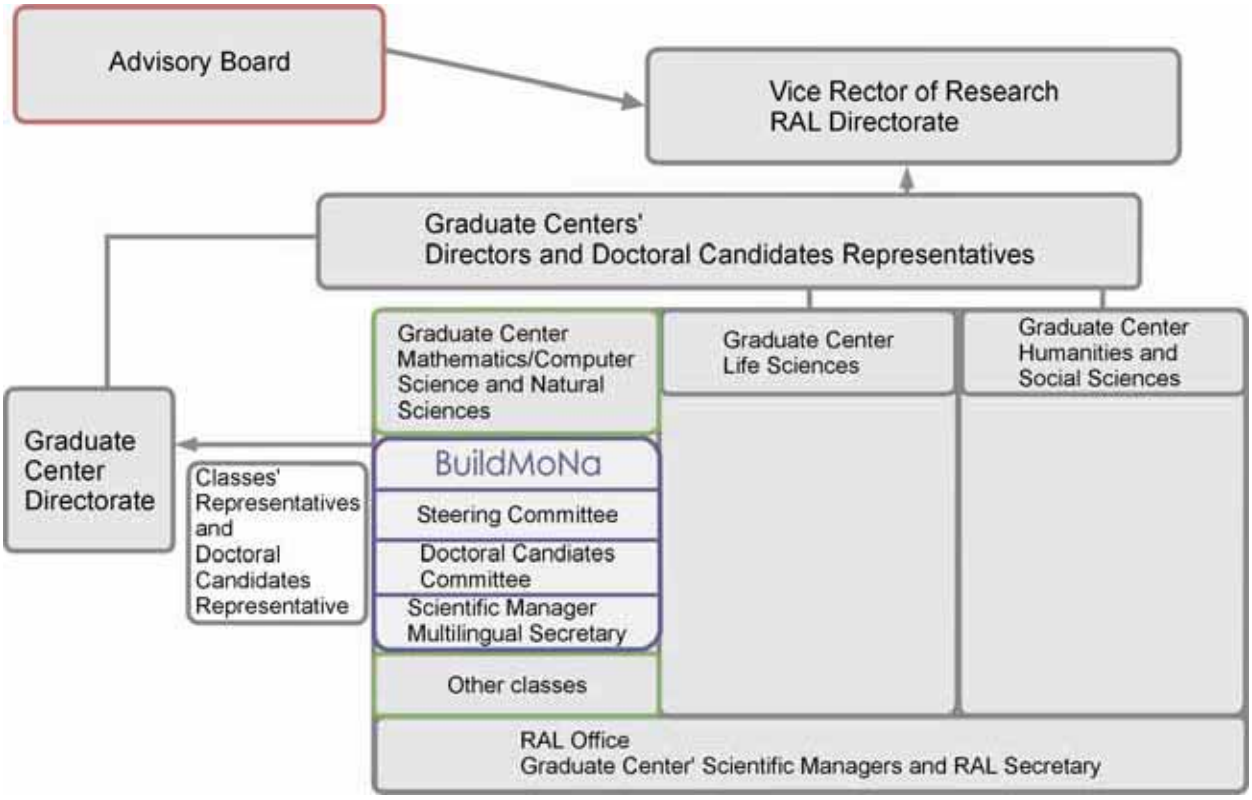


Fig. 21 Organization and management of the Graduate School BuildMoNa

The Coordinator of the Graduate School will be the head of the Steering Committee as well as the representative of the Class "BuildMoNa" in the Graduate Center Directorate. The major tasks of the Steering Committee are: coordination of activities including advertising, marketing and recruiting in collaboration with the Graduate Center, management of the recruiting process, establishment and organization of the training program, identifying and monitoring whether the program's deliverables and milestones are achieved, management of the collaboration with other involved scientific institutions and industrial partners, management of funds, and reporting. The Steering Committee meets every month and informs the PIs and doctoral candidates on a regular basis about their decisions. In addition, the Graduate School's PIs as well as

cooperation partners will meet twice a year to plan and discuss the events of the following summer or winter term.

The Steering Committee will be supported by a professional scientific manager and a multilingual secretary, who are accommodated in the office of the Graduate School BuildMoNa. The professional scientific manager will coordinate the doctoral training activities and will ensure information/communication between the participating scientists, the doctoral candidates, visiting researchers, and collaboration partners (non-university and industrial). Most of the current information will be available on the Graduate School's website and/or will be sent to the participants by e-mail. In addition, the Graduate School's Office has regular business hours, especially for requests from applicants or doctoral candidates.

The allocation of funds will proceed according to the well-defined funding plan of the Graduate School and will include two financial budgeting sessions each year. Therefore, every November and April all the planned activities (according to the research training program and the overall concept of the Graduate School BuildMoNa) have to be specified by the Graduate School's PIs and doctoral candidates. Depending on the status of each doctoral candidate, funding or co-funding for specific activities can be provided (see also 4.3). The funds will be administered by the University's Central Administration according to the university's general rules. Therefore, administrative staff will closely cooperate with the Graduate School's management.

4.2 Premises

In the last decade the participating institutions have continuously modernized their research facilities, extended the laboratory space, increased the number of seminar and lecture rooms as well as offices, purchased highly sophisticated scientific instrumentation, and made several strategic appointments at the professorial level. The developments were made to meet the requirements of the increasing numbers of students, graduates, and doctoral candidates. The Faculty of Chemistry and Mineralogy moved into a new building in 1999, which provides excellent state-of-the-art laboratories and study conditions in the fields of inorganic and organic chemistry. In total, laboratory space in the range of 2,500 m^2 for a number of 100 doctoral candidates is available. In addition, the traditional Wilhelm Ostwald Institute of Physical and Theoretical Chemistry (lab space 200 m^2) was refurbished in 1996, and the laboratories and offices of the Institutes of Analytical and Technical Chemistry, which are located in the "Technikum Analytikum" (3,300 m^2), will be reconstructed (starting in 2008). In these institutes 60 doctoral candidates can be accommodated. During the past few years, the Institute of Biochemistry, Faculty of Biosciences, Pharmacy and Psychology, has been completely renovated. All methods and technologies for modern biochemistry have been established providing excellent facilities for high-level doctoral studies (available lab space is 500 m^2 for 40 doctoral candidates). In 2000 the Institutes of Experimental Physics I and II moved into the newly renovated physics building with laboratory space of 2,500 m^2. The restored physics building and novel equipment provide excellent research conditions for the 70-80 current

doctoral candidates. The available laboratory space and offices are sufficient for 20-30 additional candidates. The Institute of Theoretical Physics moved into a new building in 2000, and obtained new computer facilities in 2006. The Center for Biotechnology and Biomedicine (BBZ) was founded in 2002 as an interdisciplinary research center of the Universität Leipzig and is located in the BioCity, a new well-equipped complex of buildings with a total of 20,000 m^2 laboratory space, divided among several biotechnology companies and the BBZ (about 600 m^2). The participating institutes in the fields of chemistry, physics, and biochemistry as well as the BBZ and the mathematical institute are situated close to each other, with distances with less than 1500 m. Access to the research facilities of these institutions is granted to the Graduate School's doctoral candidates.

In addition to the laboratory infrastructure, doctoral candidates will have a desk with a computer and an internet connection, a phone, and direct online access to the Universität Leipzig's library (www.ub.uni-leipzig.de) including full access to more than 10,000 journals, and all relevant databases (SciFinder, Web-of-Science, Beilstein Cross Fire, INSPEC, Online Contents-SSG Physik). The university library system consists of the main building "Bibliotheca Albertina" and forty branches situated near their respective academic institutions. The current stock comprises 5 million volumes and about 7,700 periodicals. The university library's services range from giving access to books and periodicals to providing information via online databases and CD-ROMs.

The Helmholtz-Center for Environmental Research (UFZ) was established in 1991 as the first and only research center of the Helmholtz Association (HGF) to be exclusively committed to environmental research providing outstanding research facilities and modern laboratory equipment. It currently employs around 780 staff members. The UFZ is mainly funded by the Federal Ministry of Education and Research (90 %), with the regional governments of Saxony and Saxony-Anhalt sharing the remaining 10 % equally. The Leibniz-Institute of Surface Modification (IOM) was founded in 1992 by recommendation of the German Science Council. The institute works on basic and applied research concerned with the interaction of radiation with matter and their technological applications. The institute is a member of the Leibniz Association and is financed in equal parts by the federal and state governments. The number of employees is about 140. The cooperation and scientific exchange between the IOM and the Universität Leipzig is intensive and fruitful, which can be seen by several third-party funded collaborative projects. The Max Planck Society decided to establish a Max Planck Institute for Mathematics in the Sciences (MPI-MiS), recognizing the increasing role of mathematics in almost all sciences and the significant developments in mathematical analysis and geometry in Germany. The institute was founded in Leipzig in 1996 and collaborates extremely closely with the Universität Leipzig. It is also a member of the ERCOM association of leading European research institutes in the fields of mathematics. The data processing equipment comprises thin-client based access to Unix workstations and several server machines, one of them with 16 and

another with 24 processors. Specialized graphics workstations and a video-equipped workplace are also provided.

These non-university institutions offer further expertise, facilities, and equipment to the Graduate School's doctoral candidates and can accommodate an additional 15 doctoral candidates.

Apart from the already existing facilities, the Graduate School's plan includes the establishment of an additional building, a Laboratory for Interdisciplinary Studies and Applications (LISA), in which the infrastructure for specialized laboratories and project-orientated collaboration with industrial partners will be housed, and relevant "hands-on" interfaculty training will be provided. The total lab space for LISA is envisioned to be 3,000 m^2. Within LISA the "BuildMoNa Office", including rooms for the scientific manager, the secretary, and a meeting room, will be located. Furthermore, a so-called "BuildMoNa Commons Room" (ca. 300 m^2) will be established as a central meeting point for doctoral candidates; it will house computer and internet facilities, e.g., for literature research and e-learning, as well as child-care facilities.

Furthermore the Graduate School will also benefit from the reconstruction of the university's campus in the city center (to be finished by 2009, when the Universität Leipzig will celebrate its 600th anniversary). Here, the Faculty of Mathematics and Computer Science will obtain modernized lecture halls and up-to-date teaching facilities. Furthermore, the university's central locations for students will become more attractive.

4.3 Doctoral candidates

In total a maximum of 90-100 doctoral candidates will be enrolled into the Graduate School. 30 doctoral candidates will be funded by scholarships provided by the Graduate School, at least 30-40 by third-party funding, and up to 30 scholarships will be provided by the Universität Leipzig/the Saxon Ministry of Science and the Fine Arts (SMWK).

Advertising and recruitment of doctoral candidates will start before the Graduate School's implementation. The Graduate School's recruitment process and marketing are carried out in collaboration with the RAL. Furthermore, facilities and offices of German institutions (DAAD, DFG, AvH), which are available abroad for interviews and selection of doctoral candidates, will be included (see also information given in chapter 4.5). Accordingly, all activities are organized in an efficient way by combining the resources of the Graduate School, the RAL, and the university.

The target groups are excellent and highly motivated students with either an MSc or a diploma degree in natural sciences from all regions of the world, and applicants with outstanding results in their bachelor's degree (see chapter 3.1).

In general, the recruitment process involves four phases: (1) advertising/publishing of calls for applications, (2) pre-selection of candidates, (3) interview, and (4) final selection (see Fig. 22).

At the beginning of the recruitment process in November 2007, a number of 30-40 third-party funded doctoral candidates will be enrolled in the Graduate School. The number of doctoral

candidates will be subsequently increased to 70-80 in 2008, and 90-100 in 2009. Calls for applications will be published three months in advance of the respective deadlines. Deadlines for application will be 30th September 2007/2010, 31st December 2007/2010, and 31st March 2008/2011.

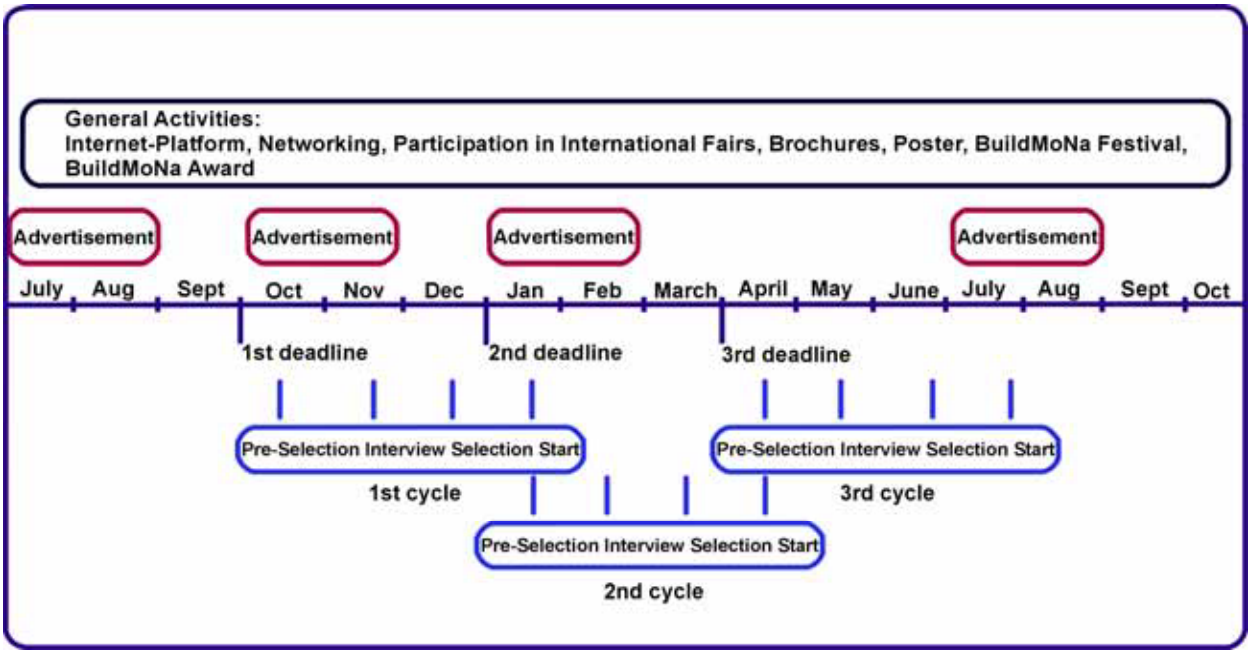


Fig. 22 Recruitment process for the years 2007/2008 and 2010/2011.

The selection of doctoral candidates follows a transparent, fair, and consistent process. It is carried out by the Graduate School's Steering Committee and involves the following steps: (1) online-submission of the application (including application form, CV, transcripts of the required prerequisites, publications, certificate of the proficiency in English, a project proposal for the proposed doctoral studies, and references), (2) pre-selection of the candidates according to the formal requirements and scientific qualification, and subsequent submission of original application documents, (3) if necessary, a telephone interview, (4) a personal interview at the Graduate School, and (5) final selection of candidates. The selection of the candidate is based on the candidate's skills and scientific background, interest and enthusiasm, as well as the expected innovative contribution of the research project to the Graduate School's academic aims (see chapter 2). In steps 4 and 5, the potential supervisors are involved to allow a clear match between the candidate's research project and the research expertise of the supervisor. Professional experiences in industry and non-university research institutions will be also taken into account. The command of the English language is mandatory. After acceptance, doctoral candidates are enrolled in the corresponding faculty and become members of the RAL (as members of the class "BuildMoNa" in the Graduate Center Mathematics/Computer Science and Natural Sciences) (Fig. 17, chapter 2.2).

As RAL members doctoral candidates can benefit from the overall offers of the RAL. Doctoral

candidates can be elected as representatives of their class within the Doctoral Candidates Committee, and the representative can participate in the Graduate Center Directorate (see chapter 4.1). These rules are specified in the RAL statutory rules valid for all the RAL classes. In addition, the Personal Development Plan (PDP) developed for each doctoral candidate at the beginning of the doctoral studies will define the research training program, monitoring, and supervising (see chapters 3.2/ 3.3). After graduation the doctoral candidates will obtain a RAL certificate including a list of research and training activities, results of exams, and credits obtained within the doctoral training.

According to the Graduate School's financial plan a number of benefits will be granted besides the scholarships provided for doctoral candidates. These offers will be also available for doctoral candidates who obtain a scholarship (university, SMWK, DAAD, or other) or are third-party funded. A survey is given in Table 3.

Table 3 Activities granted for additional doctoral candidates.

Purpose of Funding	**at least 30- 40 third-party funded doctoral candidates (employment)**	**up to 30 additional scholarships (university, SMWK, other)**
Participation in scientific and methods modules	**X**	**X**
Participation in workshops or symposia	**X**	**X**
Participation in conferences, summer or winter schools and research stays abroad candidates	**up to 50% co-financing**	**up to 50% co-financing**
Participation in transferable skills and language courses	**X**	**X**
Benefit from integrating and supporting measures	**X**	**X**
Access to literature and software (e-learning)	**X**	**X**
Child-care facilities	**X**	**X**

4.4 Staff

Besides the Graduate School's PIs, scientific staff as well as non-scientific staff funded by the university's participating institutions and other sources will be involved in the training and administration of the Graduate School. In total a number of approximately 50 scientists, 20 technical assistants, and 10 lab technicians will actively support the scientific and experimental training of the doctoral candidates. In particular, well-experienced senior scientists as well as leaders of junior research groups will be integrated in the supervision and experimental guidance of doctoral candidates. The scientific and methods modules as parts of the Graduate

School's research training will be supervised first of all by the PIs according to their scientific background (the role of every PI is specified in chapter 3.2). Here, visiting researchers and cooperating partners will also actively participate. In addition, master courses will be provided for excellent applicants with a BSc degree within the "fast track".

In general, the research training program provided by the Graduate School increases the workload of the PIs. According to the current university rules the teaching load (8 hours per week for lectures per semester) for university professors comprises only the training of BSc and MSc students, but not activities within structured doctoral training. However, the "Sächsische Hochschulgesetz" (Saxon Law for Higher Education) allows the acknowledgment of such activities. By implementation of the Graduate School the Universität Leipzig will acknowledge the PIs' workload in the Graduate School with 1-2 hours per week each semester ("Lehrdeputatsanrechnung") and will thus promote the further establishment of well-structured innovative doctoral training programs.

Besides the scientific staff, the Graduate School requires staff for administrative and management purposes. Here, experienced secretaries of the PIs will be involved in the Graduate School's activities by carrying out organizational work (e.g., organization of travels, invitations of international visiting researchers and guests, help for doctoral candidates' integration). The Graduate School itself will employ a scientific manager and a multilingual secretary for the Graduate School's management (see also chapter 4.1). They will be supported in their activities by RAL staff.

4.5 External visibility and networking

The Graduate School aims at both German and foreign doctoral candidates. Currently, about 35 % of the doctoral candidates at the participating faculties are from foreign countries with the majority coming from Central and Eastern Europe and Asia. The RAL aims at increasing the number of foreign doctoral candidates in its training programs up to 50 % by 2010.

Besides the innovative training program, the Graduate School places great emphasis on the international exchange of doctoral candidates and joint doctoral studies (so-called "*cotutelles de thèse*"*;* e.g., with the "Babes-Bolyai" University in Cluj-Napoca, Romania, and in the EU Network of Excellence SANDiE). The Graduate School supports international exchange with other scientific institutions, and the doctoral candidates have the possibility to pursue their research abroad. Thus, they learn to work in an interdisciplinary, international scientific environment. This will be easily facilitated by numerous worldwide collaborations of the participating scientists. In addition, the Graduate School benefits from the university's agreements with partner institutions abroad (e.g., Université Strassbourg Louis Pasteur, Ohio University, Universidad de Salamanca, St. Petersburg University, and Jagiellonian University Krakau/Uniwersytet Jagieloński). Based on its historical function as link between Western and Eastern Europe the Universität Leipzig is a member of the Competence Center for Central and Eastern Europe Leipzig e.V. (KOMOEL, www.uni-leipzig.de/komoel), which aims at the collaboration between

Saxon scientific and cultural institutions and industrial partners focusing their activities in/on Central and Eastern Europe. There also exist well-established relations to Eastern and South Eastern European scientific institutions. For example, the Faculty of Physics and Earth Science has established a joint master program with St. Petersburg University (AcoPHYS) formalized in a faculty agreement and financially supported by the DAAD. Collaboration with American research institutions will be supported by the university's "Eastern Excellence Initiative" ("e^2-Initiative") which provides a contact office in NYC. To attract interested American or Canadian applicants the Graduate School will be included in the American and Canadian listing for undergraduate and graduate studies.

Long-standing experience exists in the integration of international doctoral candidates. Accordingly, doctoral candidates are supported in everyday problems, such as housing, health insurance, visa issues, child care, etc. The Graduate School will intensively collaborate with the RAL and the International Center of the Universität Leipzig. Besides guidance-counseling programs, cultural activities are offered to the doctoral candidates of the Graduate School. In spite of using English as the scientific language, the Graduate School will host cultural events that incite the interest of the doctoral candidates to learn German so that they can better participate in German social life. German classes at beginners' level (intensive lecture course "Erste Hilfe für ausländische Wissenschaftler in Leipzig") and advanced levels are provided by the Graduate School. These activities will help to facilitate the integration of foreign doctoral candidates into the new cultural environment. Furthermore, a ceremonial welcoming of doctoral candidates and farewell to graduates will take place at an Annual Reception. Internationalization of the graduate studies is part of the Bologna Process, which includes the bachelor and master studies as well as the doctoral studies in its third cycle. In the winter semester 2006/2007, the Universität Leipzig almost completed the Bologna Process by replacing most of the previous traditional courses (i.e. diploma, state exams) with BSc and MSc courses. Students can now choose from 83 study programs, of which only five are still state exams and four diploma study programs. We expect that the combination of international master courses and Graduate School will particularly contribute to the internationalization. Here, the admission and integration of applicants with different degrees (i.e. BSc, MSc, or diploma) into the Graduate School BuildMoNa is extremely important, especially for attracting talented students from the United States, Australia or the UK.

Further public outreach activities will include the annual University's Campus Day, participation in the annual Leipzig Book Fair, and the organization of BuildMoNa events. The first event in the series of annual scientific symposia, the so-called BuildMoNa Festivals, is dedicated to the implementation of the Graduate School in November 2007 ("Opening Ceremony of the Graduate School"). The main focus of these symposia will be on an international and interdisciplinary exchange of research activities according to the Graduate School's academic profile by inviting visiting researchers and young researchers from around the world as

participants. Furthermore, an annual BuildMoNa Report informing about ongoing research activities will be published, which will also be distributed among cooperating industrial and non-university partners. After completion of the first cycle of three years of doctoral studies within the Graduate School, the best doctoral candidates will be honoured with the BuildMoNa Award after selection by the Steering Committee. The Graduate School will continue the established program of experimental trainee work ("Besondere Lernleistung") with excellent local high schools such as the "Wilhelm Ostwald Gymnasium" and "Thomasschule" motivate interest for natural sciences in the next generation of academics. The Graduate School BuildMoNa will be engaged and represented in the biannual organization of the "Mitteldeutsche Jobbörse" (Recruiting Day), which is based on previous activities of the Young Chemist's Forum (JCF) of the German Chemical Society (GDCh), and brings together German and international companies/SMEs (small and medium-sized enterprises), and graduate students and doctoral candidates in the natural sciences.

The planned materials science center "Laboratory of Interdisciplinary Studies and Applications" (LISA) is expected to further intensify the relations with industrial partners and external research institutions by providing a unique materials characterization facility. In the future, this shall be additionally supported by the application for funding as an EU technology platform.

We expect that the research training concept of the Graduate School BuildMoNa, the international environment, and integrating measures will make the Graduate School very attractive for highly motivated doctoral candidates from all over the world.

4.6 Gender equality

During the last years, the number of students in natural sciences at the Universität Leipzig has increased constantly (the total number of beginners at the participating faculties increased from 3,361 (female 1,603) in 2000 to 4,867 (female 2,175 in 2006). In 2006, the percentage of women ranged from 65 % to 15 % in the natural sciences depending on the individual disciplines. These numbers vary within all academic levels (see Table 4 below). Further comparison between foreign and German doctoral candidates shows that the percentage of female foreign students is lower.

Gender equality at the Universität Leipzig is part of its strategic development and future vision. This is also reflected by the Graduate School's activities aiming at complementary offers in accordance with the university's and RAL measures. The university's strategy focuses on the particular encouragement of female junior scientists through special support of doctorates, habilitations and other qualifying routes for a professorship, and the mentoring program "ELISA – Elite Promotion Saxony". A number of measures to promote young female scientists have already been implemented, e.g., a nursery and preschool for children of members and guest lecturers of the Faculty of Medicine, the child-care program MEFALE, the allocation of scholarships for female scientists after a parental leave, and the establishment of a Center for Gender Research (FraGes). Gender equality is also ensured by the faculties' equality plans

Table 4 Percentage of women across all academic levels [percentage in 2006]

	Biochemistry	Chemistry	Physics	Mathematics	Participating Faculties	University overall
BSc	**54**	**38**	**13**	**30**	**47**	**63**
MSc	**67**	**44**	**11**	**38**	**50**	**64**
Doctoral candidates	**63**	**35**	**20**	**35**	**48**	**53**
Senior scientists	**46**	**26**	**18**	**51**	**27**	**43**
Professors	**33**	**11**	**0**	**5**	**10**	**16**

("Frauenförderplan"). Currently, the Universität Leipzig has applied for recognition as a "Family-Friendly University" ("Audit familiengerechte Hochschule") within the framework of the Hertie-Stiftung Initiative. The university's representative of gender equality is involved in the strategic planning and is also a member of the board of the RAL. In accordance with the university's policies the Graduate School will establish a family-friendly working environment to clearly signal that women are welcome and that it is feasible and normal for female and male scientists to combine family and scientific career. The following points shall ensure the fulfillment of the above-mentioned goals:

(1) During the recruitment process there will be no bias on the grounds of gender, nationality, or religion.

(2) The offer of flexible child-care facilities. The establishment of a university nursery and preschool center is part of the strategic planning. The facility will provide fast availability (especially for foreign scientists), flexible opening hours, and child-care proficient in foreign languages (such as English, French, or Spanish). The opening of such a child-care center is planned for 2009 according to the decision of the University's Rectorate from 2nd March 2007. Until then, alternative child-care facilities are provided by initiatives of the RAL, and the BBZ/MPI. In addition, the child-care concept of the SFB 610, which has been successfully established at the Universität Leipzig over the last years, will be part of the Graduate School's concept. Therefore, the Graduate School will employ additional staff with a main focus on flexible child care according to the scientists' unconventional working hours (including evenings and weekends), and during the participation in conferences, excursions, workshops or whenever child care is needed.

(3) Flexible working hours and Personal Development Plan (PDP). For doctoral candidates with children flexible working hours will be facilitated. They can prepare presentations, write reports, and analyze research results at home, for which the Graduate School's computer equipment can be used (i.e. notebook and software). In addition, the PDP can be adjusted according to the overall flexible research training concept.

(4) Parental leave for scientists. Scholarships can be split in case of a parental leave in such a way that the continuation of the doctoral studies without financial loss is possible after the break. Furthermore, during the first six months after the return the working hours per week can be reduced. On request, student assistants can be employed to carry out parts of the experimental work during the pregnancy.

5 PRINCIPAL INVESTIGATORS AND SELECTED PUBLICATIONS

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Research Expertise/Activities in Research

Chemical ligation strategies; Immobilisation and chemical modification of enzymes; Structure-activity studies of neuropeptides; Ligand binding and signal transduction of G-protein coupled receptors; Peptide carriers for drug delivery

List of 10 selected publications
(188 published in refereed journals, 92 since 2001)

[1] Böhme, I.; Mörl, K.; Bamming, D.; Meyer, C.; Beck-Sickinger, A. G.
Tracking of Human Y Receptors in Living Cells – a Fluorescence Approach
Peptides 28 (2007) 226-234

[2] Goede, K.; Grundmann, M.; Holland-Nell, K.; Beck-Sickinger, A. G.
Cluster Properties of Peptides on (100) Semiconductor Surfaces
Langmuir 22 (2006) 8104-8108

[3] Lang, M.; De Pol, S.; Baldauf, C.; Hofmann, H.-J.; Reiser, O.; Beck-Sickinger, A. G.
Identification of the Key Residue of Calcitonin Gene Related Peptide (CGRP) 27-37 to Obtain Antagonists with Picomolar Affinity at the CGRP Receptor
J. Med. Chem. 49 (2006) 616-624

[4] Foerg, C.; Ziegler, Ur; Fernandez-Carneado, J.; Giralt, E.; Rennert, R.; Beck-Sickinger, A. G.; Merkle, H. P.
Decoding the Entry of two Novel Cell Penetrating Peptides in HeLa Cells: Lipid-raft Mediated Endocytosis and Endosomal Escape
Biochemistry 44 (2005) 72-81

[5] Wagner, K.; Van Mau, N.; Boichot, S.; Kajava, A. V.; Krauss, U.; Le Grimellec, C.; Beck-Sickinger, A. G.; Heitz, F.
Interactions of Human Calcitonin - fragment 9-32 with Phospholipids: a Monolayer Study
Biophysic. J. 87 (2004) 386-395

[6] David, R.; Richter, M. P. O.; Beck-Sickinger, A. G.
Expressed Protein Ligation: Methods and Application
Eur. J. Biochem. 271 (2004) 663-677

[7] Machova, Z.; von Eggelkraut-Gottanka, R.; Wehofsky, N.; Bordusa, F.; Beck-Sickinger, A. G.
Expressed Enzymatic Ligation: a New Approach for the Synthesis of Chemically Modified Proteins
Angew. Chem. Int. Ed. 42 (2003) 4916-4918

[8] David, R.; Machova, Z.; Beck-Sickinger, A. G.
Semisynthesis and Application of Carboxyfluorescein-labeled Biologically Active Human Interleukin-8
Biol. Chem. 384 (2003) 1619-1630

[9] Koglin, N.; Zorn, C.; Beumer, R.; Bubert, C.; Sewald, N.; Reiser, O.; Beck-Sickinger, A. G.
Analogues of Neuropeptide Y Containing γ-Amino-cyclopropane-carboxylic Acids are the Shortest Linear Peptides Selective for the Y_1-Receptor
Angew. Chem. Int. Ed. 42 (2003) 202-205

[10] Dinger, M. C.; Bader, J. E.; Kóbor, A. D.; Kretzschmar, A. K.; Beck-Sickinger, A. G.
Homodimerization of NPY Receptors Investigated by Fluorescence Resonance Energy Transfer in Living Cells
J. Biol. Chem. 278 (2003) 10562-10571

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Research Expertise/Activities in Research

Method development in nuclear magnetic resonance; Application of nuclear magnetic resonance to biochemistry, organic chemistry, and organometallic chemistry

List of 10 selected publications
(173 published in refereed journals, 45 since 2001)

[1] Baskyr, I.; Brand, T.; Findeisen, M.; Berger, S.
Acquisition Regime for High Resolution Heteronuclear 2D NMR Spectra
Angew. Chem. Int. Ed. Engl. 45, (2006), 7821-7824

[2] Ackermann, M.; Pascariu, A.; Höcher, T.; Siehl, H.-U.; Berger, S.
Electronic Properties of Furyl Substituents at Phosphorus and their Influence on ^{31}P-NMR Chemical Shifts
J. Amer. Chem. Soc. 128 (2006) 8434-8440

[3] Seeger, K.; Lein, S.; Reuter, G.; Berger, S.
Saturation Transfer Difference Measurements with SU(VAR)3-9 and S-adenosyl-L-methionine
Biochemistry 44 (2005) 6208-6213

[4] Peikert, C.; Seeger, K.; Bhat, R. K.; Berger, S.
Determination of the Binding Specificity of the 12S Subunit of the Transcarboxylase by Saturation Transfer Difference NMR
Org. Biomol. Chem. 2 (2004) 1777-1781

[5] Thiele, C. M.; Berger, S.
Probing the Diasterotopicity of Methylene Protons in Strychnine Using Residual Dipolar Couplings
Org. Lett. 5 (2003) 705-708

[6] Appel, M.; Blaurock, S.; Berger, S.
Wittig Reaction with 2-Furyl Substituents at the Phosphorus: Improved Z-Selectivity and Isolation of a Stable Oxaphosphetane Intermediate
Eur. J. Org. Chem. (2002) 1143-1148

[7] Fioroni, M.; Díaz, M. D.; Burger, K.; Berger, S.
Solvation Phenomena of a Tetrapeptide in Water/Trifluoroethanol and Water/Ethanol Mixtures. A Diffusion NMR, Intermolecular NOE and Molecular Dynamics Study
J. Am. Chem. Soc. 124 (2002) 7737-7744

[8] Cabrita, E. J.; Berger, S.
HR-DOSY as a New Tool for the Study of Chemical Exchange Phenomena
Magn. Reson Chem. 40 (2002) 122-S127

[9] Díaz, M. D.; Fioroni, M.; Burger, K.; Berger, S.
Evidence of Complete Hydrophobic Coating of Bombesin by Trifluoroethanol in Aqueous Solution, a NMR and Molecular Dynamics Study
Chem. Eur. J. 8 (2002) 1663-1669

[10] Schlörer, N. E.; Cabrita, E. J.; Berger, S.
Characterization of Reactive Intermediates by Diffusion Ordered NMR Spectroscopy: A Snapshot of the Reaction of $^{13}CO_2$ with $Cp_2Zr(Cl)H$
Angew. Chem. Int. Ed. 41 (2002) 107-109

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Research Expertise/Activities in Research

Transition metal-based photoinitiators; Controlled "living" (photo-) polymerization from and to surfaces; Immobilization of organo-metallic catalysts; Surface modification of meso- and macro-porous systems, applications in catalysis; Living ring-opening metathesis polymerization; Electrooptical devices and sensors

List of 10 selected publications
(153 published in refereed journals, 122 since 2001)

[1] Wang, D.; Kröll, R., Mayr, M., Wurst, K., Buchmeiser, M. R.
The First Polymer-Supported Chiral Schrock Catalysts Immobilized via the Arylimido Ligand
Adv. Synth. Catal. 348 (2006) 1567-1579

[2] Mayr, M.; Wang, D.; Kröll, R.; Schuler, N.; Prühs, S.; Fürstner, A.; Buchmeiser, M. R.
Monolithic Disk-Supported Metathesis Catalysts for Use in Combinatorial Chemistry
Adv. Synth. Catal. 347 (2005) 484-492

[3] Halbach, T. S.; Mix, S.; Fischer, D.; Maechling, S.; Krause, J. O.; Sievers, C.; Blechert, S.; Nuyken, O.; Buchmeiser, M. R.
Novel Ruthenium-Based Metathesis Catalysts Containing Electron-Withdrawing Ligands: Synthesis, Immobilization and Reactivity
J. Org. Chem. 70 (2005) 4687-4694

[4] Krause, J. O.; Wurst, K.; Nuyken, O.; Buchmeiser, M. R.
Synthesis and Reactivity of Homogenous and Heterogeneous Ruthenium-based Metathesis Catalysts Containing Electron Withdrawing Ligands
Chem. Eur. J. 10 (2004) 778-785

[5] Mayr, M.; Wurst, K.; Ongania, K.-H.; Buchmeiser, M. R.
1,3-Dialkyl- and 1,3-Diaryl-3,4,5,6-tetrahydropyrimidin-2-ylidene Rhodium (I) and Palladium (II) Complexes: Synthesis, Structure, and Reactivity
Chem. Eur. J. 10 (2004) 1256-1266

[6] Krause, J. O.; Nuyken, O.; Buchmeiser, M. R.
Factors Relevant for the Ruthenium-Benzylidene Catalyzed Cyclopolymerization of 1,6-Heptadyines
Chem. Eur. J. 10 (2004) 2029-2035

[7] Yang, L.; Mayr, M.; Wurst, K.; Buchmeiser, M. R.
Novel Metathesis Catalysts Based on Ruthenium 1,3-Dimesityl-3,4,5,6-tetrahydropyrimidin-2-ylidenes: Synthesis, Structure, Immobilization, and Catalytic Activity
Chem. Eur. J. 10 (2004) 5761-5770

[8] Krause, J. O.; Zarka, M. T.; Anders, U.; Weberskirch, R.; Nuyken, O.; Buchmeiser, M.
Simple Synthesis of Poly(acetylene) Latex Particles In Aqueous Media
Angew. Chem. 115 (2003) 6147-6151

[9] Kröll, R. M.; Schuler, N.; Lubbad, S.; Buchmeiser, M. R.
A ROMP-derived, Polymer-supported Chiral Schrock Catalyst for Enantioselective Olefin Metathesis
Chem. Commun. (2003) 2742-2743

[10] Anders, U.; Nuyken, O.; Wurst, K.; Buchmeiser, M. R.
Stereoselective Cyclopolymerisation of 1,6-Heptadiynes: Access to Alternating cis-trans-1,3-(Cyclopent-1-enylen)vinylenes by Fine-tuning of Molybdenum Imidoalkylidenes
Angew. Chem. 114 (2002) 4226-4230

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Research Expertise/Activities in Research

Hyperfine techniques, in particular perturbed angular correlations; High-energy ion-nanoprobes for analysis and as micromechanical tool; Applications in material and life sciences

List of 10 selected publications
(230 published in refereed journals, 56 since 2001)

[1] Schwertner, M.; Sakellariou,A.; Reinert, T.; Butz, T.
Scanning Transmission Ion Micro-Tomography (STIM-T) of Biological Specimens
Ultramicroscopy 106 (2006) 574

[2] Butz, T.; Spemann, D.; Han, K.-H.; Höhne, R.; Setzer, A. ; Esquinazi, P.
The Role of Nuclear Nanoprobes in Inducing Magnetic Ordering in Graphite
Hyperfine Interactions 160 (2005) 27

[3] Menzel, F.; Reinert, T.; Vogt, J.; Butz, T.
Investigations of Percutaneous Uptake of Ultrafine TiO_2 Particles at the High Energy Ion, Nanoprobe LIPSION
Nucl. Instr. and Meth. B 219-220 (2004) 82–86

[4] Esquinazi, P.; Höhne, R.; Han, K.-H.; Setzer, A.; Spemann, D.; Butz, T.
Magnetic Carbon: An Explicit Evidence on Ferromagnetism Induced by Proton Irradiation
Carbon 42 (7) (2004) 1213–1217

[5] Esquinazi, P.; Spemann, D.; Höhne, R.; Setzer, A.; Han, K.-H.; Butz, T.
Induced Magnetic Ordering by Proton Irradiation in Graphite
Phys. Rev. Lett. 91 (2003) 227201

[6] Han, K.-H.; Spemann, D.; Esquinazi, P.; Höhne, R.; Riede, V.; Butz, T.
Ferromagnetic Spots in Graphite Produced by Proton Irradiation
Advanced Materials 15 (2003) 1719

[7] Schwoerer, H.; Ewald, F.; Sauerbrey, R.; Galy, J.; Magill, J.; Rondinella, V.; Schenkel, R.; Butz, T.
Fission of Actinides Using a Tabletop Laser
Europhys.Lett. 61 (2003) 47–52

[8] Spemann, D.; Reinert, T.; Vogt, J.; Wassermann, J.; Butz, T.
Active Compensation of Stray Magnetic Fields at LIPSION
Nucl. Instr. Meth. B 210 (2003) 79

[9] Esquinazi, P.; Setzer, A.; Höhne R.; Semmelhack, C.; Kopelevich, Y.; Spemann, D.; Butz, T.; Kohlstrunk, B.; Lösche, M.
Ferromagnetism in Oriented Graphite Samples
Phys. Rev. B 66 (2) (2002) 024429

[10] Butz, T.; Lehmann, D.; Reinert, T.; Spemann, D.; Vogt, J.
Ion Microscopy and Tomography
Acta Physica Polonica 100 (2001) 603–613

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Research Expertise/Activities in Research

Low-Temperature Physics; Superconductivity; Magnetism; Acoustics

List of 10 selected publications
(187 published in refereed journals, 71 since 2001)

[1] Kempa, H.; Esquinazi, P.; Kopelevich, Y.
Integer Quantum Hall Effect in Graphite
Solid State Communications 138 (2006) 118

[2] Y. Lu, M. Muñoz, C. Steplecaru, C. Hao, M. Bai, N. Garcia, K. Schindler and P. Esquinazi,
Electrostatic force microscopy on oriented graphite surfaces: Coexistence of insulating and conducting behaviors,
Phys. Rev. Lett. 97 (2006) 076805

[3] Esquinazi, P.; Höhne, R.; Han, K.-H.; Spemann, D.; Setzer, A.; Diaconu, M.; Schmidt, H.; Butz, T.
Induced Magnetic Order by Ion Irradiation of Carbon-based Structures
In *Carbon-Based Magnetism*, T. Makarova and F. Palacio (Editors), (2006, Elsevier B. V.), Chap. 19, 437

[4] Ulrich, K.; Esquinazi, P.
Magnetothermal Transport of Oriented Graphite at Low Temperatures
J. Low Temp. Phys. 137 (2004) 217-231

[5] Ocaña, R.; Esquinazi, P.
Quasiparticles in the Mixed State of Y123 Crystals: What Do We Learn from Thermal Magnetoconductivity Tensor results?
Physica 408-410 (2004) 716-720

[6] Esquinazi, P.; Spemann, D.; Höhne, R.; Setzer, A.; Han, K.-H.; Butz, T.
Induced Magnetic Ordering by Proton Irradiation in Graphite
Phys. Rev. Lett. 91 (2003) 227201

[7] Kopelevich, Y.; Torres, J. H. S. ; da Silva, R. R.; Mrowka, F.; Kempa, H.; Esquinazi, P.
Reentrant Metallic Behavior of Graphite in the Quantum Limit
Phys. Rev. Lett. 90 (2003) 156402

[8] Esquinazi, P.; Setzer, A.; Höhne, R.; Semmelhack, C.; Kopelevich, Y.; Spemann, D.; Butz, T.; Kohlstrunk, B.; Lösche, M.
Ferromagnetism in Oriented Graphite Samples
Phys. Review B 66 (2002) 024429 (1-10)

[9] Ocaña, R.; Esquinazi, P.
Angle Dependence of the Transverse Thermal Conductivity in Y123 Single Crystals: Doppler Shift and Andreev Scattering Contributions
Phys. Rev. Lett. 87 (2001) 167006

[10] Gupta, A.; Esquinazi, P.; Braun, H.F., Neumüller, H.-W.
Thermally Activated Depinning in Polycrystalline Bi-based High Tc Superconductors
Phys. Rev. Lett. 63 (1989) 1869

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Research Expertise/Activities in Research

Semiconductors; Nanostructures; Self-assembly; Quantum dots; Quantum wires; Nano-photonics; Nano-electronics; Simulation of nanostructures

List of 10 selected publications
(over 200 papers published in refereed journals, 81 since 2001)

[1] Grundmann, M.
Introduction to Semiconductor Physics
Springer, Heidelberg, 2006, 730 pages, ISBN: 3-540-25370-X

[2] Lorenz, M.; Kaidashev, E. M.; Rahm, A.; Nobis, T.; Lenzner, J.; Wagner, G.; Spemann, D.; Hochmuth, H.; Grundmann, M.
$Mg_xZn_{1-x}O$ (0<=x<0.2) Nanowire Arrays on Sapphire Grown by High-pressure Pulsed Laser Deposition
Appl. Phys. Lett. 86 (2005) 143113

[3] Goede, K.; Busch, P.; Grundmann, M.
Binding Specificity of a Peptide on Semiconductor Surfaces
Nano Lett. 4 (2004) 2115

[4] Nobis, T.; Kaidashev, E. M.; Rahm, A.; Lorenz, M.; Grundmann, M.
Whispering Gallery Modes in Nano-sized Dielectric Resonators with Hexagonal Cross Section
Phys. Rev. Lett. 93 (2004) 103903

[5] Nobis, T.; Kaidashev, E. M.; Rahm, A.; Lorenz, M.; Lenzner, J.; Grundmann, M.
Spatially Inhomogeneous Impurity Distribution in ZnO Micropillars
Nano Letters 4 (2004) 797

[6] Grundmann, M.
Nanoscroll Formation from Strained Layer Heterostructures
Appl. Phys. Lett. 83 (2003) 2444

[7] Kaidashev, E. M.; Lorenz, M.; von Wenckstern, H.; Lenzner, J.; Benndorf, G.; Rahm, A.; Semmelhack, H. C.; Han, K.-H.; Hochmuth, H.; Bundesmann, C.; Riede, V.; Grundmann, M.
High Electron Mobility of Epitaxial ZnO Thin Films on c-Plane Sapphire Grown by Multistep Pulsed-laser Deposition
Appl. Phys. Lett. 82 (2003) 3901

[8] Stier, O.; Grundmann, M.; Bimberg, D.
Electronic and Optical Properties of Strained Quantum Dots Modeled by 8-Band k dot p Theory
Phys. Rev. B 59 (1999) 5688

[9] Grundmann, M.; Christen, J.; Ledentsov, N. N.; Böhrer, J.; Bimberg, D.; Ruvimov, S. S.; Werner, P.; Richter, U.; Gösele, U.; Heydenreich, J.; Ustinov, V. M.; Egorov, A. Yu.; Zhukov, A. E.; Kop'ev, P. S.; Alferov, Zh. I.
Ultranarrow Luminescence Lines from Single Quantum Dots
Phys. Rev. Lett. 74 (1995) 4043

[10] Grundmann, M.; Stier, O.; Bimberg, D.
InAs/GaAs Quantum Pyramids: Strain Distribution, Optical Phonons and Electronic Structure
Phys. Rev. B 52 (1995) 11969

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Research Expertise/Activities in Research

Broad NMR methodical knowledge in physical chemistry, physics; Physics of correlated electronic materials (high-temperature superconductivity); Worldwide first demonstration of NMR in pulsed high field magnets

List of 10 selected publications
(55 published in refereed journals, 23 since 2001)

[1] Kozlov, M. B.; Haase, J.; Baumann, C.; Webb, A. G.
56 Tesla 1H NMR at 2.4 GHz in a Pulsed High-field Magnet
Solid State Nuclear Magnetic Resonance 28 (2005) 64-67

[2] Haase, J.; Sushkov, O. P.; Horsch, P.; Williams, G. V. M.
Planar Cu and O Hole Densities in High-Tc Cuprates Determined with NMR
Phys. Rev. B 69 (2004) 094504-1 - 094504-9

[3] Curro, N. J.; Milling, C. T.; Haase, J.; Slichter, C. P.
Local Field Dependence of the 17O Spin Lattice Relaxation and Echo Decay Rates in the Mixed State of $YBa_2Cu_3O_7$
Phys. Rev. B 62 (2000) 3473-3479

[4] Haase, J.; Slichter, C. P.; Stern, R.; Milling, C. T.; Hinks, D. G.
Spatial Modulation of the NMR Properties of the Cuprates
Physica C 341-348 (2000) 1727-1730

[5] Haase, J.; Morr, D. K.; Slichter, C. P.
Real Space Electron Spin Susceptibility $\chi'(r)$ and NMR T2G for Incommensurate Spin Fluctuations in Cuprates
Phys. Rev. B 59 (1999) 7191-7195

[6] Haase, J.; Curro, N. J.; Stern, R.; Slichter, C. P.
New Methods for NMR of Cuprate Superconductors
Phys. Rev. Lett. 81 (1998) 1489-1492

[7] Haase, J.; Conradi, M. S.
Sensitivity Enhancement for NMR of the Central Transition of Quadrupolar Nuclei
Chem. Phys. Lett. 209 (1993) 287-291

[8] Haase, J.; Oldfield, E.
Spin-echo Behavior of Non-integral Spin Quadrupolar Nuclei in Inorganic Solids
J. Magn. Reson., Series A 101 (1993) 30-40

[9] Freude, D.; Haase, J.
NMR of Quadrupolar Nuclei in Solids
NMR Basic Principles and Progress 29 (1993) 1-90

[10] Fenzke, D.; Freude, D.; Fröhlich, T.; Haase, J.
NMR Intensity Measurements of Half-integer Quadrupole Nuclei
Chem. Phys. Lett. 111 (1984) 171-175

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Research Expertise/Activities in Research

Reactions of transition metal complexes with functionalized ligands of group 13 and 15 elements; Homo- and heterometallic s-, p-, d- and f-metal phosphides; Phosphorus and boron compounds; Heteronuclear complexes; Homogeneous catalysis; (Chiral) catalytically active MOFs (metal-organic frameworks)

List of 10 selected publications
(207 in refereed journals, 105 since 2001)

[1] Helmstedt, U.; Lönnecke, P.; Reinhold, R.; Hey-Hawkins, E.
4-Thiolatobenzoato-Bridged Rhodium/Zirconium Complexes: 32-Membered Metallamacrocycles and their Linear Dinuclear Counterparts
Europ. J. Inorg. Chem. (2006) 4922-4930

[2] Wolf, R.; Gomez-Ruiz, S.; Reinhold, J.; Böhlmann, W.; Hey-Hawkins, E.
The (P4HMes4)- Anion: Lability, Fluxionality and Structural Ambiguity (Mes = 2,4,6-Me3C6H2)
Inorg. Chem. 45 (2006) 9107-9113

[3] Wolf, R.; Hey-Hawkins, E.
Synthesis and Molecular Structure of the Cu_4P_8 cage compound $[Cu_4(P_4Ph_4)_2(PCyp_3)_3]$
Angew. Chem. Int. Ed. 44 (2005) 6241-6244

[4] Tschirschwitz, S.; Lönnecke, P.; Reinhold, J.; Hey-Hawkins, E.
From Novel Chiral Primary Aminoalkyl(phosphanyl)ferrocenes to the First Lithium–Phosphorus *closo* Cluster
Angew. Chem. Int. Ed. 44 (2005) 2965-2969

[5] Schisler, A.; Lönnecke, P.; Hey-Hawkins, E.
Synthesis and Molecular Structure of the first Rhodium(I) Complex containing a Tetra-*tert*-butyl-cyclopentaphosphanide ligand
Inorg. Chem. 44 (2005) 461-464

[6] Wolf, R.; Schisler, A.; Lönnecke, P.; Jones, C.; Hey-Hawkins, E.
Syntheses and Molecular Structures of Novel Alkali Metal Tetraorganylcyclopentaphosphanides and Tetraorganyltetraphosphane-1,4-diides
Europ. J. Inorg. Chem. (2004) 3277-3286

[7] Balueva, A. S.; Kuznetsov, R. M.; Ignat'eva, S. N.; Karasik, A. A.; Gubaidullin, A. T.; Litvinov, I. A.; Sinyashin, O. G.; Lönnecke, P.; Hey-Hawkins, E.
Self-assembly of a Novel Type of Macrocyclic Aminomethylphosphines with Hydrophobic Intramolecular Cavity
Dalton Trans. (2004) 442-447

[8] Volkis, V.; Schmulinson, M.; Shaviv, E.; Lisovskii, A.; Plat, D.; Kühl, O.; Koch, T.; Hey-Hawkins, E.; Eisen, M. S.
Group 4 Octahedral Complexes Catalyzed Stereoregular and Elastomeric Polymerization of Propylene in "Beyond Metallocenes" Next-Generation Polymerization Catalysts, A. O. Patil and G. G. Hlatky Eds, American Chemical Society Symposium Series, Washington DC, 2003, chapter 4, 46-61

[9] Höcher, T.; Blaurock, S.; Hey-Hawkins, E.
Novel Ferrocene-Derivatives with P-H-functionalized Phosphanylalkylcyclo-pentadienyl Ligands: Syntheses and Molecular Structures of rac-$[Fe\{(\eta^5\text{-}C_5H_4)CMe_2PHR\}_2]$ (R = Ph, Mes) and rac-$[Fe\{(\eta^5\text{-}C_5H_4)CMe_2PHPh(Cp^*TaCl_4)\}_2]$
Eur. J. Inorg. Chem. (2002) 1174-1180

[10] Schisler, A.; Lönnecke, P.; Huniar, U.; Ahlrichs, R.; Hey-Hawkins, E.
Natrium-Tetra-tert-butyl-cyclopentaphosphanid – Synthese, Struktur und unerwartete Bildung eines Nickel(0)-Tri-tert-butyl-cyclopentaphosphen-Komplexes
Angew. Chem. Int. Ed. 40 (2001) 4217-4219

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Research Expertise/Activities in Research

Computer simulations of phase transitions and critical phenomena; Soft-matter physics (polymers, proteins, membranes); Disordered complex systems; Systems in confined geometry; Quantum statistics in the path-integral formalism; Conformal field theory; Perturbation theory and resummation of divergent series

List of 10 selected publications
(175 published in refereed journals, 79 since 2001)

[1] Berg, B. A.; Janke, W.
Wang-Landau Multibondic Cluster Simulations for Second-Order Phase Transitions
Phys. Rev. Lett. 98 (2007) 040602

[2] Schnabel, S.; Bachmann, M.; Janke, W.
Two-State Folding, Folding Through Intermediates, and Metastability in a Minimalistic Hydrophobic-Polar Model for Proteins
Phys. Rev. Lett. 98 (2007) 048103

[3] Junghans, Ch.; Bachmann, M.; Janke, W.
Microcanonical Analyses of Peptide Aggregation Processes
Phys. Rev. Lett. 97 (2006) 218103

[4] Gökoğlu, G.; Bachmann, M.; Çelik, T.; Janke, W.
Structural Properties of Small Semiconductor-Binding Synthetic Peptides
Phys. Rev. E 74 (2006) 041802

[5] Bachmann, M.; Janke, W.
Substrate Specificity of Peptide Adsorption: a Model Study
Phys. Rev. E 73 (2006) 020901 (R)

[6] Bachmann, M.; Janke, W.
Conformational Transitions of Non-grafted Polymers Near an Absorbing Substrate
Phys. Rev. Lett. 95 (2005) 058102

[7] Chatelain, C.; Berche, B.; Janke, W.; Berche, P.-E.
Monte Carlo Study of Phase Transitions in the Bond-diluted 3D 4-State Potts Model
Nucl. Phys. B 719 (2005) 275

[8] Hamprecht, B.; Janke, W.; Kleinert, H.
End-to-end Distribution Function of Two-dimensional Stiff Polymers for All Persistence Lengths
Phys. Lett. A 330 (2004) 254

[9] Bachmann, M.; Janke, W.
Multicanonical Chain-growth Algorithm
Phys. Rev. Lett. 91 (2003) 208105

[10] Berg, B. A.; Billoire, A.; Janke, W.
Functional Form of the Parisi Overlap Distribution for the Three-dimensional Edwards-Anderson-Ising Spin Glass
Phys. Rev. E 65 (2002) 045102 (R)

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Research Expertise/Activities in Research

Laser physics; Optics; Scanning probe techniques; Langmuir monolayers; Optical imaging of the motions of individual polymer chains; Development of novel laser traps; AFM-based microrheology; Biological physics; Statistical physics; Condensed matter physics of soft matter; Polymer physics; Medical physics

List of 10 selected publications
(51 published in refereed journals, 35 since 2001)

[1] Stuhrmann, B.; Jahnke, H.-G.; Schmidt, M.; Jähn, K.; Betz, T.; Müller, K.; Rothermel, A.; Käs, J.; Robitzki, A.
Versatile Optical Manipulation System for Inspection, Laser Processing, and Isolation of Individual Living Cells
Rev. Sci. Instrum. 77 (2006) 063116

[2] Wottawah, F.; Schinkinger, S.; Lincoln, B.; Ananthakrishnan, R.; Romeyke, M.; Guck, J.; Käs, J.
Optical Rheology of Biological Cells
Phys. Rev. Lett. 94 (9) (2005) 98103

[3] Ehrlicher, A.; Betz, T.; Stuhrmann, B.; Koch, D.; Milner, V.; Raizen, M.; Käs, J.
Guiding Neuronal Growth with Light
Proc. Natl. Acad. Sci. 99 (25) (2002) 16024-16028

[4] Humphrey, D.; Duggan, C.; Saha, D.; Smith, D.; Käs, J.
Active Fluidization of Polymer Networks through Molecular Motors
Nature 416 (2002) 413- 416

[5] Mahaffy, R.; Shih, C. K.; MacKintosh, F. C.; Käs, J.
Scanning Probe-based, Frequency-dependent Microrheology of Polymer Gels and Biological Cells
Phys. Rev. Lett. 85 (4) (2000) 880-883

[6] Guck, J.; Ananthakrishnan, R.; Moon, T. J.; Cunningham, C. C.; Käs, J.
Optical Deformability of Soft Biological Dielectrics
Phys. Rev. Lett. 84 (23) (2000) 5451-5454

[7] MacKintosh, F. C.; Käs, J.; Janmey, P. A.
Elasticity of Semiflexible Biopolymer Networks
Phys. Rev. Lett. 75 (24) (1995) 4425-4428

[8] Lu, Y.-B.; Franze, K. ; Seifer, G. ; Steinhäuser, C. ; Kirchhoff, F.; Wolburg, H.; Guck, J.; Janmey, P.; Wie, E.-Q.; Käs, J.; Reichenbach, A.
Viscoelastic Properties of Individual Glial Cells and Neurons in the CNS
PNAS, published November 8, 2006, 10.1073/pnas.0606150103

[9] Käs, J.; Strey, H.; Sackmann, E.
Direct Imaging of Reptation for Semiflexible Actin Filaments
Nature 368 (1994) 226-229

[10] Käs, J.; Sackmann, E.
Shape Transitions and Shape Stability of Giant Phospholipid Vesicles in Pure Water Induced by Area-to-volume Changes
Biophys. J. 60 (1991) 825-844

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Research Expertise/Activities in Research

Supramolecular chemistry; Coordination chemistry; Bioinorganic chemistry; Molecular magnetism

List of 10 selected publications
(36 published in refereed journals, 36 since 2001)

[1] Journaux, Y.; Hausmann, J.; Lozan, V.; Kersting, B.
Stabilisation of a Paramagnetic Borohydrido-bridged Dinickel(II) Complex by a Macrodinucleating Hexaaza-dithiophenolate Ligand
Chem. Commun. (2006) 83–84

[2] Käss, S.; Gregor, T.; Kersting, B.
Diels-Alder Reactivity of Binuclear Complexes with "Calixarene-like" Structures
Angew. Chem. Int. Ed. 45 (2006) 101–104

[3] Kersting, B.
Metalated Container Molecules
Z. Anorg. Allg. Chem. 630 (2004) 765-780

[4] Hausmann, J.; Klingele, M. H.; Lozan, V.; Steinfeld, G.; Siebert, D.; Journaux, Y.; Girerd, J.-J.; Kersting, B.
Realization of Unusual Substrate Binding Motifs in Metalated Container Complexes. Synthesis, Structures, and Magnetic Properties of the Complexes $[(L^{Me})Ni_2(u\text{-}L')]^{n+}$ with L' = NO_3^-, NO_2^-, N_3^-, N_2H_4, Pyridazine, Phthalazine, Pyrazolate, and Benzoate
Chem. Eur. J. 10 (2004) 1716-1728

[5] Steinfeld, G.; Lozan, V.; Kersting, B.
cis-Bromination of Encapsulated Alkenes
Angew. Chem. Int. Ed. 42 (2003) 2261–2263

[6] Kersting, B.; Steinfeld, G.
Carboxylate and Alkyl Carbonate Coordination at the Hydrophobic Binding Site of a Redox-Active Dicobalt Amine-Thiophenolate Complex
Inorg. Chem. 41 (2002) 1140-1150

[7] Kersting, B.
Carbon Dioxide Fixation by Binuclear Complexes with Hydrophobic Binding Pocket
Angew. Chem. Int. Ed. 40 (2001) 3987–3990

[8] Kersting, B.; Steinfeld, G.
The Effect of N-methylation on the Chemical Reactivity of Binuclear Ni Amine-thiolate Complexes
Chem. Commun. (2001) 1376-1377

[9] Kersting, B.; Steinfeld, G.; Siebert, D.
Binuclear Complexes as Building Blocks for Polynuclear Complexes with High-Spin Ground States: Synthesis and Structure of a Tetranuclear Nickel Complex with an S = 4 Ground State
Chem. Eur. J. 7 (2001) 4253-4258

[10] Steinfeld, G.; Kersting, B.
Characterisation of a Triply thiolate-bridged Ni-Fe Amine-thiolate Complex: Insights into the Electronic Structure of the Active Site of [NiFe] Hydrogenase
Chem. Commun. (2000) 205–206

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Research Expertise/Activities in Research

Biological physics; Polymer physics; Semiconductor physics; Single-molecule techniques; AFM-nanolithography; Low-temperature physics

List of 10 selected publications
(over 20 in refereed journals, 21 since 2001)

[1] Keyser, U. F.; Koeleman, B.; van Dorp, S.; Krapf, D.; Smeets, R. M. M.; Lemay, S. G.; Dekker, N. H.; Dekker, C.
Direct Force Measurements on Voltage Driven DNA Translocation Through a Nanopore
Nature Physics 2 (7) (2006) 473

[2] Smeets, R. M. M.; Keyser, U. F.; Wu, M. Y.; Dekker, N. H.; Dekker, C.
Nanobubbles in Solid-state Nanopores
Phys. Rev. Lett. 97 (8) (2006) 088101

[3] Smeets, R. M. M.; Keyser, U. F.; Krapf, D.; Wu, M.-Y.; Dekker, N. H.; Dekker, C.
Salt-dependence of Ionic Transport and DNA Translocation Through Solid-state Nanopores
Nano Letters 6 (1) (2006) 89

[4] Keyser, U. F.; Krapf, D.; Koeleman, B. N.; Smeets, R. M. M.; Dekker, N. H.; Dekker, C.
Nanopore Tomography of a Laser Focus
Nano Letters 5 (11) (2005)

[5] Rogge, M. C.; Fühner, C.; Keyser, U. F.; Haug, R. J.
Spin Blockade in Capacitively Coupled Quantum Dots
Appl. Phys. Lett. 85 (4) (2004) 606

[6] Rogge, M.; Fühner, C.; Keyser, U. F.; Haug, R. J.; Bichler, M.; Abstreiter, G.; Wegscheider, W.
Combined Atomic Force Microscope and Electron-beam Lithography Used for the Fabrication of Variable-coupling Quantum Dots
Appl. Phys. Lett. 83 (6) (2003) 1163

[7] Keyser, U. F.; Fühner, C.; Borck, S.; Haug, R. J.; Bichler, M.; Abstreiter, G.; Wegscheider, W.
Kondo Effect in a Few-electron Quantum Ring
Phys. Rev. Lett. 90 (19) (2003) 199601

[8] Keyser, U. F.; Borck, S.; Haug, R. J.; Bichler, M.; Abstreiter, G.; Wegscheider, W.
Aharonov-Bohm Oscillations of a Tuneable Quantum Ring
Semicon. Sci. Technol. 17 (5) (2002) L22

[9] Keyser, U. F.; Schumacher, H. W.; Zeitler, U.; Haug, R. J.; Eberl, K.
Fabrication of a Single-electron Transistor by Current-controlled Local Oxidation of a Two-dimensional Electron System
Appl. Phys. Lett. 76 (4) (2000) 457

[10] Schumacher, H. W.; Keyser, U. F.; Zeitler, U.; Haug, R. J.; Eberl, K.
Nanomachining of Mesoscopic Electronic Devices using an Atomic Force Microscope
Appl. Phys. Lett. 75 (8) (1999) 1107

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Research Expertise/Activities in Research

Environmental chemistry; Catalysis in water; Oxidation and reduction of organic pollutants; Remediation technologies; Isotope fractionation in physical and chemical processes; Sorption and mobility of organic compounds in environmental compartments

List of 10 selected publications
(160 published in refereed journals, 40 since 2001)

[1] Mackenzie, K.; Frenzel, H.; Kopinke, F.-D.
Hydrodehalogenation of Halogenated Hydrocarbons in Water with Pd Catalysts: Reaction Rates and Surface Competition
Appl. Cat. B Environm. 63 (2006) 161-167

[2] Buchenhorst, D.; Toufar, H.; Kopinke, F.-D.; Roland, U.
Radiowellenerwärmung von Adsorbenzien und Katalysatoren. T. 1: Grundl. und technische Realisierung
Chem.-Ing. Technik 78 (2006) 45-51

[3] Buchenhorst, D.; Kopinke, F.-D.; Roland, U.
Radiowellenerwärmung von Adsorbenzien und Katalysatoren. Teil 2: Untersuchungen zur selektiven Erwärmung von Katalysatoren
Chem.-Ing. Technik 78 (2006) 548-554

[4] Kopinke, F.-D.; Georgi, A.; Richnow, H.
Comment on „New Evaluation Scheme for Two-Dimensional Isotope Analysis to Decipher Biodegradation Processes: Application to Groundwater Contamination by MTBE
Environm. Sci. Technol. 39 (2005) 8541-8542

[5] Roland, U.; Holzer, F.; Kopinke, F.-D.
Combination of Non-thermal Plasma and Heterogeneous Catalysis for Oxidation of Volatile Organic Compounds Part 3. Electron Paramagnetic Resonance (EPR) of Plasma-treated Porous Alumina
Appl. Cat. B Environm. 58 (2005) 227-234

[6] Kopinke, F.-D.; Georgi, A.; Voskamp, M.; Richnow, H. H.
Carbon Isotope Fractionation of Organic Contaminants due to Retardation on Humic Substances – Implications for Natural Attenuation Studies in Aquifers
Environm. Sci. Technol. 39 (2005) 6052-6062

[7] Mackenzie, K.; Battke, J.; Kopinke F.-D.
Catalytic Effects of Activated Carbon on Hydrolysis Reactions of Chlorinated Organic Compounds. Part 1: γ-Hexachloro-cyclohexane
Cat. Today 102-103C (2005) 148-153

[8] Mackenzie, K.; Battke, J.; Köhler, R.; Kopinke, F.-D.
Catalytic Effects of Activated Carbon on Hydrolysis Reactions of Chlorinated Organic Compounds. Part 2: 1,1,2,2-Tetrachloroethane
Appl. Cat. B Environm. 59 (2005) 171-179

[9] Kopinke, F.-D.; Mackenzie, K.; Koehler, R.; Georgi A.
Alternative Sources of Hydrogen for Hydrodechlorination of Chlorinated Organic Compounds in Water on Pd Catalysts
Appl. Cat. A General 271 (2004) 119-128

[10] Georgi, A.; Kopinke F.-D.
Interaction of Adsorption and Catalytic Reactions in Water Decontamination Processes. Part 1: Oxidation of Organic Contaminants with Hydrogen Peroxide Catalyzed by Activated Carbon
Appl. Cat. B Environm. 58 (2004) 9-18

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Research Expertise/Activities in Research

Solid state chemistry; Synthesis and handling of air sensitive materials; Molecular precursors; Clusters and polynuclear compounds; Coordination polymers; X-ray structure analysis

List of 10 selected publications
(84 published in refereed journals, 31 since 2001)

[1] Gural'skiy, I. A.; Solntsev, P. V.; Krautscheid, H.; Domasevitch, K. V.
Metal-organic Frameworks Exhibiting Strong Anion-π Interactions
J. Chem. Soc., Chem. Comm. (2006) 4808

[2] Lysenko, A. B.; Govor, E. V.; Krautscheid, H.; Domasevitch, K. V.
Metal-organic Frameworks Incorporating $Cu_3(\mu_3\text{-}OH)$ Clusters
J. Chem. Soc., Dalton Trans. (2006) 3772

[3] Schmidtke, M.; Krautscheid, H.
$(Et_4N)_2[Sn_6Se_{10}Br_6]$ – Ein Zinnselenidcluster mit trigonal prismatischer Struktur
Z. anorg. allg. Chem. 632 (2006) 1399

[4] Gerber, S.; Gröger, H.; Ensling, J.; Gütlich, P.; Krautscheid, H.
$(Pr_4N)_4[Ag_3Fe_2(ECN)_{12}]$ (E = S, Se) – Anionennetzwerke mit gegenseitiger Durchdringung
Angew. Chem. 117 (2005) 7965

[5] Lode, C.; Krautscheid, H.; Mueller, U.
$[C_3H_7N(C_2H_4)_3NC_3H_7]_2[Sn_4I_{12}]$ – An Iodostannate with Linked SnI_5 Pyramids
Z. anorg. allg. Chem. 631 (2005) 587

[6] Gerber, S.; Krautscheid, H.; Gelbrich, T.; Vollmer, H.
Synthese und Kristallstrukturen von heteronuklearen Ag^I/Fe^{II}-Koordinationspolymeren: $(Me_3PhN)_2[Ag_2Fe(SCN)_6]$, $(Me_3PhN)_6[Ag_6Fe_3(ECN)_{18}]$ (E = S, Se) und $(Me_3PhN)_4[Ag_2Fe(SCN)_8]$
Z. anorg. allg. Chem. 630 (2004) 1427

[7] Solntsev, P.; Sieler, J.; Krautscheid, H.; Domasevitch, K. V.
Fused Pyridazines: Rigid Multidentates for Designing and Fine-tuning the Structure of Hybrid Organic/Inorganic Frameworks
J. Chem. Soc., Dalton Trans. (2004) 1153

[8] Gröger, H.; Lode, C.; Vollmer, H.; Krautscheid, H.; Lebedkin, S.
Bromoplumbate mit kettenformigen und isolierten Anionen: $(BzI_4P)[PbBr_3]$, $(BzI_4P)_2[PbBr_4]$ und $(BzI_4P)_4[Pb_2Br_6][PbBr_4]$
Z. anorg. allg. Chem. 628 (2002) 57

[9] Krautscheid, H.; Vielsack, F.
Synthesis and Crystal Structures of Iodoplumbate Chains, Ribbons and Rods with New Structural Types
J. Chem. Soc., Dalton Trans. (2001) 1099

[10] Gerber, S.; Krautscheid, H.
Potassium Thiocyanato Argentates: $K_3[Ag(SCN)_4]$, $K_4[Ag_2(SCN)_6]$ and $K^{2}_{\infty}[Ag(SCN)_2]$
Acta Crystallogr. C57 (2001) 781

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Research Expertise/Activities in Research

Broadband dielectric spectroscopy; Time-resolved FTIR-spectroscopy; Experiments with optical tweezers

List of 10 selected publications
(260 published in refereed journals, 57 since 2001)

[1] Kegler, K., M. Salomo, Kremer, F.
Optical Tweezers to Measure the Forces of Interaction between "DNA – Grafted Colloids
Phys.Rev. Lett. (2006) in press.

[2] Gutsche, C.; Salomo, M.; Kim, Y. W.; Netz, R. R.; Kremer, F.
The Flow Resistance of Single DNA-grafted Colloids as Measured by Optical Tweezers
J. Microfluidics and Nanofluidics, ISSN:1613-4982 (Paper) 1613-4990 (Online)
DOI: 10.1007/s10404-006-0080-0 (2006)

[3] Salomo, M.; Gutsche, C.; Kegler, K.; Struhalla, M.; Kroy, K.; Reinmuth, J.; Skokow, W.; Immisch, C.; Kremer, F.
The Binding of TmHU to Single ds-DNA as Observed by Optical Tweezers
J. Mol. Biol. 359 (7) (2006) 69–776

[4] Serghei, A.; Huth, H.; Schellenberger, M.; Schick, C.; Kremer, F.
Pattern Formation in Thin Polystyrene Films Induced by an Enhanced Mobility in Ambient Air
Phys. Rev. E 71 (2005) 061801

[5] Jianjun, L.; Tammer, M.; Kremer, F.; Komp, A.; Finkelmann, H.
Strain-induced Reorientation and Mobility in Nematic Liquid Crystalline Elastomers as Studied by Time-resolved FTIR Spectroscopy
Europ. Journ. Phys. E Vol. 17, no.4 (2005) 423-428

[6] Tsuwi, J.; Appelhans, D.; Zschoche, S.; Friedel, P.; Kremer, F.
Molecular dynamics in poly(ethene-alt-N-alkylmaleimide)s as studied by Broadband Dielectric Spectroscopy
Macromolecules 37 (2004) 6050-6054

[7] Serghei, A.; Kremer, F.
Confinement-induced Relaxation Process in Thin Films of cis-Polyisoprene
Phys. Rev. Lett. 91 (2003) 165702-1-165702-4

[8] Brodowsky, H. M.; Terentjew, E. M.; Kremer, F.; Zentel, R.
Induced Roughness in Thin Films of Smectic C* Elastomers
Europhysics Letters 57 (2002) 53-59

[9] Lehmann, W.; Skupin, H.; Tolksdorf, C.; Gebhard, E.; Zentel, R.; Krüger, P.; Lösche, M.; Kremer, F.
Giant Lateral Electrostriction in Ferroelectric Liquid Crystalline Elastomers
Nature 410 (2001) 447-450

[10] Kremer, F.;Skupin, H.; Lehmann, W.; Hartmann, L.; Stein, P.; Finkelmann, H.
Structure, Mobility and Piezoelectricity in Ferroelectric Liquid Crystalline Elastomers
Adv. in Liqu. Crystals (Ed. J. Vij): A special volume of Adv. Chem. Phys. 113 (2000) 183-201

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Research Expertise/Activities in Research

Polymers (equilibrium, non-equilibrium dynamics); Colloidal gelation (non-equilibrium structure formation); Proteins, gels and cells (cytoskeletal networks, tissue elasticity); Granular materials (Aeolian sand transport, structure formation)

List of 10 selected publications
(32 published in refereed journals, 22 since 2001)

[1] Hallatschek, O; Frey, E.; Kroy, K.
Tension Dynamics in Semiflexible Polymers. I. Coarse-grained Equations of Motion & II. Scaling Solutions and Applications
Phys. Rev. E (2007)

[2] Bausch, A. R.; Kroy, K.
A Bottom-up Approach to Cell Mechanics
Nature Phys. 2 (2006) 231

[3] Hallatschek, O.; Frey, E.; Kroy, K.
Propagation and Relaxation of Tension in Stiff Polymers
Phys. Rev. Lett. 94 (2005) 77804

[4] Frey, E. and Kroy, K.
Brownian Motion: a Paradigm of Soft Matter and Biological Physics
Ann. Phys. (Leipzig) 14 (2005) 20

[5] Kroy, K.; Cates, M. E.; Poon, W. C. K.
A Cluster Mode-coupling Approach to Weak Gelation in Attractive Colloids
Phys. Rev. Lett. 92 (2004) 148302

[6] Kroy, K.; Sauermann, G.; Herrmann, H. J.
Minimal Model for Aeolian Sand Dunes
Phys. Rev. Lett. 88 (2002) 054301, Phys. Rev. E 66 (2002) 031302

[7] Hohenadl, M.; Storz, T.; Kirpal, H.; Kroy, K.; Merkel, R.
Desmin Filaments Studied by Quasi-elastic Light Scattering
Biophys. J. 77 (1999) 2199

[8] Hinner, B.; Tempel, M.; Sackmann, E.; Kroy, K.; Frey, E.
Entanglement, elasticity, and viscous relaxation of actin solutions
Phys. Rev. Lett. 81 (1998) 2614

[9] Kroy, K.; Frey, E.
Dynamic Scattering from Solutions of Semiflexible Polymers
Phys. Rev. E 55 (1997) 3092

[10] Kroy, K.; Frey, E.
Force-Extension Relation and Plateau-Modulus for Wormlike Chains
Phys. Rev. Lett. 77 (1996) 306

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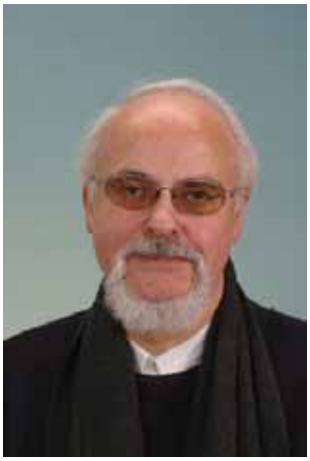

Research Expertise/Activities in Research

Molecular beams; Electron spectroscopy; Ion spectroscopy; Surface analysis; MD computer simulation; Surface analysis by means of particle spectroscopies; Investigation of the mechanisms of heterogeneous catalysis; Combination of thermodynamic concepts with surface spectroscopies

List of 10 selected publications
(89 published in refeered journals, 10 since 2001)

[1] Schulze, K. D.; Morgner, H.
Investigation of the Electric Charge Structure and the Dielectric Permittivity at Surfaces of Solutions Containing Ionic Surfactants
J. Phys.: Condens. Matter. 18 (2006) 9823-9839

[2] Krebs, T.; Andersson, G.; Morgner, H.
Chemical Potential of a Nonionic Surfactant in Solution
J. Phys. Chem. B 110 (2006) 24015-24020

[3] Krebs, T.; Tan, H. L.; Andersson, G.; Morgner, H.; Van Patten, P. G.
Increased layer interdiffusion in polyelectrolyte films upon annealing in water and aqueous salt solutions
Phys. Chem. Chem. Phys. 8 (2006) 5462-5468

[4] Kirmse, K.; Morgner, H.
Binary Liquid Mixtures. The Relation between Surface Tension and Surface Composition as Studied by MIES (Metastable Induced Electron Spectroscopy)
Langmuir 22 (2006) 2193-9

[5] Andersson, G.; Krebs, T.; Morgner, H.
Activity of Surface Active Substances Determined from their Surface Excess
Phys. Chem. Chem. Phys. 7 (2005) 136-42

[6] Andersson, G.; Krebs, T.; Morgner, H.
Angle Resolved Ion Scattering Spectroscopy Reveals the Local Topography around Atoms in a Liquid Surface
Physical Chemistry Chemical Physics 7 (2005) 2948-2954

[7] Berlich, A.; Liu, Y. C.; Morgner, H.
Evaporation of Ni and Carbon Containing Species onto a NiO Surface as Case Study for Metal Support Catalysts with MIES (=Metastable Induced Electron Spectroscopy)
Radiation Physics and Chemistry 74 (2005) 201-207

[8] Jin, G.; Morgner, H.; Ido, T.; Goto, S.
Formation of a Third Liquid Phase and its Reuse for Dibenzyl Ether Synthesis in Tetraalkyl-ammonium Salts Phase Transfer Catalytic System
Catalysis letters 86 (2003) 207-210

[9] Andersson, G.; Morgner, H.
Investigations on Solutions of Tetrabutyloniumsalts in Formamide with NICISS and ICISS: Concentration Depth Profiles and Composition of the Outermost Layer
Surface Science 445 (2000) 89-99

[10] Morgner, H.
The Characterization of Liquid and Solid Surfaces with Metastable Helium Atoms
Adv. At. Mol. Opt. Physics 42B (2000) 387-488

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Research Expertise/Activities in Research

Calculus of variations; Singular structures and geometry measure theory; Microstructure in crystalline solids; Multi-scale problems; Nonlinear partial differential equations

List of 10 selected publications
(90 published in refereed journals, 40 since 2001)

[1] Friesecke, G.; James, R. D.; Müller, S.
A Hierarchy of Plate Models Derived from Nonlinear Elasticity by Gamma-convergence
Arch. Rat. Mech. Anal. 180 (2006) 183-236

[2] Müller, S.; Šverák, V.
Convex Integration for Lipschitz Mappings and Counterexamples to Regularity
Ann. Math. 157 (2003) 715-742

[3] Friesecke, G.; James, R. D.; Müller, S.
A Theorem on Geometric Rigidity and the Derivation of Nonlinear Plate Theory from Three Dimensional Elasticity
Comm. Pure Appl. Math. 55 (2002) 1461-1506

[4] De Simone, A.; Kohn, R. V.; Müller, S.; Otto, F.
A Reduced Theory for Thin-film Micromagnetics
Comm. Pure Appl. Math. 55 (2002) 1408-1460

[5] Freire, A.; Müller, S.; Struwe, M.
Weak Convergence of Harmonic Maps from (2+1)-dimensional Minkowski Space to Riemannian Manifolds
Inv. Math. 130 (1997) 589-617

[6] Kohn, R. V.; Müller, S.
Surface Energy and Microstructure in Coherent Phase Transitions
Comm. Pure Appl. Math. 47 (1994) 405-435

[7] Müller, S.
Singular Perturbations as a Selection Criterion for Periodic Minimizing Sequences
Calculus of variations 1 (1993) 169-204

[8] Geymonat, G.; Müller, S.; Triantafyllidis, N.
Homogenisation of Nonlinearly Elastic Materials, Microscopic Bifurcation and Macroscopic Loss of Rank-1 Convexity
Arch. Rat. Mech. Anal. 122 (1993) 231-290

[9] Kohn, R.V.; Müller, S.
Branching of Twins Near an Austenite/twinned-martensite Interface
Phil. Mag. A 66 (1992) 697-715

[10] Müller, S.
Homogenization of Nonconvex Integral Functionals and Cellular Elastic Materials
Arch. Rat. Anal. Mech. 99 (1987) 189-212

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Research Expertise/Activities in Research

Solid state physics; Surface physics; Thin film physics and analysis; Ion and laser beam physics; Nanotechnology

List of 10 selected publications
(378 published in refereed journals, 124 since 2001)

[1] Ziberi, B.; Frost, F.; Rauschenbach, B.
Pattern Transitions on Ge Surfaces during Low-energy Ion Beam Erosion
Appl. Phys. Lett. 88 (2006) 173115

[2] Gerlach, J. W.; Hofmann, A.; Höche, T.; Frost, F.; Rauschenbach, B.
High quality m-plane GaN thin films deposited on γ-$LiAlO_2$ by ion beam assisted molecular beam epitaxy
Appl. Phys. Lett. 88 (2006) 011902

[3] Schubert, E.; Höche, T.; Frost, F.; Rauschenbach, B.
Nanostructure Fabrication by Glancing Angle Ion Beam Assisted Deposition of Silicon
Appl. Phys. A 81 (2005) 481-486

[4] Ziberi, B.; Frost, F.; Höche, T.; Rauschenbach, B.
Highly Ordered Self-organized Dot Pattern on Si Surfaces by Ion Beam Erosion
Appl. Phys. Lett. 87 (2005) 033113

[5] Ziberi, B.; Frost, F.; Höche, T.; Rauschenbach, B.
Ripple Pattern Formation on Silicon Surfaces by Low-energy Ion-beam Erosion: Experiment and Theory
Phys. Rev. B *72* (2005) 235310

[6] Höche, T.; Böhme, R.; Gerlach, J. W.; Frost, F.; Zimmer, K.; Rauschenbach, B.
Semiconductor Nanowires Prepared by Diffraction-mask-projection Excimer-laser Patterning
Nano Letters 4 (2004) 895-897

[7] Kritschil, A.; Kielburg, A.; Witte, H.; Krost, A.; Christen, J.; Wenzel, A.; Rauschenbach, B.
Electrical Field Effect of H-implantation Induced Defect States in GaN
Appl. Phys. Lett. 82 (2003) 403-405

[8] Frost, F.; Rauschenbach, B.
Nanostructuring of Solid Surfaces by Ion Beam Erosion
Appl. Phys. A 77 (2003) 1-9

[9] Keckes, J.; Gerlach, J. W.; Averbeck, R.; Riechert, H.; Bader, S.; Hahn, B.; Lugauer, H.-J. Lell, A.; Härle, V., Wenzel, A.; Rauschenbach, B.
Temperature Dependence of Stresses in GaN Thin Films Grown on (0001) Sapphire: Modelling of Thermal Stress
Appl. Phys. Lett. 79 (2001) 4307-4309

[10] Rauschenbach, B.
Plasma Immersion Implantation
in The Encyclopedia of Materials: Science and Technology,
Eds. K.H.J.Buschow, et al.
Elsevier, Oxford 2000, Vol. VII, 7023

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Research Expertise/Activities in Research

Molecular tissue engineering, molecular cell biology, semiconductors, nanostructures, cell and tissue based micro-arrays, bioelectronic drug screening, microlaser dissection and catapulting, neural microprobes, cardiovascular based biosensor

List of 10 selected publications
(64 published in refereed journals, 37 of which and 7 patents since 2001)

[1] Rothermel, A.; Volpert, K.; Burghardt, M.; Lantzsch, C.; Robitzki, A.; Layer, P. G.
Knock-down of GRF□4 Expression by RNA Interference Affects the Development of Retinal Cell Types in Three Dimensional Histotypic Retinal Spheres
Invest Ophthalmol Vis Sci (IOVS) 47(6) (2006) 2716-2725

[2] Stuhrmann, B.; Jahnke, H.-G.; Schmidt, M.; Jähn, K.; Müller, K.; Rothermel, A.; Käs, J. A.; Robitzki, A.
A Versatile Optical Manipulation System for Inspection, Laser Processing, and Isolation of Individual Living Cells
Reviews Scientific Instruments 77 (2006) 063116 1-11

[3] Nowak, K.; Lange-Dohna C.; Zeitschel, U.; Günther, A.; Lüscher, B.; Robitzki, A.; Perez-Polo, R.; Roßner, S.
The transcription Factor Yin Yang 1 Is an Activator of BACE Expression
J. Neurochem. 96 (2006) 1696-1707

[4] Bartholomä, P.; Impitjiati, Reininger-Mack, A.; Zhang, Z.; Thielecke, H.; Robitzki, A.
A More Aggressive Breast Cancer Spheroid Model Coupled to an Electronic Capillary Sensor System for a High Content Screening of Cytotoxic Agents in Cancer Therapy
J. Biomol. Screen. 10 (2005) 705-714

[5] Rothermel, A.; Kurz, R.; Rüffer, M.; Weigel, W.; Jahnke, H.-G.; Stepan, H.; Faber, R.; Schulze-Forster, K.; Robitzki, A.
Cells on a Chip - the Use of Electric Properties for Highly Sensitive Monitoring of Blood-derived Factors Involved in Angiotensin II Type I Receptor Signaling
Cell Physiol. Biochem. 16 (2005) 51-58

[6] Rothermel, A.; Biedermann, T.; Weigel, W.; Kurz, R.; Rüffer, M.; Layer, P. G.; Robitzki, A.
Artificial Design of 3D Retina-like Tissue from Dissociated Cells of the Mammalian Retina by Rotation-mediated Cell Aggregation
Tissue Eng. 11 (2005) 1749-56

[7] Bartholomä, P.; Gorjup, E.; Monz, D.; Reininger-Mack, A.; Thielecke, H.; Robitzki, A.
Three-dimensional in Vitro Re-aggregates of Embryonic Cardiomyocytes: a Potential Model System for Monitoring Effects of Bioactive Agents
J. Biomol. Screen. 10 (2005) 814-22

[8] Paraoanu, L. E.; Weiss, B.; Robitzki, A. A.; Layer, P. G.
Cytochrome-c Oxidase is One of Several Genes Elevated in Marginal Retina of the Chick Embryo
Neuroscience 132 (2005) 665-672

[9] Layer, P. G.; Robitzki, A.; Rothermel, A.; Willbold, E.
Of Layers and Spheres: the Reaggregate Approach in Tissue Engineering
Trends Neurosci. 25 (2002) 131-134

[10] Reininger-Mack, A.; Thielecke, H.; Robitzki, A.
3D-Biohybrid Systems: Applications in Drug Screening
Trends Biotechnol. 20 (2002) 56-61

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Research Expertise/Activities in Research

Vertebrate cell culture and in vitro alternatives to toxicity testing; Detection of sublethal effects on biochemical and gene expression level; Toxicological analysis; Determination of cell-internal exposure concentrations

List of 10 selected publications
(43 published in refereed journals, 11 since 2001)

[1] Schirmer, K.
Proposal to Improve Vertebrate Cell Cultures to Establish them as Substitutes for the Regulatory Testing of Chemicals and Effluents using Fish
Toxicology 224 (2006) 163-183

[2] Bopp, S.; Bols, N. C.; Schirmer, K.
Development of a Solvent-free, Solid-phase *in vitro* Bioassay Using Vertebrate Cells
Environmental Toxicology and Chemistry 25(5) (2006) 1390-1398

[3] Boaru, A.; Dragos N.; Schirmer, K.
Microcystin-LR induced Cellular Effects in Mammalian and Fish Primary Hepatocyte Cultures and Cell Lines: A Comparative Study
Toxicology 218 (2006) 134-148

[4] Bopp, S. K.; Weiß, H.-J.; Schirmer, K.
Time-integrated Monitoring of PAHs in Ground Water Using the Ceramic Dosimeter Passive Sampling Device
Journal of Chromatography A 1072 (2005) 137-147

[5] Schirmer, K.; Dayeh, V. R.; Bopp, S. K.; Russold, S.; Bols, N. C.
Applying Whole Water Samples to Cell Bioassays for Detecting Dioxin-like Compounds at Contaminated Sites
Toxicology 205 (2004) 211-221

[6] Brack, W.; Schirmer, K.
Effect-directed Identification of Oxygen and Sulfur Heterocycles as Major Cytochrome P4501A-inducers in a Contaminated Sediment
Environmental Science and Technology 37 (2003) 3062-3070

[7] Dayeh, V. R.; Schirmer, K.; Bols, N. C.
Development and Application of Fish Cell Line Bioassays for Evaluating the Toxicity of Industrial Effluents
Water Research 36 (2002) 3727-3738

[8] Schirmer, K.; Chan, A. G. J.; Bols, N. C.
Transitory Metabolic Disruption and Cytotoxicity Elicited by Benzo[a]pyrene in Two Cell Lines from rainbow trout liver.
Journal of Biochemical and Molecular Toxicology 14(5) (2000) 262-276

[9] Bols N. C.; Schirmer, K.; Heikkila, E. M.; Greenberg, B. M.; Dixon, D. G.
Induction of 7-ethoxyresorufin-*o*-deethylase activity by polycyclic aromatic hydrocarbons in a rainbow trout liver cell line and the derivation of toxic equivalency factors
Ecotoxicology and Environmental Safety 44 (1999) 118-128

[10] Schirmer, K.; Dixon, D. G.; Greenberg, B. M.; Bols, N. C.
Ability of 16 Priority PAHs to be Directly Cytotoxic to a Cell Line from the Rainbow Trout Gill Toxicology 127 (1998) 129-141

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