LNQE

Laboratorium für
Nano- und Quantenengineering

Leibniz
Universität
Hannover

Jahresbericht 2015

Laboratorium für Nano- und Quantenengineering

Annual Report 2015

Laboratory of Nano and Quantum Engineering

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Titelbild/*Cover picture*
Workshop NanoSaTox
(Foto: L. David)

Liebe Leserin, lieber Leser,

nach der erfolgreichen Evaluation unseres Laboratoriums für Nano- und Quantenengineering (LNQE) als interdisziplinäres Forschungszentrum der Leibniz Universität Hannover steht für die nächsten Jahre die gemeinsame Finanzierung des Betriebs des LNQE-Forschungsbaus durch Mittel des Präsidiums, der beteiligten Fakultäten und den LNQE-Instituten.

Im Jahr 2015 konnten wir aus dem LNQE heraus einen Antrag auf ein DFG-Gerätezentrum und den Folgeantrag für unser Niedersächsisches Promotionsprogramm Hannover School for Nanotechnology ausarbeiten. Ob diese Anträge letztendlich bewilligt werden, wird sich im Jahre 2016 zeigen. Dem LNQE-Mitglied Bernd-Arno Behrens, Leiter des Instituts für Umformtechnik und Umformmaschinen, gelang es, einen neuen Sonderforschungsbereich zum Thema „Tailored Forming“ an der Leibniz Universität Hannover zu etablieren. Gratulation! Weitere aktiv aus dem LNQE hervorgebrachte Anträge auf kooperative Drittmittelmaßnahmen sind für die Zukunft sehr wichtig. Daran wird derzeit intensiv in mehreren Initiativen gearbeitet und wir bauen hier auf die aktive Beteiligung der LNQE-Mitglieder.

Unser Bachelor- und Masterstudiengang Nanotechnologie wurde offiziell erfolgreich reakkreditiert und die Studierendenzahlen entwickeln sich hervorragend. Ein besonderer Dank geht an die Studiengangskoordinatorin, Frau Dr. Raddatz, die inzwischen auch die Organisation der Herbstuniversität Nanotechnologie übernommen hat.

2015 beteiligten wir uns an den Hochschulinformationstagen, dem Niedersachsen-Technikum und waren beim Wirtschaftsempfang der Leibniz Universität Hannover vertreten. Der Workshop NanoDay fand in diesem Jahr zum elften Mal statt. Ein besonderes Highlight mit beträchtlicher Ausstrahlung war ein thematisch konzentrierter Workshop über Nanosicherheit und Nanotoxikologie, zu dem wir auch viele externe Gäste im Leibniz-Haus begrüßen konnten.

Viele Spaß beim Lesen!

Dear Reader,

after the successful evaluation of our Laboratory of Nano and Quantum Engineering (LNQE) as an interdisciplinary research center of the Leibniz Universität Hannover is the joint funding of the operation of LNQE research building by means of the presidium, the participating faculties and LNQE institutes ensured for the coming years.

In 2015 we were able to develop an application for a DFG core facility and the subsequent application for our Lower Saxony PhD-program Hannover School for Nanotechnology from the LNQE out. Whether these applications will finally be approved, will be seen in the year 2016. The LNQE member Bernd-Arno Behrens, head of the Institute of Metal Forming and Metal Forming Machine Tools, succeeded to establish a new Collaborative Research Centre on “Tailored Forming” at the Leibniz Universität Hannover. Congratulations! More actively brought forth from the LNQE applications for cooperative external funding measures are very important for the future. Thereon we currently working intensively in several initiatives and we are building here on the active participation of LNQE members.

Our Bachelor’s and Master’s degree program nanotechnology was officially successfully re-accredited and the number of students develops outstandingly. A special thanks goes to the course coordinator, Dr. Raddatz, who has also taken over now the organization of the Autumn University nanotechnology.

2015, we participated in the university information days, the Niedersachsen-Technikum and were represented at the business reception of the Leibniz Universität Hannover. The workshop NanoDay was held for the eleventh time this year. A special highlight with considerable radiance was a thematically concentrated workshop on nanosafety and nanotoxicology, to which we were able to welcome many external guests at the Leibniz house.

Enjoy the reading!

Peter Behrens
- Sprecher des Vorstands -
- Speaker of the executive board -

Fritz Schulze Wischeler
- Geschäftsführer -
- Chief operating officer -

Ziele des Laboratoriums
Goals of the Laboratory

LNQE-Forschungsbau am Schneiderberg 39, 30167 Hannover, Deutschland.
LNQE research building at Schneiderberg 39, 30167 Hannover, Germany.

Die Synthese und Kontrolle von Materialien auf Größenskalen im Mikro- bis Nanobereich liefert den Zugang zu völlig neuartigen Material- und Systemeigenschaften. Auf diesen Skalen treten Quanteneffekte in Erscheinung, in denen ein noch weitgehend unausgeschöpftes Potenzial an revolutionären, neuartigen Funktionalitäten liegt. Die kontrollierte Manipulation und Beherrschung solcher Materialien und Funktionalitäten erfordert neuartige Werkzeuge. Die Forschung von Naturwissenschaftlern und Ingenieuren fließt bei diesen Strukturgrößen zusammen und setzt so synergetisch Ressourcen frei. Hieraus entwickeln sich völlig neue, nanotechnologische Bauelemente.

Für die dazu erforderliche interdisziplinäre Forschung findet sich im Laboratorium für Nano- und Quantenengineering eine Basis. Hierzu wird in einer breiten Anstrengung das Know-how verschiedener Fachgebiete fokussiert und gebündelt, um aufbauend auf zielgerichteter Grundlagenforschung neue Anwendungsfelder zu erschließen und die Nanotechnologie wirtschaftlich zu nutzen.

Zweck des LNQE ist die selbstlose Förderung der angewandten Forschung auf dem Gebiet mesoskopischer Systeme im Mikro- und Nanobereich. In diesem Rahmen führt die Einrichtung Forschungsvorhaben in interdisziplinärer Zusammenarbeit durch. Deren Ergebnisse macht die Einrichtung der interessierten Öffentlichkeit in geeigneter Form zugänglich.

Synthesis and control of materials on the micro and nanometer scale gives access to all new material and system properties. On this scale quantum effects appear which have the potential to provide revolutionary capabilities. The manipulation and control of such materials needs new tools. The development of structures on such small scales causes the merger of the research of scientists and engineers. This promotes collaboration and hence the sharing of resources, which leads to new solutions for nanotechnology devices.

The Laboratory of Nano and Quantum Engineering provides a base for such essential interdisciplinary research. The know-how of different fields will be focused together to develop new areas of application based on targeted basic research and to utilize nanotechnology economically.

The aim of the LNQE is the selfless support of applied research in the field of mesoscopic systems on the micro and nano-scale. Within this scope, the organization undertakes research projects in interdisciplinary cooperation and makes the results available to the interested public in a suitable form.

The main task of the organization is basic research in mesoscopic scales and transfer of knowledge into practical application, particularly in the major fields of nanomaterials, mechanics / magnetics, nanoelectronics, optics, quantum systems. A further aim is the education and promotion of young researchers in these fields.

Leibniz Forschungszentrum LNQE
Zur Förderung interdisziplinärer Forschung gibt es in der Leibniz Universität Hannover hochschulintern eine innovative Organisationsstruktur, welche untergliedert ist in interdisziplinär ausgerichteten Leibniz Forschungsinitiativen, Leibniz Forschungszentren und die Leibniz Forschungsschulen, in denen hoch relevante Schwerpunktthemen fach- und fakultätsübergreifend bearbeitet werden. Das LNQE ist eine von zurzeit sieben Einrichtungen, die als Leibniz Forschungszentrum eingestuft sind.

Aufgabe der Einrichtung ist die Grundlagenforschung in mesoskopischen Größenskalen und deren Umsetzung in praktische Anwendung, insbesondere in den Schwerpunktfachgebieten Nanomaterialien, Mechanik/Magnetik, Nanoelektronik, Optik, Quantensysteme sowie Ausbildung und Nachwuchsförderung auf diesen Gebieten.

Hierbei hat die Einrichtung insbesondere

- Forschungs- und Entwicklungsvorhaben durchzuführen, die sich auf die Erschließung neuer oder die Verbesserung bereits bekannter Anwendungsmöglichkeiten für Mikro- und Nanotechnik richten;
- Für die praktische Anwendung wissenschaftlicher Erkenntnisse zu sorgen und Kräfte der angewandten Forschung und der Praxis zusammenzuführen;
- Aus- und Fortbildungstätigkeit zu leisten und Hilfseinrichtungen für die wissenschaftliche Arbeit und deren Auswertung in der angewandten Forschung zu betreiben;
- Die interdisziplinäre Zusammenarbeit der einzelnen Mitglieder zu fördern und zu verbessern, insbesondere durch die Einrichtung eines gemeinsamen Pools von Verfahrens- bzw. Diagnostiktechniken, der den einzelnen Mitgliedern zur Verfügung steht;
- Bei Erfüllung der ordnungsgemäßen Aufgaben der Einrichtung mit anderen Forschungseinrichtungen des In- und Auslands zusammenzuarbeiten.

Zur Verwirklichung seiner Zwecke und Aufgaben betreibt das Laboratorium für Nano- und Quantenengineering ein eigenes Gebäude in Hannover mit Laboren, Geräten etc. und insbesondere Reinräumen.

The LNQE would like to achieve the following goals

- *Execute research and development which is directed to open up new applications or improve already known applications for micro- and nano-scale techniques;*
- *Arrange for practical application of scientific findings and to combine the forces of applied research and practice.*
- *Give education and training and to operate auxiliary facilities for the scientific work and its realization in applied research;*
- *Promote and improve the interdisciplinary cooperation of its individual members, in particular by implementing a shared pool of processing and diagnostic techniques, which is accessible by the individual members;*
- *Cooperate with other research centers, both in Germany and abroad.*

To realize its mission the Laboratory of Nano and Quantum Engineering runs its own building in Hanover hosting labs, equipment, etc. and in particular clean room facilities.

LNQE beim Wirtschaftsempfang der Leibniz Universität Hannover am 23. April 2015 im Lichthof des Welfenschlosses.
LNQE at business reception of Leibniz Universität Hannover on 23 April 2015 in the atrium of the Welfenschloss.

Leibniz Research Center LNQE
Leibniz Universität Hannover has set up its own innovative organizational structure to promote interdisciplinary research, consisting of Leibniz Research Initiatives, Leibniz Research Centers and Leibniz Research Schools. The system enables scientists to pursue cutting-edge research across traditional subject and faculty boundaries. The LNQE is one of seven facilities currently ranked as a Leibniz Research Center.

Forschung
Research

Die Arbeitsgruppen des LNQE arbeiten Interdisziplinär über die Fachgrenzen hinweg zusammen auf dem Gebiet Nanotechnologie. Die Begriffe Nanoengineering, Nanoanalytik und Nanomaterialien kennzeichnen die Forschung des LNQE. Zusätzlich konzentriert sich das LNQE auf (zurzeit) zwei übergreifende Forschungsschwerpunkte: Nanotechnologie für Energieforschung und Nanotechnologie für Sensorik.

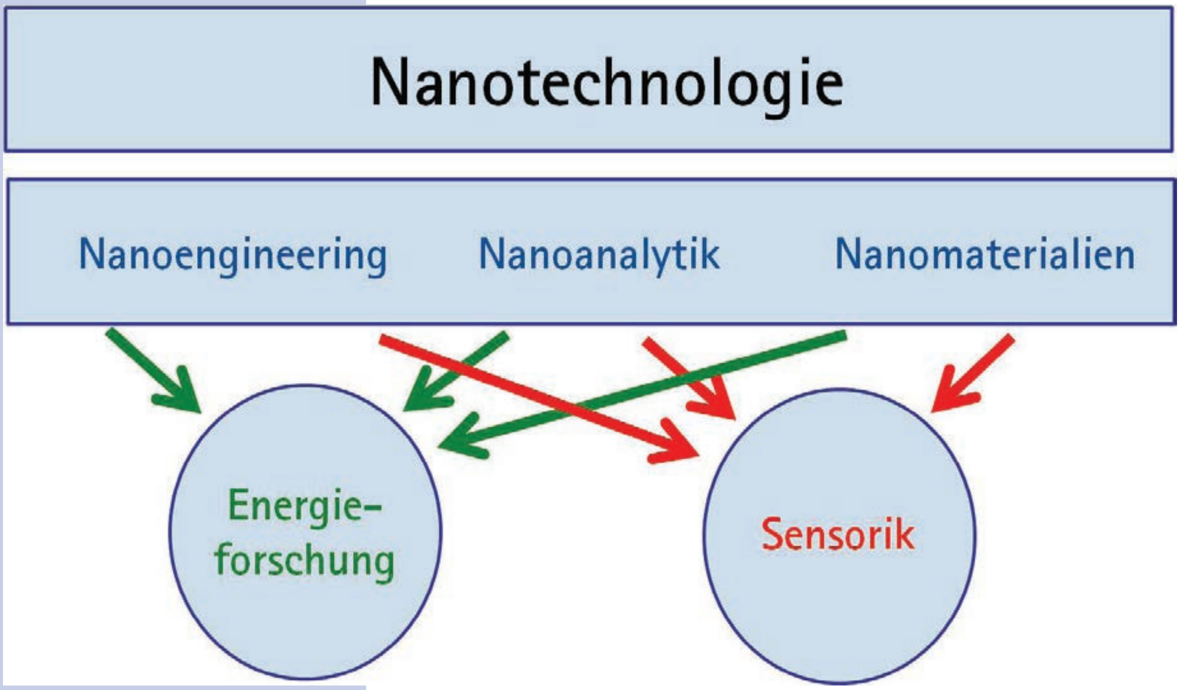
Nanotechnologie

Der Nanotechnologie beschreibt die Erforschung und Manipulation von Dingen auf kleinsten Dimensionen. Generell beschäftigt sich die Nanotechnologie mit Strukturen im Größenbereich von 1-100 Nanometer in mindestens einer Raumrichtung. 100 Nanometer sind in etwa ein Tausendstel des Durchmessers eines normalen menschlichen Haares. Bei diesen kleinen Abmessungen treten Oberflächeneigenschaften gegenüber den Volumeneigenschaften der Materialien immer mehr in den Vordergrund und darüber hinaus müssen oft quantenphysikalische Effekte berücksichtigt werden.

The work groups of the LNQE Interdisciplinary work across disciplinary boundaries along in the field of nanotechnology. The terms nanoengineering, nanoanalytics and nanomaterials featuring the research of the LNQE. In addition, the LNQE focuses on (currently) two overarching research areas: nanotechnology for energy research and nanotechnology for sensing.

Nanotechnology

The nanotechnology describes the study and manipulation of objects at the smallest sizes. In general, nanotechnology deals with structures ranging in size from 1-100 nanometers in at least one spatial direction. 100 nanometers are roughly one-thousandth of the diameter of a normal human hair. With these small dimensions surface properties come to the forefront compared with the bulk properties of materials and often quantum effects must be considered.



Forschungsstruktur des Laboratoriums für Nano- und Quantenengineering.
Research structure of the Laboratory of Nano and Quantum Engineering.

Nanoengineering

Nanoengineering ist das Engineering auf der Nanoskala, also das gezielte künstliche Herstellen von Strukturen der Nanotechnologie wie zum Beispiel winzigster Transistoren auf Computerchips. Der mit dem Nanoengineering eng verwandte Begriff Quantenengineering zielt auf die Erzeugung und Manipulation eines definierten Quantenzustandes ab, wie zum Beispiel der Realisierung eines Bose-Einstein-Kondensats oder eines Bauelements mit gezielt eingestelltem Elektronenspin. Die Größe solcher Systeme ist oft ebenfalls im Nanometerbereich.

Beispiele für aktuelle Forschungsarbeiten im Laboratorium sind Quanteninterferenz und Quantentransport in niedrigdimensionalen Systemen, Quantensensoren auf der Basis von integrierten atomoptischen Systemen, atomare Systeme in Nanostrukturen, atomare Inertialsensoren, Einsatz von einfachen und gekoppelten Quantenpunktsystemen bei der Quanteninformationsverarbeitung und sowie Spineffekte. Anwendung von nanoskaligen Materialien in Dünnschichtsolarzellen, Herstellung und Charakterisierung von Photonischen Kristallen, Nanostrukturen und Bausteine für die Plasmonik, Kohärenzeffekte bei der Elektron-Loch-Spin-Kopplung und Anwendung von spinpolarisierten Ladungsträgern in Halbleiterlasern.

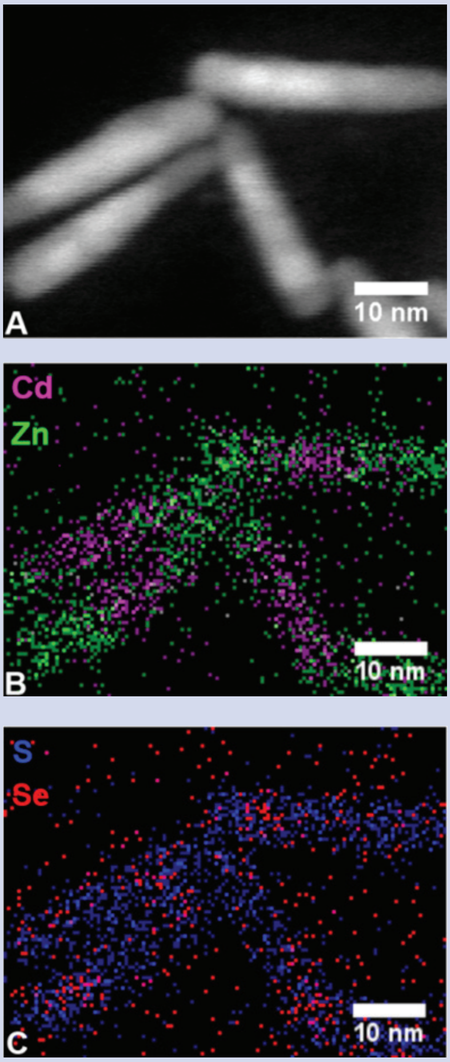
Für die Herstellung kleinster Strukturen werden vielfältigste Techniken verwand, wobei die Weiterentwicklung und das Verständnis dieser Techniken zum Teil selbst Gegenstand der Forschung sind. Die Strukturierungstechniken sind zum Beispiel Fotolithographie, Elektronenstrahllithographie, Oberflächen-Laserstrukturierung, 3D Two-Photon Lithographie, Oberflächenbearbeitung mit dem Rasterkraftmikroskop und Strukturierung mit dem Rastertunnelmikroskop. Hinzu kommen die Dünnschichttechniken der Halbleitertechnologie wie Aufdampfen, Sputtern, Tempern, chemische Gasphasenabscheidung, Molekularstrahlepitaxie, Implantieren von Ionen, Oxidation, Ätzprozesse (Plasmaätzen, RIE und Nasschemisches Ätzen) und Atomlagenabscheidung.

Nanoengineering

Nano engineering is engineering on the nanoscale, i. e. the selective artificial fabrication of nanotechnology structures such as tiny transistors on computer chips. The closely related term, quantum engineering, aims to produce and manipulate a defined quantum state, such as the realization of a Bose-Einstein condensate or an electronic device with controllable electron spin. The size of such systems is also often in the nanometer range.

Examples of current research in the laboratory are quantum interference and quantum transport in low dimensional systems, quantum sensors based on integrated atom-optical systems, atomic systems in nanostructures, atomic inertial sensors, use of single and coupled quantum dot systems in quantum information processing, and spin effects. Applications of nanoscale materials in thin film solar cells, characterization of photonic crystals, nanostructures and devices for plasmonics, coherence effects at electron-hole-spin coupling and application of spin-polarized carriers in semiconductor lasers.

For the manufacture of very small structures a wide variety of techniques are used in the laboratory. The further development and understanding of these techniques is in part the subject of the research. The structuring techniques are for example photolithography, electron beam lithography, laser surface structuring, 3D two-photon lithography, surface processing with an atomic force microscope and patterning with the scanning tunneling microscope. In addition the thin film techniques of semiconductor technology are used such as evaporation, sputtering, annealing, chemical vapor deposition,molecular beam epitaxy, implanting ions, oxidation and etching processes (plasma etching, etching with RIE and wet chemical etching) and atomic layer deposition.



CdSe @ CdS / ZnS-Nanostäbchen, die segmentartig aufgebaut sind und durch Ausnutzung eines sequentiellen Kationenaustauschmechanismus realisiert werden. A zeigt das STEM-HAADF Bild von mehreren Nanostäbchen. Die entsprechende EDX-Mapping sind in B und C gezeigt. Zusätzlich zu den deutlichen CdS und ZnS Abschnitten kann sogar der CdSe-Kern erkannt werden.
CdSe@CdS/ZnS nanorods which are built in a segment like manner are realized exploiting a sequential cation exchange mechanism. Panel A shows the STEM-HAADF image of several nanorods. The corresponding EDX mapping is shown in the panels B and C. In addition to the distinct CdS and ZnS sections even the CdSe core can be detected.
(P. Adel, A. Wolf, T. Kodanek, D. Dorfs/ PCI)

Nanoanalytik

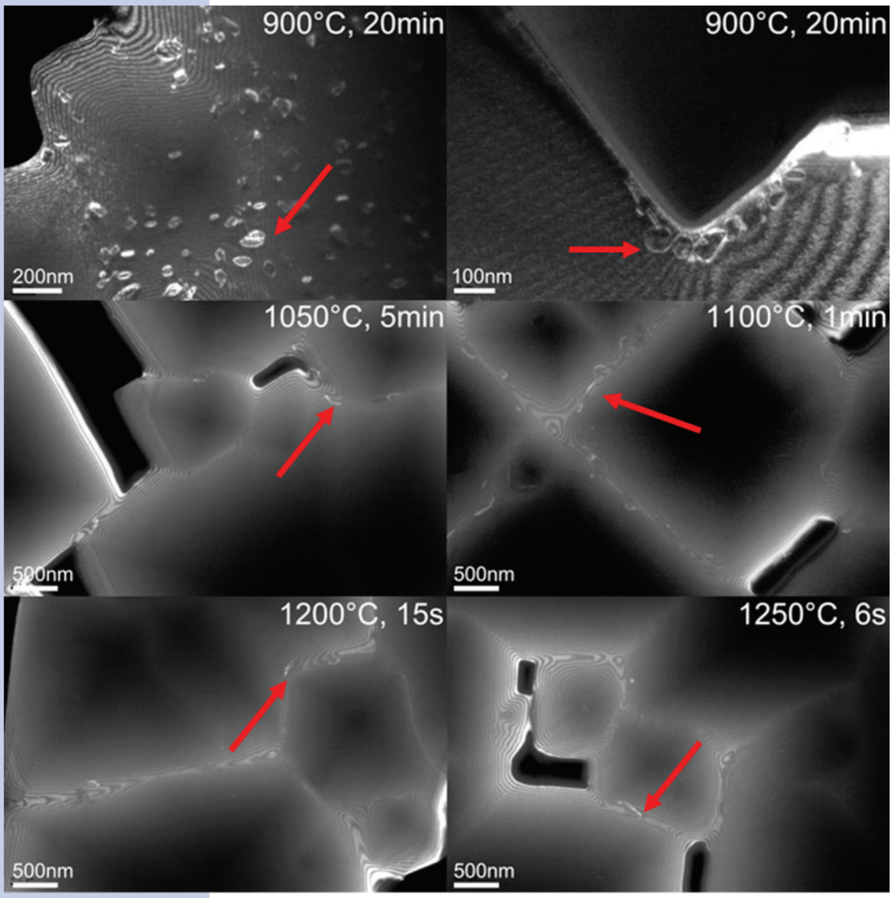
Die künstlich erzeugten Strukturen und Materialien werden auf vielfältigste Art untersucht und analysiert. Die Analytik im Nanometerbereich benötigt unterschiedlichste und neuste Geräte und Verfahren. Die nötige technologische Ausrüstung steht den Arbeitsgruppen zentral im LNQE-Forschungsbau zur Verfügung (unter „Technologie im Forschungsbau“ auf der Website) und wird durch die Ausstattung in den Instituten (als „Gerätepool der Mitglieder“ auf der Website) ergänzt.

Als wichtige Verfahren der Nanoanalytik sind zu nennen: Transmissionselektronenmikroskopie (TEM), Rasterelektronenmikroskopie (REM), Rasterkraftmikroskopie (AFM), Rastertunnelmikroskopie (STM), Konfokalmikroskopie, Spektrale Ellipsometetrie, Röntgen-Diffraktometrie etc.

Nanoanalytics

The artificially created structures and materials are investigated in a wide variety and analyzed. The analysis in the nanometer range requires variety and latest equipment and techniques. The necessary technological equipment is centrally located in the LNQE research building (under “Technology in the Research Building” on the website) and is complemented by the equipment in the institutions (as “Equipment Pool of the Members” on the website).

Important methods of nanoanalysis: transmission electron microscopy (TEM), scanning electron microscopy (SEM), atomic force microscopy (AFM), scanning tunneling microscopy (STM), confocal microscopy, spectral ellipsometry, X-ray diffractometry etc.



TEM-Aufnahmen von mit Bor implantierten Silizium für Photovoltaik. Zur Minimierung der durch die Implantation entstehenden Defekte wird thermisch ausgeheilt. Bei kleinen Temperaturen sind noch viele Versetzungsschleifen (rote Pfeile) zu finden, bei höheren Temperaturen nimmt deren Dichte ab.
TEM images of with boron implanted silicon for photovoltaics. In order to minimize the defects associated with the implantation, it is thermally cured. At low temperatures are still many dislocation loops to find (red arrows), at higher temperatures the density of defects decreases.
(J. Krügener, E. Bugiel, H. J. Ostenl/MBE & R. Peibst, F. Kiefer, R. Brendel/ISFH)

Nanomaterialien

Nanomaterialien verschiedenster Form, Stoffzusammensetzung und Größe im Nanometerbereich werden im Laboratorium hergestellt und untersucht. Nanopartikel besitzen aufgrund ihrer kleinen Abmessungen spezielle chemische und physikalische Eigenschaften, die sich deutlich von den Eigenschaften von makroskopischen Partikeln und Festkörpern unterscheiden. Die Ursache hierfür ist das große Verhältnis von Oberfläche zu Volumen der Nanopartikel, wodurch sie stark mit Ihrer Umgebung wechselwirken. Hinzu kommen gegebenenfalls quantenmechanische Effekte.

Die Herstellung von Nanopartikeln mit gezielt einstellbaren Eigenschaften, die Nutzbarmachung von Nanopartikeln für bestimmte Anwendungen und das physikalische Grundlagenverständnis von Nanopartikeln und deren Wirkungsweise stehen im Laboratorium im Vordergrund. Die Nanopartikel werden chemisch synthetisiert oder lasergestützt erzeugt.

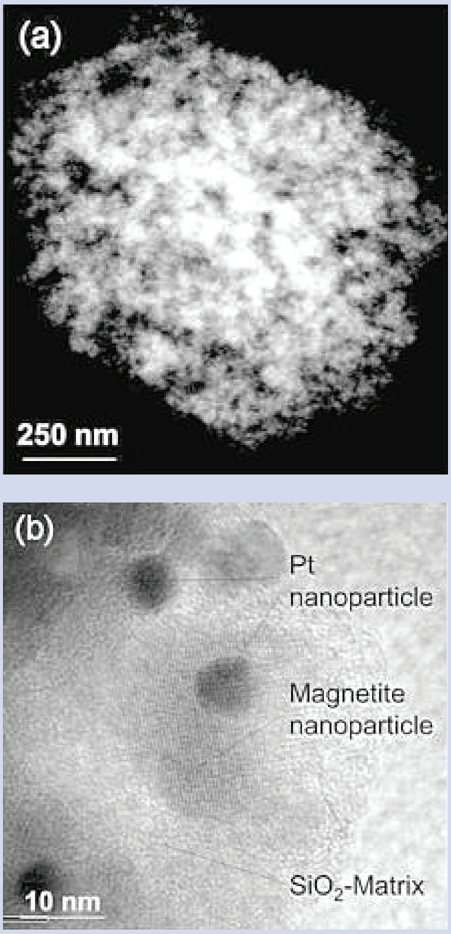
Aktuelle Forschungsvorhaben sind unter anderem Untersuchungen von Nanopartikeln für Farbstoff-Solarzellen, Beschichtungen mit Nanopartikeln für selbstreinigende Oberflächen, Nanopartikel mit photokatalytischen Eigenschaften zur Reinigung von Luft und Wasser, Überstrukturen von Nanopartikeln, erweiterte Formkontrolle von Nanopartikeln sowie biokompatible Nanomaterialien für die Medizin wie zum Beispiel Implantate für das Innenohr. Darüber hinaus wird immer auch die mögliche Toxizität von Nanomaterialien berücksichtigt und untersucht. Ein weiterer Schwerpunkt ist die Simulation auf der Nano-Ebene, es werden in Multiskalen-Analysen der Einfluss der Nanomaterialien und allgemein Grenzflächen auf makroskopische Objekten modelliert.

Nanomaterials

Nanomaterials of various shapes, composition, and size in the nanometer range are produced and analyzed in the laboratory. Nanoparticles due to their small size have special chemical and physical properties that differ significantly from the properties of macroscopic particles and solids. This is due to the large ratio of surface to volume of the nanoparticles, so that they strongly interact with their environment. Added to this in many cases is the increased importance of quantum mechanical effects.

The preparation of nanoparticles with controlled properties, the utilization of nanoparticles for specific applications and the fundamental physical understanding of nanoparticles and their function are in the foreground of the laboratory. The nanoparticles are synthesized chemically or produced via laser-based techniques.

Current research projects include studies of nanoparticles for dye solar cells, creating self-cleaning surfaces by nanoparticle coatings, nanoparticles with photocatalytic properties for the purification of air and water, superstructures of nanoparticles, advanced shape control of nanoparticles, and bio-compatible nanomaterials for medical applications such as implants for the inner ear. In addition, the potential toxicity of nanomaterials must always be considered and investigated. Another focus is the simulation and modeling at the nano level, in multi-scale analysis of the impact of nanomaterials and interfaces on macroscopic objects.



Magnetisches Kügelchen mit Pt-Nanopartikeln gebunden an der Oberfläche (a) vollständiges Kügelchen, (b) Vergrößerung.
Magnetic bead with Pt nanoparticles bound to the surface (a) complete bead, (b) enlargement.
(C. Ruffert, L. Rissing/ACI, N. Bigall/PCI)

Übergreifender Forschungsschwerpunkt: Nanotechnologie für Energieforschung

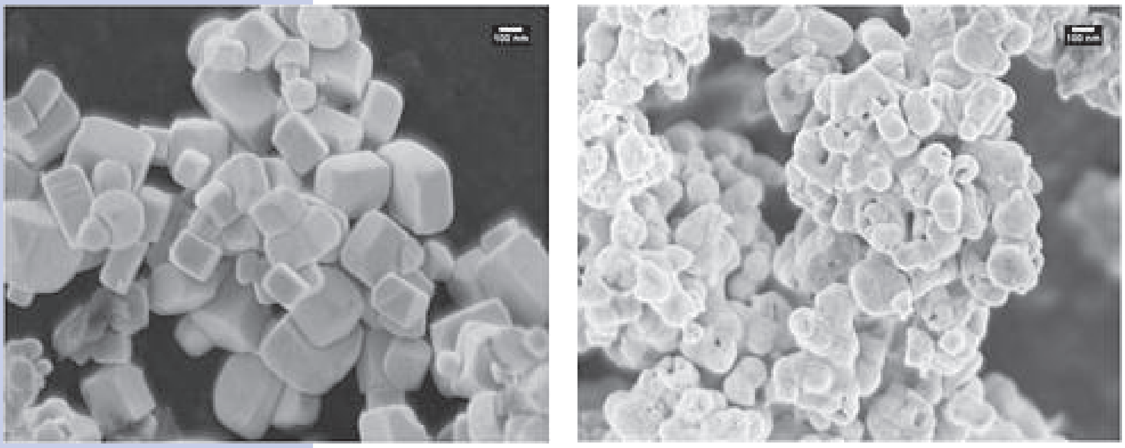
Energiewandlung, Energietransport und Energiespeicherung sind grundlegende Fragen für die Zukunft unserer Gesellschaft. Hier kann das neue Gebiet der Nanotechnologie wichtige Beiträge leisten. Der Energietransport auf der Nanoskala, sowie die Energiewandlung in nanostrukturierten Systemen stellen bis heute nur sehr wenig untersuchte Themenkomplexe dar. Allerdings können die auftretenden wissenschaftlichen Fragestellungen nur interdisziplinär von Naturwissenschaftlerinnen und Naturwissenschaftlern, von Ingenieurinnen und Ingenieuren gemeinsam bewältigt werden, da hierbei die grundlegenden Quanteneffekte in Nanostrukturen sowohl aus physikalischer als auch aus chemischer Sicht untersucht werden müssen und diese Effekte nur nutzbar gemacht werden können, wenn auch materialwissenschaftliche und ingenieurwissenschaftliche Aspekte berücksichtigt werden. Für die Bearbeitung dieser Fragestellungen sind deshalb interdisziplinär ausgebildete Wissenschaftlerinnen und Wissenschaftler notwendig.

Das Niedersächsische Promotionsprogramm „Hannover School for Nanotechnolgy (hsn)“ des LNQE beschäftigt sich als Forschungsschwerpunkt mit dieser Thematik.

Overarching research areas: nanotechnology for energy research

Energy conversion, energy transport and energy storage are fundamental issues for the future of our society. Here, the new field of nanotechnology can make important contributions. The energy transport at the nanoscale, as well as the conversion of energy in nanostructured systems represent today very little investigated topics. However, the occurring scientific questions can only be interdisciplinary tackled jointly by natural scientists and engineers, since in this case the basic quantum effects in nanostructures must be examined from both a physical and a chemical perspective, and these effects can only be made available when materials science and engineering aspects are considered. Therefore interdisciplinary trained scientists are necessary to deal with these issues.

The Lower Saxony doctoral program “Hannover School for Nanotechnolgy (hsn)” of the LNQE deals with this issues as a overarching research area.



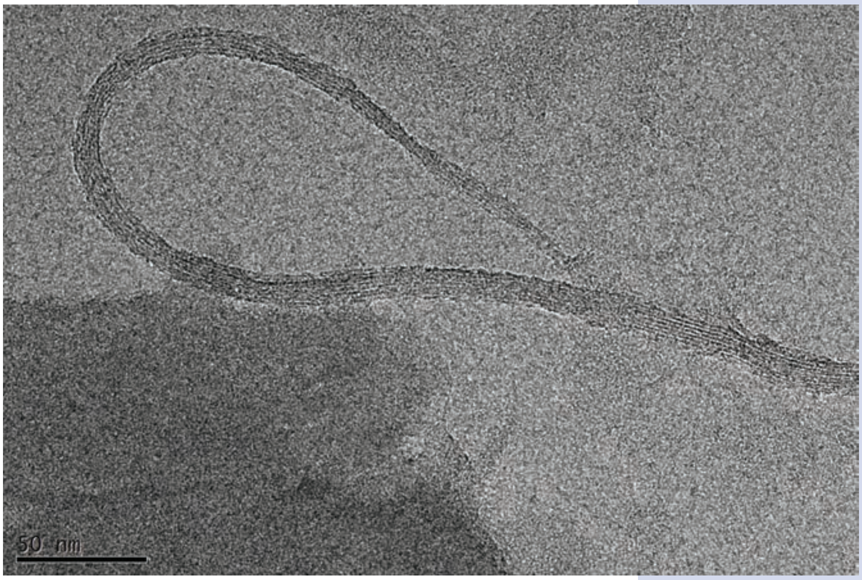
REM-Aufnahmen von reinem (links) und La-dotiertem NaTaO$_3$ (rechts) für Untersuchungen zur photokatalytischen Wasserspaltung.
SEM images of pure (left) and La-doped NaTaO3 (right) for studies on the photocatalytic water splitting.
(I. Ivanova, T. Kandiel, D. Bahnemann/TCI)

Übergreifender Forschungsschwerpunkt: Nanotechnologie für Sensorik

Im Bereich Sensorik spielt Nanotechnologie eine immer größere Rolle. Sensoren mit nanoskaligen Oberflächen, Sensoren, die Informationen aus der nanoskopischen Welt in die makroskopische Welt übertragen und Sensoren, die Nanoeffekte als Sensorprinzip nutzen, können zusammenfassend als Nanosensoren definiert werden. Ziel ist zum einem eine deutliche Verbesserung der Empfindlichkeit und Präzision mit Nanosensoren gegenüber herkömmlichen Sensoren, zum anderen aber auch die Möglichkeit zur Detektion von Dingen, die vorher nicht möglich waren, wie z. B. Schnelltests für Krebs oder gezielter Nachweis von Einzelmolekülen. Gegenwärtig gibt es viele mögliche Herstellungsstrategien für Nanosensoren, darunter Top-down-Lithographie, Bottom-up-Assembly und der molekularen Selbstorganisation.

Overarching research areas: nanotechnology for sensing

In sensor technologies, nanotechnology plays an increasingly important role. Sensors with nanoscale surfaces, sensors that transfer information from the nanoscopic world in the macroscopic world and sensors that use nanoeffects as sensor principle can be defined as nanosensors in summary. The aim is on the one hand a significant improvement in sensitivity and precision with nanosensors over conventional sensors, and on the other hand, the possibility of detecting things that were previously not possible, such as rapid tests for cancer or specific detection of individual molecules. There are currently many possible strategies for producing nano-sensors, including top-down lithography, bottom-up assembly and molecular self-assembly.



TEM-Aufnahmen von einem einwandigen Kohlenstoff-Nanoröhrchen.
TEM image of a single wall carbon nanotube.
(A. Satalov, N. Burblies, P. Behrens/ACI)

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Kernkompetenzen/*Core competencies:*
- Photokatalyse/*Photo catalysis*
- Selbstreinigende, superhydrophile und antibakterielle Oberflächen/*Self-cleaning, superhydrophilic, and antibacterial surfaces*
- Metall- und Halbleiter-Nanopartikel/*Metal and semiconductor particles*
- Nanokristalline transparente Beschichtungen/*Nanocristalyne transparent coatings*
- Funktionsprüfungen nach DIN, CEN und ISO/*Functional test according to DIN, CEN, and ISO*

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Kernkompetenzen/*Core competencies:*
- Blechumformung/*Sheet metal forming*
- Massivumformung/*Massive forming*
- Umformmaschinen/*Metal forming machines*
- CA – Techniken/*Computer aided engineering*
- Numerische Methoden/*Numerical methods*
- Biomedizintechnik/Prothesendesign/*Biomedical Engineering/prosthesis design*

Prof. Dr. Peter Behrens
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Kernkompetenzen/*Core competencies:*
- Kontrollierte Synthese von Festkörpern, Materialien und Nanomaterialien/*Controlled synthesis of solid-state compounds, materials, and nanomaterials*
- Sol-Gel-Prozesse, kontrollierte Kristallisation, Solvothermalsynthesen/*Sol-gel processes, controlled crystallisation, solvothermal syntheses*
- Nanoporöse Materialien/*Nanoporous materials*
- Biomaterialien/*Biomaterials*
- Biomineralisation/*Biomineralisation*
- Modellierung von Festkörpern/*Modelling of solid-state compounds*

Kernkompetenzen/*Core competencies:*
- Überstrukturen von Nanopartikeln (superparamagnetisch, plasmonisch, halbleitend)/*Superstructures of nanoparticles (superparamagnetic, plasmonic, semiconducting)*
- Hydrogele und Aerogele aus kolloidalen Nanopartikeln/*Hydrogels and aerogels from colloidal nanoparticles*
- Kolloidale Überkristalle von Nanopartikeln/*Colloidal supercrystals of nanoparticles*
- Multifunktionale Polymernanobeads/*Multifunctional polymernanobeads*
- Funktionalisierung und Phasentransfer von Nanopartikeln/*Functionalization and phase transfer of nanoparticles*

Dr. Nadja Bigall
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Aufnahme: Fotostudio Megr

Kernkompetenzen/*Core competencies:*
- Simulation von Solarzellen/*Simulation of solar cells*
- Si-Materialforschung/*Si material research*
- Si-Dünnschichtzellen/*Si thin-film solar cells*
- Si-Waferzellen/*Si wafer cells*
- Zellcharakterisierung/*Characterisation of solar cells*
- Modultechnologie/*Module technology*
- Selektive Schichten/*Selective layers*
- Sonnenkollektoren/*Solar thermal collectors*

Prof. Dr.-Ing. Rolf Brendel
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Kernkompetenzen/*Core competencies:*
- Katalyse/*Catalysis*
- Membrane/*Membranes*
- Poröse Materialien/*Porous materials*
- Wirt/Gast-Komposite/*Host-guest composites*
- Brennstoffzellen/*Fuel cells*
- Farbstoff-Solarzellen/*Dye solar cells*
- Elektronenmikroskopie/*Electron microscopy*

Prof. Dr. Jürgen Caro
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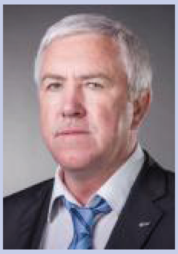

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Kernkompetenzen/*Core competencies:*
- Nanotechnologie mit dem Laser/*Nanotechnology with laser*
- Zwei-Photonen-Polymerisation/*Two-photon polymerization*
- Charakterisierung von Laserprozessemissionen/*Characterisation of laser process emissions*
- Nichtlineare maskenlose Lithographie/*Nonlinear maskless lithography*
- Laserbasierte Nanopartikel-Erzeugung/*Laser-based nanoparticle generation*
- EUV-Messtechnik/*EUV-Metrology*

Dr. Dirk Dorfs
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Kernkompetenzen/*Core competencies:*
- Synthese von kolloidalen Nanopartikeln (Halbleiter und Metalle)/*Synthesis of colloidal nanoparticles (semiconductors and metals)*
- Kolloidale Nanopartikel komplexer Zusammensetzung/*Colloidal nanoparticles of complex composition*
- Erweiterte Formkontrolle von Nanopartikeln (Stäbchen, verzweigt, hohl, etc.)/*Advanced shape control of nanoparticles (rods, branched, hollow, etc.)*
- Optische Eigenschaften von Nanopartikeln/*Optical properties of nanoparticles*
- Wechselwirkungen verschiedener Nanopartikel (Metall/Halbleiter etc.)/*Interactions of various nanoparticles (metal / semiconductor, etc.)*

Prof. Dr. Wolfgang Ertmer
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Kernkompetenzen/*Core competencies:*
- Quantenengineering/*Quantum engineering:*
  - Optische Atomuhren/*Optical atom clocks*
  - Bose-Einstein-Kontdensate/*Bose-Einstein condensates*
  - Ultrakalte Bose-Fermi Mischungen/*Ultra-cold Bose-Fermi mixtures*
  - Rein-optische Atomlaser/*Pure optical atom lasers*
  - Ultrakalte Neon-Atome/*Ultra-cold neon atoms*
- Quantensensoren/Quantum sensors:
  - Sagnac-Interferometrie/*Sagnac interferometry*
  - Atominterferometrie/*Atom interferometry*
  - Atomoptik mit Mikrostrukturen/*Atom optics with microstructures*
- Fundamentale Physik im Weltraum/*Fundamental physics in space*
- Lasermedizin und Biophotonik/*Laser medicine and biophotonics*

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Kernkompetenzen/*Core competencies:*
- Erzeugung, Stabilisierung, Funktionalisierung und Anwendung von Nanopartikeln und Nanostrukturen/*Fabrication, stabilization and application of nanoparticles and nanostructures*
- Partikelstabilisierung und Funktionalisierung/*stabilization and functionalization of nanoparticles*
- Maßgeschneiderte Nanokomposite und Nanopartikel-Dünnschichten sowie magnetische Nanomaterialien/*Optimized polymer nanocomposite materials and nanoparticulate and nanocomposite thin films as well as magnetic nanomaterials*

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Kernkompetenzen/*Core competencies:*
- Quanteneffekte/*Quantum Effects*
- Nanostrukturierung/*Nanostructuring*
- Niederdimensionale Systeme/*Low dimensional systems*
- Nanoelektronik/*Nanoelectronics*
- Quanten Hall Effekt/*Quantum Hall effect*
- Quantenpunkte/*Quantum dots*

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Kernkompetenzen/*Core competencies:*
- Basistechnologien in der organischen Synthese/*Enabling technologies in organic synthesis:*
  - Festphasen-unterstützte Synthese/ *Solid-phase assisted synthesis*
  - Mikroreaktoren/ *microreactors*
  - neuartige Strategien zur Immobilisierung von Katalysatoren/*novel immobilization strategies for catalysts*
  - Methodenentwicklung in der organischen Synthese/ *methodology development in organic synthesis.*
- Naturstoffsynthese/ *Natural product synthesis:*:
  - Totalsynthese und Mutasynthese von biologisch aktiven Naturstoffen - Antiinfektiva, Antitumormittel, etc/ *otal synthesis and mutasynthesis of biologically active natural products - antiinfectives, antitumor agents, etc*
  - Natürliche Produkte als Werkzeuge für die Medikamentenforschung und Auffinden von biologischen Target/ *Natnatural products as tools for drug research and finding of biological targets.*

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Kernkompetenzen/*Core competencies:*

- Ultrakalte Materie/*Ultra-cold matter*
- Atomare Bose-Einstein-Kondensate und quantenentartete Fermigase/ *Atomic Bose-Einstein condensates and quantum degenerate Fermie gases*
- Ultrakalte Moleküle/*Ultra-cold molecules*
- Nichtklassische Materiewellen/*Non-classical matter waves*
- Squeezing und Verschränkung von neutralen Atomen/*Squeezing and entanglement of neutral atoms*

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Kernkompetenzen/*Core competencies:*

- Modellierung und Simulation von/*Modelling and simulation of:*
  - Nanostrukturierten Bauelementen und Schaltungen/*Nanostructured devices and circuits*
  - Atomkraftmikroskopie (EFM, MFM)/ *Atomic force microscopy (EFM, MFM)*
  - Nano-elektromechanischen Systemen (NEMS)/*Nano electro mechanical systems (NEMS)*

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Kernkompetenzen/*Core competencies:*

- Spinelektronik in Halbleitern/*Spinelectronics in semiconductors:*
  - Spin-Rausch Spektroskopie/*Spin-noise spectroscopy*
  - g-Faktor Spektroskopie/*g-Factor spectroscopy*
  - Optische Spin-Auswahlregeln/*Optical spin-selection rules*
  - Reduktion der Laserschwelle/*Reduction of laser threshold*
  - Spin-Dephasierung/*Spin dephasing*
- Dynamik von Biexitonen/*Dynamics of biexitons*

Kernkompetenzen/*Core competencies:*
- Quantenkontrolle gespeicherter Ionen in Hinblick auf Quanteninformation und Präzisionsmessungen/*Quantum control of stored ions in terms of quantum information and precision measurements*

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Kernkompetenzen/*Core competencies:*
- Atomare und molekulare Quantengase und ultrakalte Moleküle/*Atomic and molecular quantum gases and ultracold molecules*

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Kernkompetenzen/*Core competencies:*
- Neuartigen Materiallösungen für die Si-basierende Elektronik/*New materials for Si-based electronics*
- Alternative Bauelemente-Konzepte, neue nanoelektronische Funktionalität/*Alternative device concepts, new nanoelectronic functionalities*
- Kristalline Selten-Erden-Oxide/*Crystalline rare earth oxides*
- Wachstum von ultradünnen epitaktische Heterostrukturen mit vergrabenen Metalloxiden in Silizium/*Growth of ultra-thin epitaxial heterostructures with buried metal oxides on silicon*
- Engineering der Grenzflächen von 2D-Nanostrukturen/*Interface engineering of 2D nanostructures*

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Kernkompetenzen/*Core competencies:*

- Leitfähigkeit in reduzierten Dimensionen/*Conductivity in reduced dimensions*
- Molekulare Elektronik/*Molecular electronics*
- Funktionalisierte Isolatoren/*Functionalized insulators*
- Nanostrukturierte Metall/Isolator-Systeme/*Nanostructured metal/insulator systems*

Prof. Dr. Ernst Rasel
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Kernkompetenzen/*Core competencies:*

- Atomoptik/*Atom Optics*
- Quantenoptik/*Quantum Optics*
- Präzisionssensoren für Raum und Zeit/*Precision Sensors of Space and Time*

Prof. Dr. Franz Renz
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Kernkompetenzen/*Core competencies:*

- Koordinationschemie/*Coordination chemistry*
- Molekulare Schalter/*Molecular switches*
- Mößbauer Spektroskopie/*Mößbauer spectroscopy*

Prof. Dr.-Ing. Lutz Rissing
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Kernkompetenzen/*Core competencies:*

- Dünnfilmtechnik/*Thin Film Technology*
- Mechanische Mikrobearbeitung und –montage/*Mechanical Micromachining and Microassembly*
- Mikrotribologie/*Microtribology*
- Konzepte im Bereich der Aus- und Weiterbildung in der Mikrosystemtechnik/ *Concepts of education and advanced training in microtechnology*
- Aufbau- und Verbindungstechnik auf Waferniveau/*Assembly and packaging at wafer level*

Kernkompetenzen/*Core competencies:*

- Entwicklung und präzise Kontrolle von Ionenprozessen zur Herstellung hochwertiger optischer Schichten / *Development and precise control of modern ion processes for the production of high quality and stable optical coatings*
- Charakterisierung optischer Laserkomponenten / *Characterization of optical laser components*

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www.lzh.de/de/abteilungen/laserkomponenten

Kernkompetenzen/*Core competencies:*

- Graphen und Nanostrukturierung von Graphen/*Graphene and nanostructuring of graphene*
- Funktionalisierung von Halbleiteroberflächen/*Functionalization of semiconductor surface*s
- Korrelierte elektronische Systeme/*Correlated electronic systems*
- Kollektive Phänomene/*Collective phenomena*
- Transport in niedrigdimensionalen Strukturen/*Transport in low dimensional structures*

Prof. Dr. Christoph Tegenkamp
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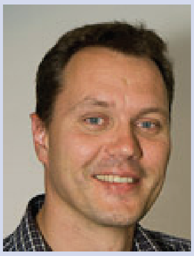

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Kernkompetenzen/*Core competencies:*

- Silizium-basierte nano- und optoelektronische Bauelemente/*Silicon-based nanoelectronic and optoelectronic devices*
- Materialien für optoelektronische Bauelemente auf Siliziumsubstraten/*Materials for optoelectronic devices on silicon substrates*
- Molekularstrahlepitaxie mit Silizium und Germanium/*Molecular beam epitaxy of silicon and germanium*
- Modifikation der Hetero-Epitaxie mit Surfactants/*Modification of heteroepitaxy with surfactants*
- Herstellung und Charakterisierung von Si/Ge-epitaktischen Filmen und Hetero-Bauelementen/*Fabrication and characterization of Si/Ge-epitaxial films and heterodevices*

Prof. Dr.-Ing. Peter Wriggers
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Kernkompetenzen/*Core competencies:*

- Biomechanik/*Biomechanics*
- Konstitutive Modellierung von Materialien/*Constitutive modelling of materials*
- Kontaktmechanik/*Contact mechanics*
- Finite Elemente Algorithmen/*Finite element algorithms*
- Mikromechanik/*Micromechanics*
- Multiphysik/*Multiphysics*
- Multi-Skalen-Analysen für Materialien und Grenzflächen/*Multi-scale analysis for materials and interfaces*
- Optimierung/*Optimizing*
- Symbolische Ansätze in FEM/*Symbolic approaches in FEM*

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Kernkompetenzen/*Core competencies:*

- Sensorik und Messtechnik/*Sensors and Measurement Science*
- Medizin- und Sicherheitstechnik/*Medical and Safety Technology*
- Mikrosystemtechnik/*Micro system technology*

Emeriti

Kernkompetenzen/*Core competencies:*
- Rechnergestützter Entwurf mikroelektronischer Schaltungen und Systeme/ *Electronic Design Automation (EDA)*
- Verfahren für den Analog- und Mixed-Signal-Entwurf/*Methods for analog and mixed-signal design*
- Werkzeuge für den physikalischen Entwurf und seine Verifikation/*Tools for physical design and its verification*
- Methoden zum Entwurf robuster Schaltungen/*Tools for design of robust circuits*

Prof. Dr.-Ing. Erich Barke
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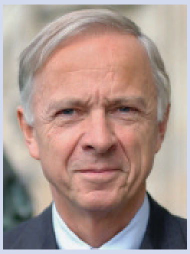

Kernkompetenzen/*Core competencies:*
- Mikro- und Nanosensorik/*Micro- and nanosensors*
- Mikro- und Nanoaktorik/*Micro- and nanoactors*
- Mikro- und Nanotribologie/*Micro- and nanotribology*
- Mechanische Mikro- und Nanobearbeitung/*Mechanical micro- and nanoprocessing*
- Mikromontage/*Micro assembly*
- Management of Technology (MOT)/ *Management of Technology (MOT)*
- Ausbildungskonzepte für Mikro- und Nanotechnik/*Educational concepts for mikro and nano technics*

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Kernkompetenzen/*Core competencies:*
- MOSFETs mit hochbeweglichen heteroepitaktischen Germanium-Kanälen auf Siliziumsubstraten/*MOSFETs with high-mobility heteroepitaxial germanium channels on silicon substrates*
- Resonante Tunnelbauelemente/*Resonant-tunneling devices*
- Nanocluster MOS-Speicher/*Nanocluster MOS-memories*
- Gatedielektrika hoher Dielektrizitätskonstante/*Gate dielectrics with high dielectric constant*
- Degradationsphänomene in Gate- und Tunneloxiden/*Degradation phenomena in gate- and tunnel-oxides*
- Full-band Monte-Carlo Transportsimulation/*Full-band Monte-Carlo transport simulation*

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Aktuell in 2015
News in 2015

15.01.2015


Nutzungsordnung
des Laboratoriums für Nano- und Quantenengineering
der Leibniz Universität Hannover
Datum: 15.01.2015

LNQE-Nutzerordnung.
LNQE User Agreement.

Nutzungsordnung

Die neue Nutzungsordnung für den Forschungsbau ist in Kraft

Für die Nutzung des LNQE-Forschungsbaus hat der Vorstand eine Nutzungsordnung beschlossen.

Die Nutzungsordnung beinhaltet insbesondere:

- Das Leistungsangebot
- Den Zugang und die Einweisung
- Das Kostenmodell
- Arbeitssicherheit
- Details zur technischen Durchführung
- Hinweise zu Publikationen und Patenten

Die Nutzungsordnung kann von der LNQE-Webseite im internen Bereich und in der LNQE-Wiki heruntergela den werden.

User Agreement

The new User Agreement for the research building is in force

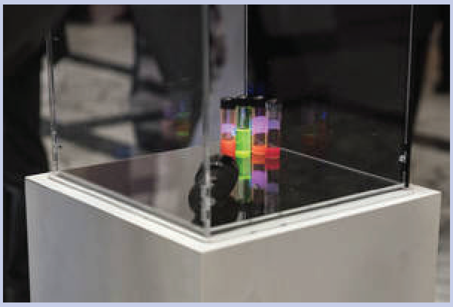
For the use of LNQE research building, the Executive Board decided a User Agreement.

The User Agreement includes in particular:

- *The range of services*
- *The access and admission*
- *The cost model*
- *Safety at work*
- *Details of the technical implementation*
- *Information about publications and patents*

The User Agreement can be downloaded from the LNQE-website in the internal area and in the LNQE-wiki.

06.05.2015



Ausstellungsstand des LNQE auf dem Wirtschaftsempfang 2015 – Vielen Dank an die Arbeitsgruppe Bigall für die wunderbar fluoreszierenden Nanopartikel.
Exhibition stand of LNQE on the business reception 2015 - Thanks to the research group Bigall for the wonderful fluorescent nanoparticles.

Wirtschaftsempfang 2015

Politik und Wirtschaft zu Gast in der Leibniz Universität Hannover

Der diesjährige Wirtschaftsempfang der Leibniz Universität Hannover am 23. April 2015 im Lichthof des Welfenschlosses hatte als Motto „WissensRÄUME“. Mit den WissensRÄUMEN an der Universität wurden die Forschungszentren und Forschungsbauten präsentiert. Insgesamt rund 700 Gäste aus Politik, Wissenschaft und insbesondere Wirtschaft nahmen teil.

Das Laboratorium für Nano- und Quantenengineering war als Austeller vertreten. Unser Angebot an Interessierte:

- Kooperation für FuE-Vorhaben der Nanotechnologie
- Vermittlung von Absolventen des Studiengangs Nanotechnologie (BSc und MSc) und Promovenden der Nanotechnologie
- Technologische Auftragsforschung zur Nanostrukturierung

Business Reception 2015

Guests from politics and business at the Leibniz Universität Hannover

This year’s business reception of Leibniz Universität Hannover on 23 April 2015 in the atrium of the Welfenschloss had the motto “WissensRÄUME“ („knowledge spaces”). With the” knowledge spaces” at the university research centers and research buildings were presented. A total of about 700 guests from politics, science and economy in particular participated.

The Laboratory of Nano and Quantum Engineering was represented as an exhibitor. Our offer to those interested:

- *Cooperation for R & D projects in nanotechnology*
- *Placement of graduates of the study program Nanotechnology (BSc and MSc) and doctoral students of nanotechnology*
- *Technological contract research for nanostructuring*

Wechsel im Vorstand

Prof. Dr.-Ing. Stefan Zimmermann (Elektrotechnik und Messtechnik) in den Vorstand gewählt.

Am 17.06.2015 fand die jährliche Mitgliederversammlung des LNQE statt. Wie schon länger geplant, übernahm Prof. Dr.-Ing. Stefan Zimmermann vom Institut für Elektrotechnik und Messtechnik den Vorstandsposten von Prof. Dr. Jörg Osten vom Institut für Materialien und Bauelemente der Elektronik.

Die Mitglieder des LNQE danken Prof. Dr. Jörg Osten ganz herzlich für sein jahrelanges Engagement im Vorstand des LNQE, seine Unterstützung beim Personal des Forschungsbaus und beim Studiengang Nanotechnologie.

Change in Executive Board

Prof. Dr.-Ing. Stefan Zimmermann (electrical engineering and measurement technology) elected to the board.

On 17.06.2015 the annual General Assembly of LNQE took place. As planned for some time, Prof. Dr.-Ing. Stefan Zimmermann from the Institute for Fundamental Electrical Engineering and Measurement Technology took over the board position of Prof. Dr. Jörg Osten from the Institute of Electronic Materials and Devices.

The members of the LNQE thank Prof. Dr. Jörg Osten very much for his years of commitment to the Board of LNQE, his support for staff of the research building and for the degree program nanotechnology.

23.06.2015

Prof. Dr.-Ing. Stefan Zimmermann

Studiengang Nanotechnologie erfolgreich reakkreditiert

Verlängerung der Akkreditierung bis 30.09.2021

Nach der Erfüllung aller Auflagen ist der Bachelor- und Masterstudiengang Nanotechnologie an der Leibniz Universität Hannover jetzt offiziell erfolgreich reakkreditiert. Es gab keine Beanstandungen durch die ASIIN in Bezug auf die Erfüllung von Auflagen und Empfehlungen. Die Akkreditierung wurde bis 30.09.2021 verlängert. Von den Gutachtern wurden besonders die gute Zusammenarbeit der Studiengangsverantwortlichen mit den Studierenden und die allgemeine, große Zustimmung der Studierenden zu Ihrem Studiengang hervorgehoben.

Der Bachelorstudiengang Nanotechnologie startete im Wintersemester 2008 mit damals 32 Studierenden. Der Masterstudiengang Nanotechnologie startete drei Jahre später, als die ersten studierenden mit ihrem Bachelorabschluss machten. Seit dem hat der Studiengang Nanotechnologie kontinuierlich steigende Studierendenzahlen. Im Winterse-

Study Course Nanotechnology Successfully Re-accredited

Extension of accreditation until 30.09.2021

After fulfilling all the requirements the Bachelor's and Master's degree program nanotechnology at the Leibniz Universität Hannover is now re-accredited officially successful. There were no complaints by the ASIIN regarding the fulfillment of requirements and recommendations. The accreditation was extended until 30/09/2021. From the experts especially the good cooperation of the degree program responsible with the students and the general, strong support of the students to their degree program have been highlighted.

The Bachelor's degree program nanotechnology launched in the winter semester 2008 with back then 32 students. The master's degree nanotechnology launched three years later, when the first students went with their bachelor's degree. Since the degree program nanotechnology has been continuously rising student numbers. In the winter

16.07.2015

mester 2014 starteten ganze 98 Studierende ein Bachelorstudium der Nanotechnologie, im Sommersemester 2015 starteten 10 Studierende ihr Masterstudium. Der Master kann im Winter- und Sommersemester begonnen werden. Insgesamt studieren zurzeit über 210 Studentinnen und Studenten Nanotechnologie an der Leibniz Universität Hannover.

semester 2014 started all 98 students a bachelor of nanotechnology, in the summer term 2015 started 10 students their master's degree. The master can be started in the winter and summer semesters. Overall, currently studying more than 210 students nanotechnology at the Leibniz Universität Hannover.

16.07.2015

Neuer Sprecher des Vorstandes

Prof. Dr. Peter Behrens

Professor Peter Behrens (Anorganische Chemie) übernimmt den Vorsitz

Wie bereits auf der letzten Mitgliederversammlung angekündigt, hat der Vorstand des LNQE Prof. Dr. Peter Behrens vom Institut für Anorganische Chemie jetzt als neuen Sprecher gewählt.

Das LNQE dankt dem bisherigen Sprecher, Prof. Dr. Rolf Haug, für sein jahrelanges Engagement als Sprecher des Vorstandes. Er wird den Vorstand weiterhin als Mitglied unterstützen.

New Speaker of the Executive Board

Professor Peter Behrens (inorganic chemistry) took the chair

As announced at the last General Meeting, the Board of LNQE has now elected Prof. Dr. Peter Behrens from the Institute of Inorganic Chemistry as a new speaker.

The LNQE thanks the previous speaker, Prof. Dr. Rolf Haug, for his many years of commitment as Speaker of the Executive Board. He will continue to support the Executive Board as a member.

11.09.2015

Neues Mitglied aus der Partikeltechnik

Prof. Dr. Georg Garnweitner

Professor Garnweitner (TU Braunschweig) wird Mitglied

Neustes Mitglied im Laboratorium für Nano- und Quantenengineering ist Prof. Dr. Georg Garnweitner.

Professor Garnweitner leitet den Bereich „Nanomaterialien“ am Institut für Partikeltechnik an der Technischen Universität Braunschweig. Bereich Nanomaterialien beschäftigen sich mit der Erzeugung, Stabilisierung, Funktionalisierung und Anwendung von Nanopartikeln und Nanostrukturen. Die Nanopartikel werden über „bottom-up“-Methoden mittels chemischer Synthese hergestellt. Neben der Synthese wird die Partikelstabilisierung und Funktionalisierung eingehend untersucht. Die Nanopartikel werden für neuartige Anwendungen maßgeschneidert.

New Member from the Particle Technology

Professor Garnweitner (TU Braunschweig) becomes member

Newest member in the Laboratory of Nano and Quantum Engineering is Prof. Dr. Georg Garnweitner.

The research group "Nanoparticles and Nanocomposites" investigates the fabrication, stabilization and application of nanoparticles and nanostructures. The nanoparticles are synthesized via "bottom-up" methods. In addition to the synthesis, the stabilization and functionalization of nanoparticles is a crucial issue for applications and thus is investigated in detail. Chemically tailored nanoparticles are deveoped for novel application.

Niedersachsen-Technikum

Informationsveranstaltung für Abiturientinnen im LNQE zur Nanotechnologie

Am 05.10.2015 war das Niedersachsen-Technikum zu Gast im LNQE. In einem kurzen Vortrag, einer Laborführung und im abschließenden Gespräch wurden die Gäste über aktuelle Nanotechnologie-Forschung und über die Studiermöglichkeiten mit Bachelor- und Masterstudiengang Nanotechnologie informiert.

Das Niedersachsen-Technikum ist ein neues Konzept für die Gewinnung des weiblichen MINT-Fachkräftenachwuchses in Wissenschaft und Wirtschaft. Es richtet sich an junge Frauen, die das Abitur an einem allgemeinbildenden Gymnasium oder einem Fachgymnasium absolviert haben.

Niedersachsen-Technikum

Information event for female high school graduates in LNQE on nanotechnology

On 05.10.2015 the Niedersachsen-Technikum was guest in the LNQE. In a short lecture, a lab guide and in the final discussion, the guests were informed of current nanotechnology research and the study possibilities with Bachelor's and Master's program nanotechnology.

The Niedersachsen-Technikum is a new concept for attracting women for technical and science subjects. It is aimed at young women who have just finished high school.

16.07.2015

Niedersachsen-Technikum im LNQE.
Niedersachsen-Technikum at LNQE.
(Photos: L. David)

NanoDay 2015

NanoDay 2015

Laboratorium für Nano- und Quantenengineering

Leibniz Universität Hannover

NanoDay 2015
Donnerstag 01.10.2015
Vorträge: Appelstr. 4, 30167 Hannover, Multimediahörsaal, Technische Informatik (Gebäude 3703)
Postersitzung: Schneiderberg 39, 30167 Hannover, Foyer, Laboratorium für Nano- und Quantenengineering (Gebäude 3430)

Programm

www.LNQE.uni-hannover.de

Gäste sind herzlich willkommen!

Der elfte NanoDay des LNQE in Hannover

Am Donnerstag, den 1. Oktober 2015 fand der jährliche NanoDay des Laboratoriums für Nano- und Quantenengineering in Hannover statt. In acht Vorträgen und einer Postersitzung wurden die neusten Forschungsergebnisse aus den interdisziplinären Arbeitsgruppen auf dem Gebiet Nanotechnologie präsentiert. Die durch die Leibniz Universitätsgesellschaft e. V. geförderten Posterpreise gingen dieses Jahr an:

The eleventh NanoDay of LNQE in Hannover

On Thursday 1th October 2015 the annual NanoDay of the Laboratory of Nano and Quantum Engineering took place in Hanover/Germany. In eight lectures and a poster session the latest research results from the interdisciplinary working groups in the field of nanotechnology were presented. The Poster prizes funded by Leibniz Universitätsgesellschaft e. V. were awarded this year to:

“Organic-silicon solar cells exceeding 20% efficiency“
Dimitri Zielke, Claudia Niehaves, Wilfried Lövenich, Andreas Elschner, Matthias Hörteis and Jan Schmidt
Institut für Solarenergieforschung Hameln

„Chemical and Biological Investigations of Ansamitocin-Nanoparticle-Conjugates as Multifunctional Cancer Therapy Agent“
Katja Seidel, Mona Oltmanns, Asha Balakrishnan, Michael Ott, Andreas Kirschning
Institut für Organische Chemie

„Ultrafast Surface Plasmon-Polariton Logic Gates And Half-Adder“
Tobias Birr, U. Zywietz, P. Chhantyal, T. Fischer, B. Chichkov and C. Reinhardt
Laser Zentrum Hannover e.V., Nanotechnology Department, Nanophotonic Group, Hollerithallee 8, 30419 Hannover, Germany

Herzlichen Glückwunsch und vielen Dank an alle Vortragenden und Teilnehmer des NanoDay 2015!

Congratulations and thank you to all lecturers and participants of the NanoDay 2015!

Vorträge des NanoDay 2015/*Talks of the NanoDay 2015:*

“Aharonov-Bohm effect in graphene”
Dmitri Smirnov
Institut für Festkörperphysik, Abteilung Nanostrukturen

„Functional Assemblies of Nanocrystals“
Jan Poppe
Institut für Physikalische Chemie und Elektrochemie, Arbeitsgruppe Bigall

„Non-cubic Gd_2O_3 on Silicon Substrates“
Matthias Möllers
Institut für Materialien und Bauelemente der Elektronik

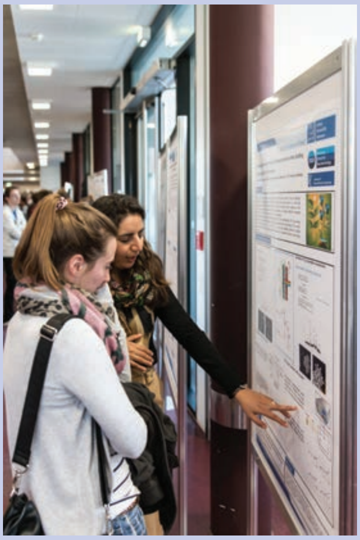
„Stable anodes for lithium ion batteries made of self-organized mesoporous silicon“
Sascha J. Wolter
Institut für Solarenergieforschung, Abteilung Photovoltaik

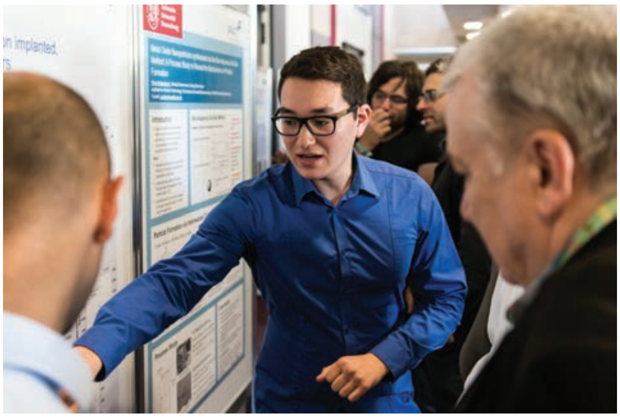
“Einstein-Podolsky-Rosen entanglement in Bose-Einstein condensates”
Bernd Lücke
Institut für Quantenoptik

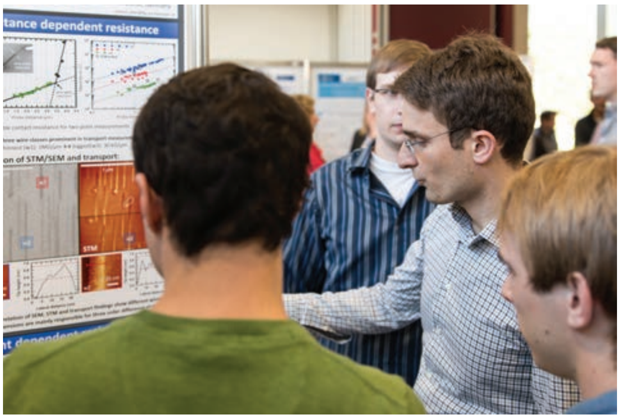
“Surface functionalization at micro- and nanoscale by ultrashort laser pulses”
Elena Fadeeva
Laser Zentrum Hannover e.V., Nanotechnology Department

„Plasmons in low dimensional systems“
Timo Lichtenstein
Institut für Festkörperphysik, Abteilung Atomare und Molekulare Strukturen

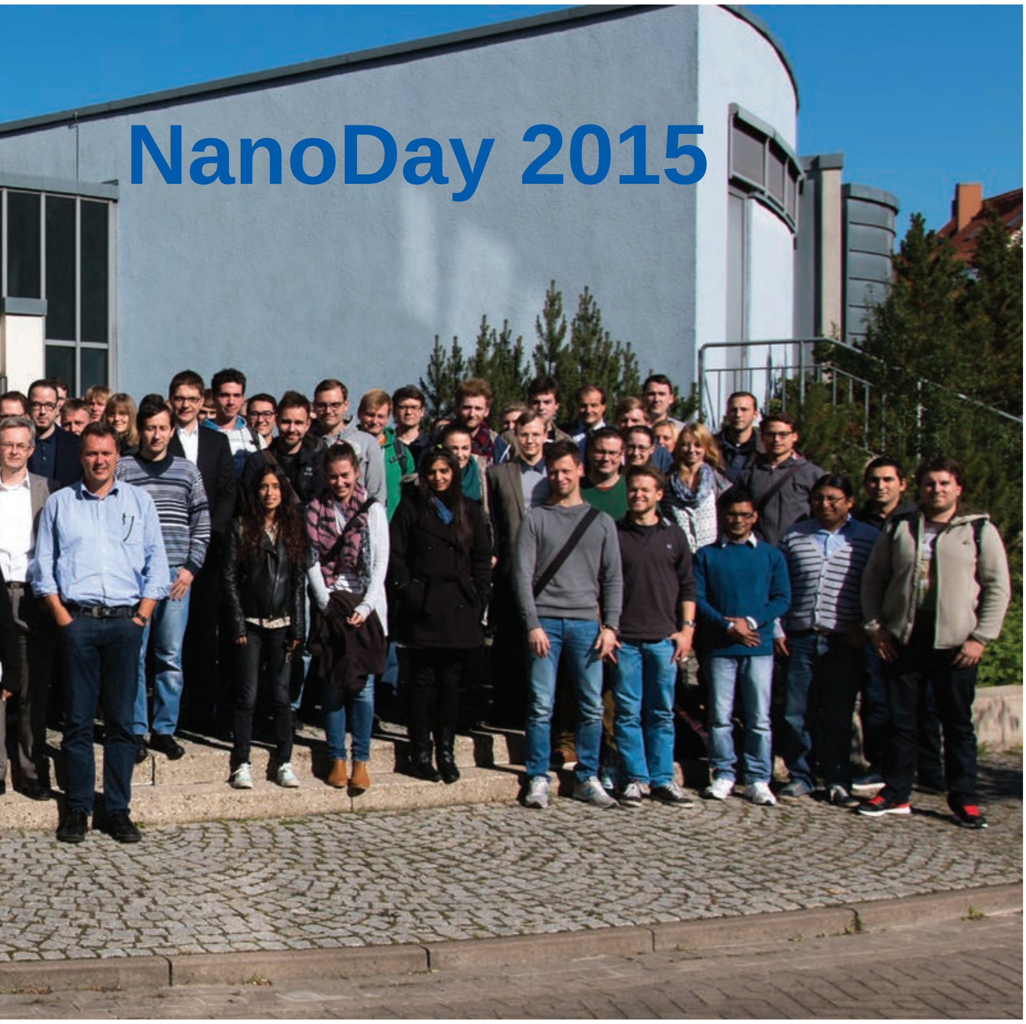
„Improving Biomedical Silicone by Sophisticated Silica Particles“
Tanja Heemeier
Institut für Anorganische Chemie, AK Festkörper- und Materialchemie

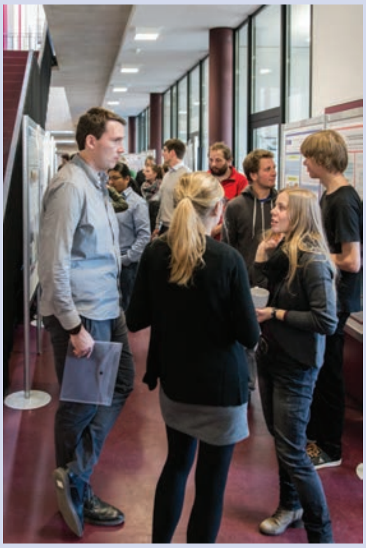




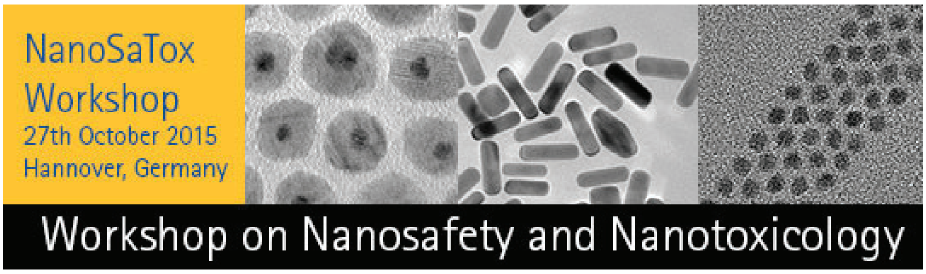


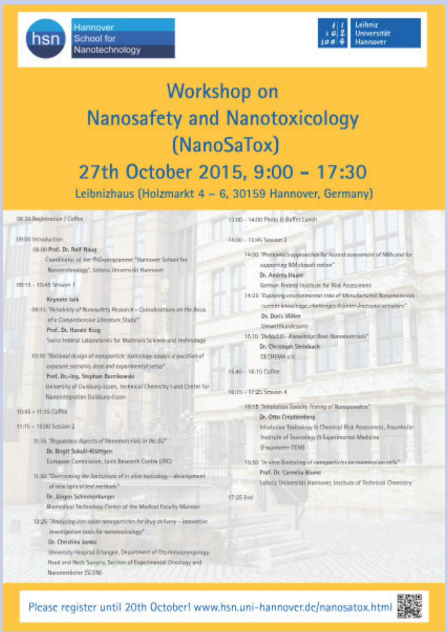
NanoDay 2015





Fotos: L. David




hsn Hannover School for Nanotechnology

Leibniz Universität Hannover

Workshop on
Nanosafety and Nanotoxicology
(NanoSaTox)
27th October 2015, 9:00 – 17:30
Leibnizhaus (Holzmarkt 4 – 6, 30159 Hannover, Germany)

08:30 Registration / Coffee

09:00 Introduction
09.00 **Prof. Dr. Rolf Haug**
Coordinator of the PhD-programme "Hannover School for Nanotechnology", Leibniz Universität Hannover

09:15 – 10:45 Session 1
Keynote talk
09:15 *"Reliability of Nanosafety Research – Considerations on the Basis of a Comprehensive Literature Study"*
Prof. Dr. Harald Krug
Swiss Federal Laboratories for Materials Science and Technology
10:10 *"Rational design of nanoparticle toxicology assays: a question of exposure scenario, dose and experimental setup"*
Prof. Dr.-Ing. Stephan Barcikowski
University of Duisburg-Essen, Technical Chemistry I and Center for Nanointegration Duisburg-Essen

10:45 – 11:15 Coffee

11:15 – 13:00 Session 2
11:15 *"Regulatory Aspects of Nanomaterials in the EU"*
Dr. Birgit Sokull-Klüttgen
European Commission, Joint Research Centre (JRC)
11:50 *"Overcoming the limitations of in vitro toxicology – development of new optical test methods"*
Dr. Jürgen Schnekenburger
Biomedical Technology Center of the Medical Faculty Münster
12:25 *"Analyzing iron oxide nanoparticles for drug delivery – innovative investigation tools for nanotoxicology"*
Dr. Christina Janko
University Hospital Erlangen, Department of Otorhinolaryngology, Head and Neck Surgery, Section of Experimental Oncology and Nanomedicine (SEON)

13:00 – 14:00 Photo & Buffet Lunch

14:00 – 15:45 Session 3
14:00 *"Proteomics approaches for hazard assessment of NMs and for supporting NM classification"*
Dr. Andrea Haase
German Federal Institute for Risk Assessment
14:35 *"Exploring environmental risks of Manufactured Nanomaterials – current knowledge, challenges & inter-/national activities"*
Dr. Doris Völker
Umweltbundesamt
15.10 *"DaNa2.0 – Knowledge Base Nanomaterials"*
Dr. Christoph Steinbach
DECHEMA e.V.

15:45 – 16:15 Coffee

16:15 – 17:25 Session 4
16:15 *"Inhalation Toxicity Testing of Nanopowders"*
Dr. Otto Creutzenberg
Inhalation Toxicology & Chemical Risk Assessment, Fraunhofer Institute of Toxicology & Experimental Medicine (Fraunhofer ITEM)
16:50 *"In vitro Biotesting of nanoparticles on mammalian cells"*
Prof. Dr. Cornelia Blume
Leibniz Universität Hannover, Institute of Technical Chemistry

17:25 End

Please register until 20th October! www.hsn.uni-hannover.de/nanosatox.html

Nanotechnologie wird als eine der vielversprechendsten Schlüsseltechnologien, die zur Lösung vieler Probleme der Menschheit beitragen kann, angesehen. Zusätzlich zu den potenziellen Chancen der Nanotechnologie gibt es Warnhinweise auf mögliche Risiken der Nanotechnologie für die Umwelt und die Gesundheit. Der „Workshop über Nanosicherheit und Nanotoxikologie (NanoSaTox)“ untersuchte dieses komplexe Thema mit verschiedenen Präsentationen von verschiedenen Institutionen, um ein differenziertes Bild über den aktuellen Stand der Forschung zu geben.

Datum: 27. Oktober 2015 (Dienstag), 9.00 bis 17.30 Uhr

Ort: Leibnizhaus (Holzmarkt 4-6, 30159 Hannover, Deutschland)

Der Workshop wurde vom Promotionsprogramm „Hannover School for Nanotechnology“ des Laboratoriums für Nano- und Quantenengineering der Leibniz Universität Hannover organisiert.

Nanotechnology is regarded as one of the most promising key technologies that can contribute to the solution of many problems of mankind. In addition to the potential opportunities of nanotechnology, there are warnings on possible risks of nanotechnology for the environment and health. The “Workshop on Nanosafety and Nanotoxicology (NanoSaTox)” examined this complex subject with various presentations from different institutions to give a differentiated picture of the current state of research.

Date: 27th October 2015 (Tuesday), 9:00 - 17:30

Location: Leibnizhaus (Holzmarkt 4 – 6, 30159 Hannover, Germany)

The workshop was organized by the PhD-programme „Hannover School for Nanotechnology“ of the Laboratory of Nano and Quantum Engineering from Leibniz Universität Hannover.

Vorträge von NanoSaTox/*Talks of NanoSaTox:*

Keynote talk
“Reliability of Nanosafety Research - Considerations on the Basis of a Comprehensive Literature Study”
Prof. Dr. Harald Krug
Swiss Federal Laboratories for Materials Science and Technology

“Rational design of nanoparticle toxicology assays: a question of exposure scenario, dose and experimental setup”
Prof. Dr.-Ing. Stephan Barcikowski
University of Duisburg-Essen, Technical Chemistry I and Center for Nanointegration Duisburg-Essen

“Regulatory Aspects of Nanomaterials in the EU”
Dr. Birgit Sokull-Klüttgen
European Commission, Joint Research Centre (JRC)

“Overcoming the limitations of in vitro toxicology - development of new optical test methods”
Dr. Jürgen Schnekenburger
Biomedical Technology Center of the Medical Faculty Münster

“Analyzing iron oxide nanoparticles for drug delivery – innovative investigation tools for nanotoxicology”
Dr. Christina Janko
University Hospital Erlangen, Department of Otorhinolaryngology, Head and Neck Surgery, Section of Experimental Oncology and Nanomedicine (SEON)

“Proteomics approaches for hazard assessment of NMs and for supporting NM classification”
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German Federal Institute for Risk Assessment

“Exploring environmental risks of Manufactured Nanomaterials - current knowledge, challenges & (inter-)national activities”
Dr. Doris Völker
Umweltbundesamt

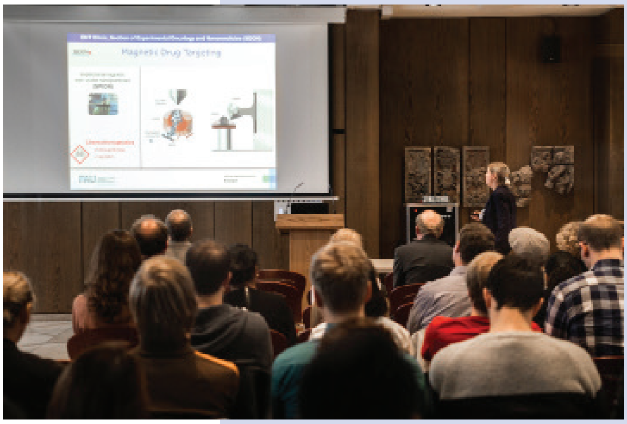
“DaNa2.0 – Knowledge Base Nanomaterials”
Dr. Christoph Steinbach
DECHEMA e.V.

“Inhalation Toxicity Testing of Nanopowders”
Dr. Otto Creutzenberg
Inhalation Toxicology & Chemical Risk Assessment, Fraunhofer Institute of Toxicology & Experimental Medicine (Fraunhofer ITEM)

“In vitro Biotesting of nanoparticles on mammalian cells”
Prof. Dr. Cornelia Blume
Leibniz Universität Hannover, Institute of Technical Chemistry

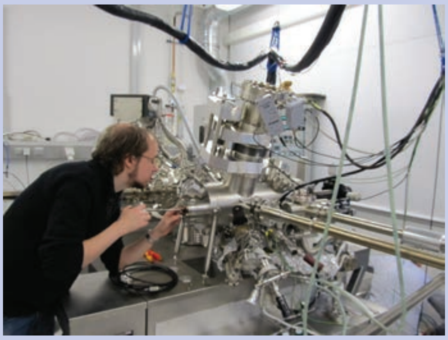
NanoSaTox

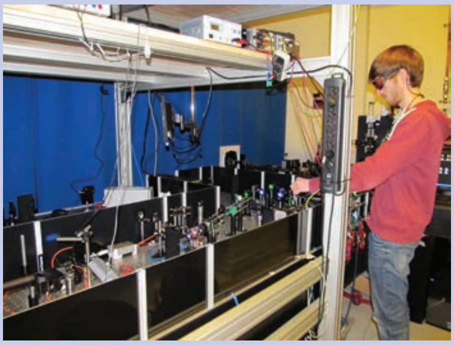
nanostrukturen
uni hannover
Field of research:
Quantum effects
in small semiconducting structures
Institute for Solid State Physics
Leibniz Universität Hannover



Fotos: L. David

Forschungsbau
Research Building





Zur Verwirklichung seiner Ziele betreibt das LNQE ein eigenes Forschungsgebäude in Hannover. Die Labore (435 m^2), der Forschungsreinraum (409 m^2) und die Büroräume (509 m^2) für ca. 50 Personen werden für interdisziplinäre Projekte, insbesondere aus erfolgreich eingeworbenen, größeren Drittmittelprojekten der Mitglieder genutzt.

Der Forschungsbau wurde vom Land Niedersachsen und mit Bundesmitteln nach einer Empfehlung durch den Wissenschaftsrat (nach Art. 91b Grundgesetz) in besonderer Weise gefördert und ist nach zweijähriger Bauzeit am 20. November 2009 fertig gestellt worden.

Durch das Gebäude werden hochwertige Infrastruktur und Technologien zur Verfügung gestellt, die den einzelnen Arbeitsgruppen in Ihren Instituten nicht zur Verfügung stehen. Die offene Bauweise verstärkt nach dem Konzept „Sehen und Begegnen“ den täglichen Kontakt der Wissenschaftler aus den unterschiedlichen Fächern. Dadurch wird es möglich, komplexe Problemstellungen zu lösen, die Kompetenzen aller Fachrichtungen bei allen Teilschritten der

To achieve its objectives LNQE operates its own research building in Hanover. The laboratories (435 m^2), research clean room (409 m^2) and offices (509 m^2) for about 50 persons are used for interdisciplinary projects, particularly from successfully acquired third-party funded large projects of the members.

The new research building was funded by Lower Saxony and with federal funds after a recommendation by the German Wissenschaftsrat (under Article 91b Basic Law) in a special way, and is completed after two years of construction on 20th November 2009.

By the building, high quality infrastructure and technologies are made available to the various working groups that are in their institutes are not available. The open design of the building enhances by the concept of “see and meet” the daily contact between scientists from different disciplines.This makes it possible to solve complex problems that require the skills of all disciplines at all stages of the problem simultaneously. This differs markedly from the usual sequential work-sharing in joint projects and

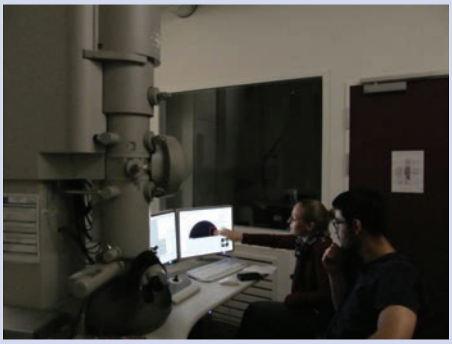
LNQE-Forschungsbau, Schneiderberg 39, 30167 Hannover, Deutschland.
LNQE research building, Schneiderberg 39, 30167 Hannver, Germany

Problemlösung gleichzeitig benötigen. Dies unterscheidet sich deutlich von der sonst üblichen sequenziellen Arbeitsaufteilung in Verbundprojekten und ist somit national, wenn nicht sogar international, vorbildlich und beispielhaft. Durch die Beteiligung von Wissenschaftlerinnen und Wissenschaftler aus den Natur- und Ingenieurwissenschaften werden hierbei sowohl die Grundlagen, als auch mögliche neuartige Anwendungen von Anfang an gleichwertig in der Forschung berücksichtigt.

Zentraler Bestandteil des Forschungsbaus ist der Reinraum. Er ist nach ISO5 / RK 100 im Handlingbereich und ISO6 / RK1000 in den Fluren zertifiziert. Die Hauptfläche des Reinraums ist in mehrere Unterräume unterteilt, in denen sich eine komplette Linie für die Mikroelektronik befindet, d. h. es können ausgehend von einem Wafer komplett alle Prozessschritte ausgeführt werden, um neuartige Bauelemente als Prototypen herzustellen. Durch die Aufteilung in zwei Lithografiebereiche ist sowohl die Bearbeitung von Element- als auch von Verbindungshalbleiter möglich (wobei die Linie hauptsächlich für Silizium ausgelegt ist). Hinzu kommen einige Messräume für Experimente unter Reinraumbedingungen.

is nationally, if not even internationally, model and best-practice example. By participation of scientists and engineers both the fundamentals as well as possible new applications are considered equivalent in research from the beginning.

A central part of the research building is the clean room. It is certified to ISO5 / RK 100 in the handling area and ISO6 / RK1000 in the floors. The main area of the clean room is divided into several subspaces with an entire line for microelectronics, ie starting from a wafer all process steps can be performed to create novel devices as prototypes. By dividing the lithography into two areas, it is possible to process both element and compound semiconductors (where the line is designed primarily for silicon). There are also some measuring rooms for experiments under clean room conditions.



Zahlen und Fakten

Räume/Hauptnutzflächen
- Labore (435 Quadratmeter): Laserlabore, Chemielabore, Messlabore
- Forschungsreinraum (409 Quadratmeter)
- Büroräume für 44 Personen (509 Quadratmeter)

Personen
- Betreiberteam
- 50 Wissenschaftlerinnen und Wissenschaftler aus den Bereichen Chemie, Elektrotechnik, Maschinenbau und Physik

Baukosten
- 14 Mio. Euro

Förderung
- Der Forschungsbau wird nach einer erfolgreichen Evaluation durch den Wissenschaftsrat (nach Artikel 91b Abs. 1 Nr. 3 des Grundgesetzes) durch den Bund gefördert

Bauzeit
- ca. 24 Monate
- Die feierliche Schlüsselübergabe war am 20. November 2009

Numbers and Facts

Rooms/main usable area
- *Labs (435 square meters): laser laboratories, chemical laboratories, test laboratories*
- *Research clean room (409 square meters)*
- *Office space for 44 people (509 square meters)*

People
- *Operator team*
- *50 scientist from the fields of chemistry, electrical engineering, mechanical engineering and physics*

Construction costs
- *14 Mio. euro*

Funding
- *The new construction is funded with federal funds after a recommendation by the German Wissenschaftsrat (under Article 91b para 1 nr. 3 of the Basic Law of Germany ("Grundgesetz"))*

Construction time
- *about 24 month*
- *The handover was at 20th November 2009*

Technologie im Forschungsbau
Technology in the Research Building

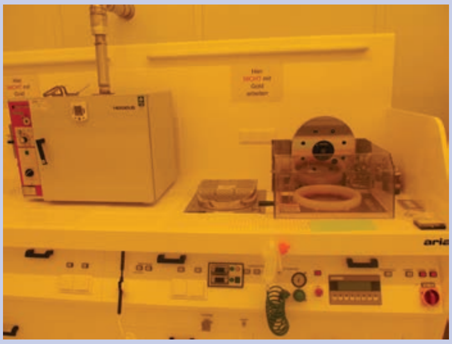
Reinraum allgemein

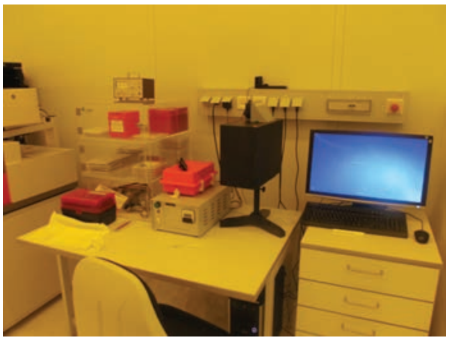
Der Reinraum ist nach ISO5 / Reinraumklasse 100 im Handlingbereich und ISO6 / Reinraumklasse 1000 in den Fluren zertifiziert. Die gemessenen Werte sind besser, es wird Reinraumklasse 10 im Handlingbereich und sonst Reinraumklasse 100 erreicht.

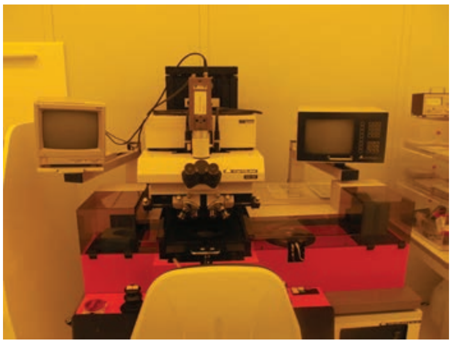
Allgemein: Temperatur: 22 °C +- 2, Luftfeuchtigkeit 40...60 %

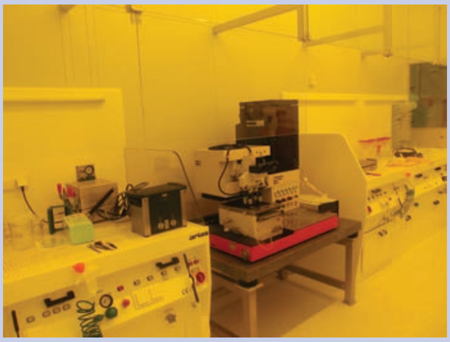
Fotolithografie Elementhalbleiter (Silizium/Germanium)

Hier: Temperatur: 22 °C +- 1, Luftfeuchtigkeit 40 +- 5 %
- UV Kontakt- und Proximity-Belichter für runde Wafer (Silizium und Germanium) bis 100 mm Durchmesser. Maskengröße 150*150 mm^2 quadratisch, minimale Linienbreite 900 nm (SÜSS MA 150)
- UV Handbelichter für Bruchstücke und kleine Wafer
- Lackschleuder mit Heizplatte für runde Wafer bis 200 mm Durchmesser. Ausheizen bis 200°C (SÜSS DELTA 80/8)
- Trockenofen zur Bedampfung von Haftvermittlern
- Nassbänke für die Entwicklung und die Lackentfernung im Ultraschall
- Kühlschränke für Lackchemie
- Plasma-Asher für runde Wafer bis 100 mm Durchmesser, zur Beseitigung von Fotolackresten im O2-Plasma (TEPLA 100)



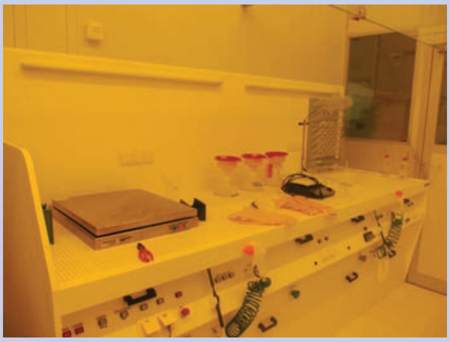


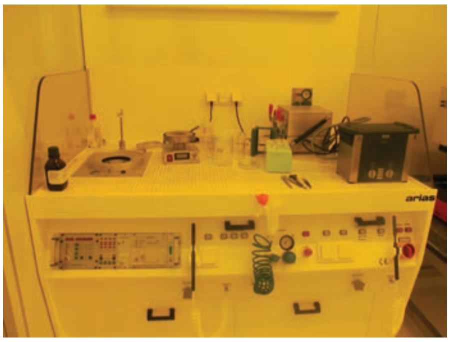


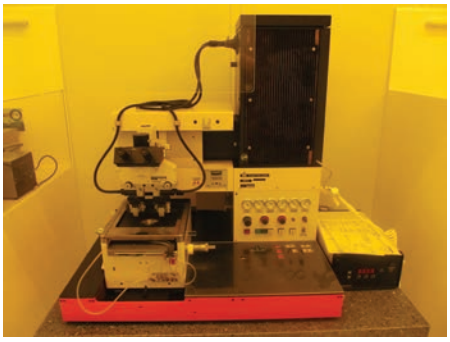


Fotolithografie Verbindungshalbleiter

Hier: Temperatur: 22 °C +- 1, Luftfeuchtigkeit 40 +- 5 %
- UV Kontakt- und Proximity-Belichter für runde Wafer (Verbindungshalbleiter) bis 100 mm Durchmesser. Maskengröße 150*150 mm^2 quadratisch, minimale Linienbreite 700 nm (SÜSS MA6)
- Lackschleuder mit Heizplatte für runde Wafer bis 100 mm Durchmesser. Ausheizen bis 200°C
- Nassbänke für die Entwicklung und die Lackentfernung





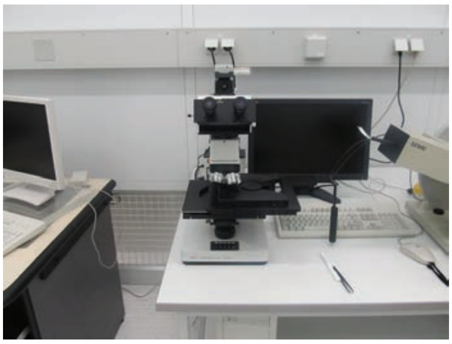


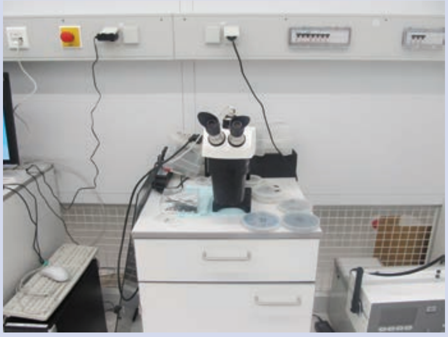
Nassbänke

Nassbänke für die nasschemische Strukturierung und Reinigung von runden Wafern bis 200 mm Durchmesser (auch Solar)

- RCA-Reinigung (SC1, SC2, HF-Dip)
- Quick-Dump-Rinser
- Spin-Rinser-Dryer
- Nasschemische Ätzprozesse allgemein

Lichtmikroskope





Spektrales Ellipsometer

Spektrales Ellipsometer für runde Wafer bis 200 mm Durchmesser (auch Solar), 250-800 nm Wellenlänge, Stage für automatisiertes Mapping der Oberfläche (SENTECH SE 800)

Konfokalmikroskop

Konfokalmikroskop mit Mirau Interferometer, bis 1500-fache Vergrößerung, Höhenauflösung bis 1 nm (LEICA DCM 3D)

Plasma Asher

Plasma Asher TePla 100

Schnellheizöfen

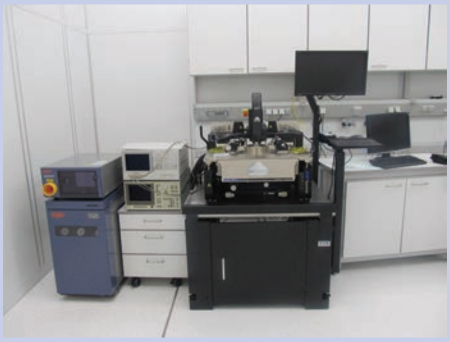
Schnellheizöfen bei Normaldruck, für runde Wafer bis 150 mm Durchmesser, auch Solar, Temperung bis 1100°C unter Ar, O2, N2 oder N2H2. (AST SHS 2000 und Eigenbau)

Polyimid-Ofen

Bis 100 mm Durchmesser, Tempern unter Ar, N2 oder im Feinvakuum, bis 950°C, rezeptgesteuert.

Reaktives Ionenätzen (RIE)

Reaktives Ionenätzen für runde Wafer bis 100 mm Durchmesser, ätzen unter Ar, O2, SF6 und CHF3 (ALCATEL RIE)



Wafer-Probe Station

Wafer-Probe Station für runde Wafer bis 200 mm Durchmesser (auch Solar), -65°C bis +200°C Probentemperatur, digitales Kamerasystem, 4 Messnadeln (CASCADE SUMMIT 11000). Mit Impedance Analyzer (Agilent 4294A) und Semiconductor Parameter Analyzer (HP 4155).

Plasma-CVD

Plasma-CVD für runde Wafer bis 100 mm Durchmesser, Herstellung von Oxiden, Nitriden, Poly und Germanium, Substrattemperatur bis 400°C (OXFORD PLASMALAB 90)

Kathodenzerstäubungsanlage

Kathodenzerstäubungsanlage für runde Wafer bis 200 mm Durchmesser, Gleich- und Wechselspannung, Co-Sputtern von zwei Targets möglich, Plasmaätzen, Magnetron-Anlage (LEYBOLD Z590)

Aufdampfanlage

Aufdampfanlage für Runde Wafer bis 100 mm Durchmesser, 4-fach Tiegel und Einzeltiegel, Co-Verdampfen (BALZERS BAK 610)

Ionenimplantation

Ionenimplanter für runde Wafer bis 300 mm Durchmesser, auch Solar, As, P, B, 5-60 keV (VARIAN VIISta HC)

Vertikalofensystem

Vertikalofensystem Verticoo 200 von Centrotherm, Oxidationsrohr, vertikal, Oxidation trocken und feucht, Feuchtoxidation mit Steamer (Wasserdampf aus DI-Wasser) oder Hydrox-Brenner (Wasserdampf aus H_2 und O_2 verbrannt). Scheibengröße 150 und 200 mm, mit Adaptern auch 100 mm und „Stückchen“, Vollhandlingsystem, aber auch manuell bedienbar. Alle Oxidationsrohre haben einen DCE-Bubbler eingebaut.

Die Anlage ist im Rahmen einer Kooperation mit Fa. Centrotherm im LNQE-Forschungsbau aufgestellt.

Horizontalofensystem Oxidation und LPCVD

Horizontalofensystem Centrotherm „Europa 2000“ mit LPCVD mit folgender Bestückung der Anlage:

- Oben: SiC-Rohr bis 1285 °C, Oxidation trocken und feucht, Feuchtoxidation mit Steamer (Wasserdampf aus DI-Wasser) oder Hydrox-Brenner (Wasserdampf aus H_2 und O_2 verbrannt).
- Darunter: Polysilizium-Rohr, dotiert und undotiert, amorph und polykristallin, n und p mittels Phosphin und Diboran sowie mit Sauerstoff dotiert als SIPOS.
- Darunter: Nitrid-Rohr, stöchiometrisch (Si_3N_4) und Si-reiches Nitrid mit niedrigen Verspannungen d.h. „low-stress-nitride“ herstellbar (kompressiver und tensiler Schichtstress).
- Darunter: LPCVD-TEOS-Rohr, Tieftemperatur-Oxide, momentan noch ohne Plasma-Unterstützung, Temperaturen ab 450°C.

Alle Rohre für 200 mm ausgelegt, Einsatzboote für rechteckige Solarwafer, runde 150 und 100 mm sowie 2“ und 3“ vorhanden. Alle Oxidationsrohre haben einen DCE-Bubbler eingebaut, um eine hochtemperatur-Reinigung mit Chlor zu ermöglichen. Damit erreicht man eine gute Metallionenfreiheit.

Die Anlage ist im Rahmen einer Kooperation mit Fa. Centrotherm im LNQE-Forschungsbau aufgestellt.

III-V Compact 21 MBE System

Ultrahochvakuum (10^{-11} Torr) Molekularstrahlepitaxie Anlage von RIBER zum Wachsen von hoch qualitativen Galliumarsenid basierten III-V Verbindungshalbleiter Schichtsystemen.
Verfügbare Materialien: Ga, As, Al, In
Dotierstoff: Si (n-Typ)

Gerät vom Exzellenzcluster QUEST

Transmissionselektronenmikroskop (TEM)

Das neue TEM im LNQE hat eine Beschleunigungsspannung von 200 kV und als Elektronenemitter eine Feldeffektkathode. Wichtigste Paramater sind:

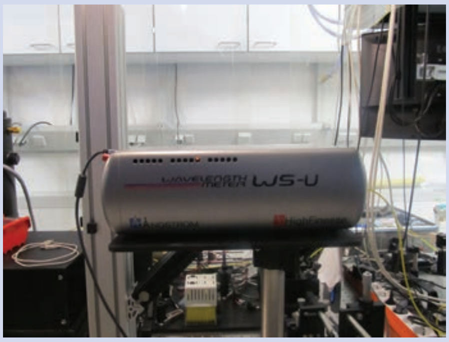
- Gerätetyp: TEM Tecnai G2 F20 TMP von Fa. FEI
- 200 kV Feldeffekt FEG
- Ölfreies Vakuum
- TEM point resolution: 0,27 nm
- Information limit: 0,14 nm (gemessen!)
- STEM resolution: 0,24 nm
- 1 Hellfeld- und 2 Dunkelfeld-Detektoren +1 HAADF-Detektor
- Tomografie +- 70°

Ionendünnung zur TEM-Probenpräparation

Präzisions-Ionen-Polier-System PIPS von Fa. Gatan für kleine Beschusswinkel variabel zwischen 0° und ±10° zur einseitigen und doppelseitigen Ionenstrahldünnung mit:

- LowEnergy Penning-Ionenquellen 0,1 – 6,0 kV
- Dual Beam Modulation zur Sektoren-Querschnittspräparation Probenschleuse
- Probenhaltern für ein- und doppelseitige Dünnung
- Ölfreiem Vakuumsystem
- Zoom-TV-Kamerasystem (400x bis 2600x)
- Cold Stage

Wellenlängemessgerät



Wavelength meter HF-ANGSTROM WS/U-2 von TOPTICA Photonics, 350-1120 nm, mit Multichannel Option und Laser Control Option.

4-Spitzen STM/SEM

Nanotechnologie-Großgerät 4-Spitzen STM/SEM von Fa. Omicron, das die Vorteile eines Rasterelektronenmikroskops (SEM) mit denen eines Rastertunnelmikroskops (STM) verknüpft und durch Aufsetzen der Spitzen auf Nanostrukturen elektrische 4-Punkt-Messungen im Ultrahochvakuum erlaubt

Gerät vom Institut für Festkörperphysik, Abteilung Atomare und Molekulare Strukturen

Studiengang Nanotechnologie
Study Course Nanotechnology

Durch das LNQE initiiert, bietet die Leibniz Universität Hannover den interdisziplinären Bachelorstudiengang Nanotechnologie an, seit dem Wintersemester 2011/2012 auch als Masterstudiengang. Der Studiengang Nanotechnologie vermittelt die Grundlagen in den Kernfächern Chemie, Elektrotechnik, Maschinenbau und Physik (ergänzt durch Mathematik), wobei den Erfordernissen, die aus der Nanotechnologie erwachsen, im Besonderen Rechnung getragen wird.

Initiated by the LNQE, Leibniz Universität Hannover provides the interdisciplinary Bachelor study course nanotechnology and also as a master's degree since the winter semester 2011/2012. The study course nanotechnology teaches the basics in the core subjects of chemistry, electrical engineering, mechanical engineering and physics (supplemented by mathematics), while the realization, arising from nanotechnology, considered in particulaly.

Erstsemesterbegrüßung der Nanotechnologen 2015.
Welcome of the first semester nanotechnology students 2015.

Bachelorstudiengang
Bachelor‘s degree

Struktur des Studienganges

Die Regelstudienzeit des Bachelorstudiengangs Nanotechnologie beträgt sechs Semester. Die Ausbildung setzt sich zum einem aus Vorlesungen und Übungen zusammen. Darin werden Grundlagen und vertiefende Kenntnisse aus verschiedenen Studienschwerpunkten gelehrt. Darüber hinaus werden Tutorien angeboten, die dem Erwerb von Schlüsselkompetenzen dienen. Zum anderen erfolgt die praktische Ausbildung durch Laborpraktika, durch insgesamt 12 Wochen berufspraktische Tätigkeiten und Fachexkursionen sowie der Bachelorarbeit als Abschlussarbeit. Insgesamt sind 180 Leistungspunkte (LP) zu erreichen.

Grundlagenstudium

Der Bachelorstudiengang gliedert sich ein Grundlagenstudium und in ein Vertiefungsstudium. In den ersten drei Semestern des Grundlagenstudiums werden technische, mathematische und naturwissenschaftliche Kenntnisse vermittelt. Das Grundlagenstudium gliedert sich dabei in folgende Kompetenzfelder: Allgemein, Chemie, Elektrotechnik und Informatik, Maschinenbau, Mathematik, und Physik. Die Kurse der ersten drei Semester sind festgelegt.

Structure of the Study Course

The standard period of study of the bachelor program nanotechnology is six semesters. The training is comprised of lectures and exercises on the one hand. Basisc ideas and indeph knowledge from different major fields od study are taught. In addition, tutoring is offered to the acquisition of key competencies. On the other hand, the practical training occurs by lab courses, by a total of 12 weeks of practical training activities and study tours, and a bachelor thesis as complementary work. A total of 180 credit points (CP) is to be achieved.

Basis Study

The bachelor‘s degree is divided into a basic study and a deeper study. In the first three semesters of study are studied the basis of technical, scientific and mathematical skills. The basic study is divided into the following knowledge: general, chemistry, electrical engineering and computer science, mechanical engineering, mathematics, and physics. The courses of the first three semesters are determined.

Grundlagenkurse/*Basic Courses*	109 LP/*CP*
Vorlesungen und Labore des Vertiefungsstudiums *Lectures and laboratory studies of the deepening study*	32 LP/*CP*
Schlüsselkompetenzen/*Key Competencies*	11 LP/*CP*
Fachpraktikum (12 Wochen)/*Internship (12 weeks)*	15 LP/*CP*
Fachexkursionen (3 Tage)/*Study Tours (3 days)*	1 LP/*CP*
Bachelorarbeit (300 Stunden)/*Bachelor Thesis (300 hours)*	12 LP/*CP*
Summe/*Sum:*	**180 LP/*CP***

Übersicht über zu erbringende Leistungen im Bachelorstudium.
Overview of achievements to be proved in the bachelor's degree

Vertiefungsstudium

Im Vertiefungsstudium erfolgt eine fachliche Spezialisierung der erlernten Grundlagen in zwei von den Kompetenzfeldern Chemie, Elektrotechnik und Informatik, Maschinenbau und Physik, d. h. die Studierenden wählen sich zwei Kompetenzfelder nach ihren Wünschen aus und gestalten so ihren Stundenplan. Zusätzlich erfolgt eine weitere Spezialisierung durch die Belegung eines Wahl-Kompetenzfeldes aus dem Masterprogramm. Das Vertiefungsstudium beinhaltet darüber hinaus ein Praktikum, Fachexkursionen, die Studienarbeit und die Bachelorarbeit im 6. Semester.

Schlüsselkompetenzen

Das Modul Schlüsselkompetenzen besteht aus einem Seminar zur Nanotechnologie und einer Reihe von Vorlesungen, aus denen frei gewählt werden kann (z. B. Kurse für Schlüsselkompetenzen, Projektmanagement, Recht, Firmengründungskurse etc.).

Fachexkursionen

Fachexkursionen zu Firmen, Forschungseinrichtungen oder Fachmessen in einem Umfang von drei Tagen.

Deepening Study

In the deepening study a specialization of the learned basics is carried out in two of the competence areas chemistry, electrical engineering and computer science, mechanical engineering and physics, that is the students choose two areas of expertise in accordance with their wishes, and create their timetable. In addition, a further specialization by the choice of a selectable area of expertise from the master program occurs. The deepening study also includes an internship, study tours, study thesis and the Bachelor thesis in the 6th Semester.

Key Competences

The module key competences consists of a seminar on nanotechnology and a series of lectures, from which can be chosen freely (eg courses for key skills, project management, law, company formation courses, etc.).

Study Tours

Excursions to companies, research institutions or trade fairs in a range of three days.

Leibniz Universität Hannover

Kurs- und Modulkatalog Nanotechnologie Studienjahr 2013/14

Kurs- und Modulkatalog

Studienführer für den Studiengang Nanotechnologie mit den Abschlüssen

Bachelor of Science
Master of Science

Studienjahr 2013/14 - PO 2013

Kurs- und Modulkatalog Nanotechnologie.
Course and module catalog nanotechnology.

Nanotechnologie studieren in Hannover

Website zum Studiengang: www.lnqe.uni-hannover.de/study_nano.html
Website of the study course: www.lnqe.uni-hannover.de/study_nano.html

Kompetenzfeld: Allgemein (4 LP)/*Area of Expertise: General (4 CP)*
Einführung in die Nanotechnologie/*Introduction to nanotechnology*
Kompetenzfeld: Chemie (16 LP)/*Area of Expertise: Chemistry (16 CP)*
Einführung in die Allgemeine und Anorganische Chemie /*Introduction to general and inorganic chemistry*
Physikalische Chemie I/*Physical chemistry I*
Kompetenzfeld: Elektrotechnik und Informatik (21 LP) *Area of Expertise: Electrical Engineering and Computer Science(21 CP)*
Grundlagen der Elektrotechnik I/*Fundamentals of electrical engineering I*
Grundlagen der Elektrotechnik II/*Fundamentals of electrical engineering II*
Grundpraktikum Elektrotechnik/*Basic lab course electrical engineering*
Informationstechnisches Praktikum/*Information technology practical*
Kompetenzfeld: Maschinenbau (16 LP) *Area of Expertise: Mechanical Engineering (16 CP)*
Mikro- und Nanotechnologie/*Micro and nanotechnology*
Technische Mechanik I für Maschinenbau/*Applied mechanics I for mechanical engineering*
Technische Mechanik II für Maschinenbau/*Applied mechanics II for mechanical engineering*
Kompetenzfeld: Mathematik (26 LP) *Area of Expertise: Mathematics (26 CP)*
Mathematik für Ingenieure I/*Mathematics for engineers I*
Mathematik für Ingenieure II/*Mathematics for engineers II*
Mathematik für Ingenieure III/*Mathematics for engineers III*
Mathematik für Ingenieure IV/*Mathematics for engineers IV*
Kompetenzfeld: Physik (26 LP)/*Competence Area: Physics (26 CP)*
Physik I – Mechanik und Relativität /*Physics I - Mechanics and relativity*
Physik II - Elektrizität/*Physics II - Electricity*
Physik III - Optik, Atomphysik, Quantenphänomene/*Physics III - Optics, atom physics, quantum phenomena*
Grundpraktikum Physik/*Basic lab Course physics*

Kurse im Grundlagenstudium/*Courses of the basic study*

Fachpraktikum

Ein berufsbezogenes Fachpraktikum bildet einen wesentlichen Bestandteil des Studiums. Das 12 wöchige Fachpraktikum dient dem Erwerb von Erfahrungen in typischen Aufgabenfeldern und Tätigkeitsbereichen von Absolventen und Absolventinnen in der beruflichen Praxis. Die Studierenden sollen Erfahrungen in der Anwendung ihrer im Studium erworbenen Kenntnisse und Fertigkeiten sammeln. Das Fachpraktikum ist daher durch die Eingliederung der Praktikanten und Praktikantinnen in ein Arbeitsumfeld von Ingenieuren oder entsprechend qualifizierten Personen mit überwiegend entwickelndem, planendem oder lenkendem Tätigkeitscharakter gekennzeichnet. Detaillierte Informationen zum Praktikum liefert die Praktikantenordnung.

Internship

An occupational internship is an essential part of the course. The 12 week co-op program serves the acquisition of experience in typical job fields and fields of activity of graduates in professional practice. The students will get experience in the application of their studies in the acquired knowledge and skills. The practical training is therefore characterized by the integration of the trainees in a work environment for engineers or suitably qualified persons with predominantly evolving, planning or leadership character. Detailed information about the internship is given in the intership regulations.

Kompetenzfeld: Chemie (16 LP)/ *Area of Expertise: Chemistry (16 CP)*
Instrumentelle Methoden I/*Instrumental methods I*
Anorganische Chemie I/*Inorganic chemistry I*
Technische Chemie I/*Technical chemistry I*
Kompetenzfeld: Elektrotechnik und Informatik (16LP) *Area of Expertise: Electrical Engineering and Computer Science(16 CP)*
Grundlagen der Materialwissenschaften/*Basics of materials science*
Regelungstechnik I/*Automatic control technique I*
Grundlagen der Halbleiterbauelemente/*Basics of semiconductor devices*
Sensorik und Nanosensoren/*Sensor technology and nanosensors*
Kompetenzfeld: Maschinenbau (16 LP) *Area of Expertise: Mechanical Engineering (16 CP)*
Regelungstechnik I/*Automatic control technique I*
Mikro- und Nanosysteme/*Micro and nano systems*
Werkstoffkunde/*Material science*
Kompetenzfeld: Physik (16 LP)/*Area of Expertise: Physics (16 CP)*
Einführung in die Festkörperphysik/*Introduction to solid state physics*
Elektronik und Messtechnik/*Electronics and measurement technology*
Schlüsselkompetenzen (11 LP) *Key Competences (11 CP)*
Nanotechnologie-Seminar + weitere, wählbare Kurse zu Schlüsselkompetenzen/*Nanotechnology seminar + more selectable courses in key competences*

Kurse im Vertiefungsstudium/*Courses of the deepening study*

Bachelorarbeit

Den Abschluss des Studiums bildet die Bachelorarbeit mit einer Gesamtdauer von drei Monaten. Die Bachelorarbeit soll zeigen, dass der Prüfling in der Lage ist, innerhalb einer vorgegebenen Frist ein Problem selbstständig nach wissenschaftlichen Methoden zu bearbeiten. Die Art der Aufgabe und die Aufgabenstellung müssen mit der Ausgabe des Themas festliegen. Die Bachelorarbeit muss von zwei Prüfern bewertet werden. Sie kann in der Form einer Gruppenarbeit angefertigt werden. Der als Prüfungsleistung zu bewertende Beitrag des einzelnen Prüflings muss aufgrund der Angabe von Abschnitten, Seitenzahlen oder anderer objektiver Kriterien deutlich abgrenzbar und für sich zu bewerten sein. Nähere Informationen zur Bachelorarbeit sind der Prüfungsordnung zum Studiengang „Nanotechnologie“ zu entnehmen.

Bachelor Thesis

The completion of the course is the bachelor thesis, with a total duration of three months. The bachelor thesis is to show that the student is in a position to solve a problem alone within a specified time according to scientific methods. The type of the task and the task must be determined with the issue of the topic. The bachelor thesis must be evaluated by two reviewers. It may be made in the form of a working group. The performance audit assessed contribution of each candidate must be a result of the indication of the sections, page numbers or other objective criteria clearly identifiable and are to be valued. Further information on the bachelor thesis can be taken from the examination rules of the study course „nanotechnology“.

Masterstudiengang

Master‘s degree

Der Studiengang Nanotechnologie hat eine sehr engagierte Studierendenschaft. Es finden regelmäßig treffen des Fachrates im LNQE-Forschungsbau statt. *The degree program nanotechnology has a very dedicated student body. It holds regular meeting of student council in LNQE research building.*

Der akkreditierte Masterstudiengang Nanotechnologie ist als Weiterführung des Bachelorstudiengangs Nanotechnologie konzipiert. Neben den Bachelorabsolventinnen und -absolventen der Nanotechnologie steht er aber auch den Studienrichtungen Maschinenbau, Elektrotechnik, Chemie und Physik offen. Die Regelstudiendauer beträgt vier Semester, wovon ein Semester auf die Masterarbeit entfällt. Insgesamt sind 120 Leistungspunkte (LP) zu erreichen.

Grundlagenkurse

Die Grundlagenkurse des Pflicht-Kompetentfeldes sind von allen Studierenden zu besuchen und vermitteln wichtige Kenntnisse aus den Methoden der Nanotechnologie.

Wahlkompetenzfelder

Neben den Grundlagenkursen sind von den Studierenden drei der angebotenen Wahlkompetenzfelder als Vertiefungsfächer zu wählen:

- Chemie
- Chemie der Nanowerkstoffe
- Lasertechnik/Photonik
- Materialphysik
- Mikro- und Nanoelektronik
- Mikroproduktionstechnik
- Biomedizintechnik

Wahlbereich

Im Wahlbereich können Veranstaltungen aus einer Liste von Fachkursen gewählt werden.

The accredited master study course nanotechnology is designed as continuation of the bachelor course nanotechnology. In addition to the bachelor’s graduates in nanotechnology, he is also open to the study of mechanical engineering, electrical engineering, chemistry and physics. The standard course duration is four semesters with one semester for the Master’s thesis. A total of 120 credit points (CP) must be reached.

Basisc Courses

The basic courses of the mandatory area of expertise have to be attended by all students and provide important skills on the methods of nanotechnology.

Selectable Areas of Expertise

Besides the foundation courses three of the competence areas of choice are to be chosen as majors by the students:

- *Chemistry*
- *Chemistry of nanomaterials*
- *Laser technology / photonics*
- *Materials physics*
- *Micro and nanoelectronics*
- *Micro production technology*
- *Biomedical engineering*

Courses of Choice

In elective courses from a list of professional courses can be selected.

Pflicht-Kompetenzfeld „Methoden der Nanotechnologie“/*Mandatory Area of Expertise “Methods of Nanotechnology”*	13 LP/*CP*
3 Wahlkompetenzfelder/*3 Selectable Areas of Expertise*	35-39 LP/*CP*
Wahlbereich/*Courses of Choice*	20-24 LP/*CP*
3 Labore 360 Stunden/ *3 Lab Courses 360 hours*	12 LP/*CP*
Studium Generale/*General Studies*	6 LP/*CP*
Masterarbeit 6 Monate/*Master Thesis 6 month*	30 LP/*CP*
Summe/*Sum:*	**120 LP/*CP***

Übersicht über zu erbringende Leistungen im Masterstudium.
Overview of achievements to be proved in the master’s degree

Labore

Im Rahmen des Studiums müssen die Studierenden drei verschiedene Labore absolvieren. Als Labore sind ein Halbleitertechnologie-Labor, ein Laborpraktikum Festkörperphysik sowie ein Mikrotechnik-Labor vorgesehen.

Studium Generale

Für das Studium Generale besteht die Wahlfreiheit aus dem gesamten Angebot der Universität.

Masterarbeit

Den Abschluss des Studiums bildet die Masterarbeit mit einer Gesamtdauer von sechs Monaten.

Lab courses

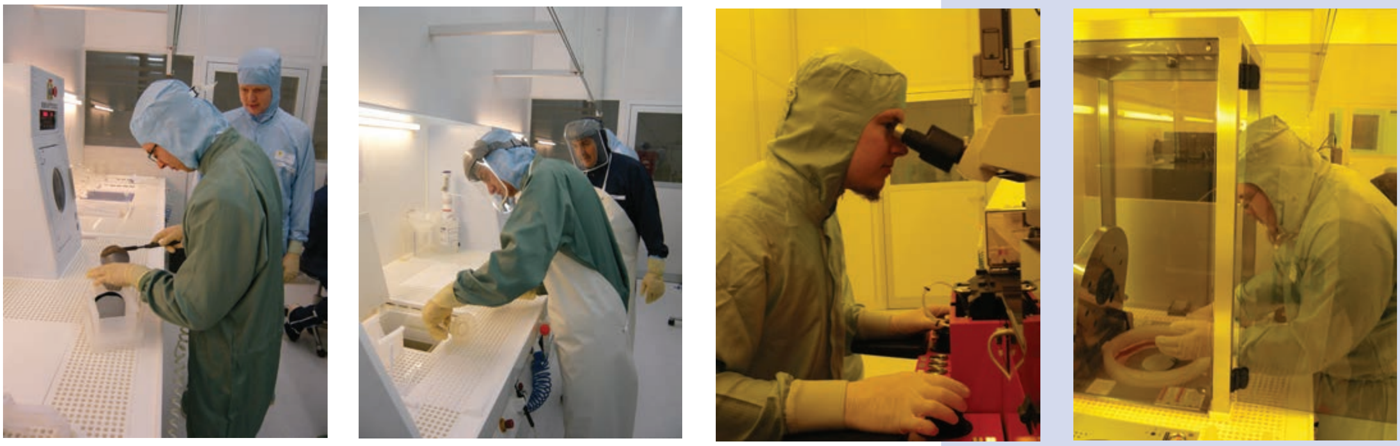
As part of the study course, students must complete three different lab courses. A semiconductor technology lab course, a solid-state physics lab course and a microtechnology lab course are provided.

General Studies

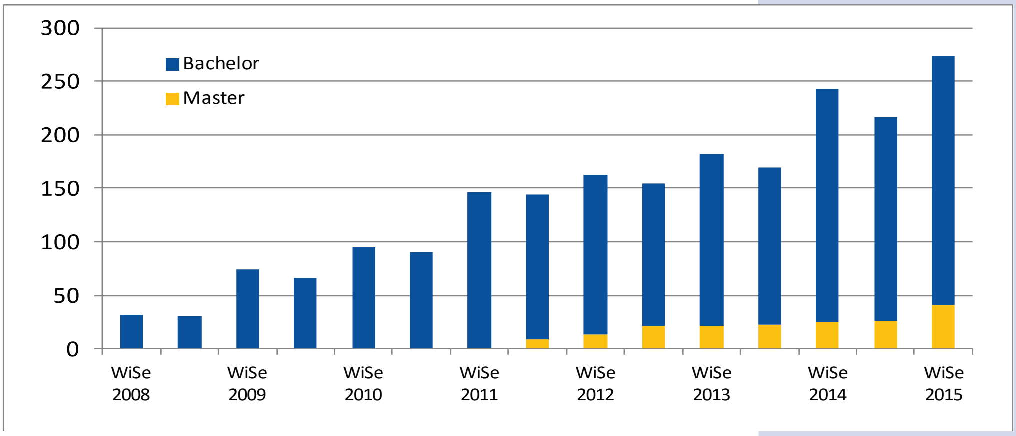
For General Studies there is freedom of choice from the full range of the university.

Master Thesis

The completion of the study course is the Master's thesis with a total duration of six months.



Halbleiter-Labor im Nanotechnologie-Studium. Im Reinraum werden in Kleingruppen von 3-4 Personen MOS-Strukturen und pn-Dioden hergestellt und später charakterisiert.
Semiconductor lab cours in the nanotechnology study course. In the clean room MOS structures and p-n diodes are fabricated and characterized later in small groups of 3-4 people.



Gesamtzahl der Studierenden der Nanotechnologie an der Leibniz Universität Hannover im Bachelor (Blau) und Master (Orange).
Total number of students in nanotechnology at the Leibniz Universität Hannover in the Bachelor (Blue) and Master (Orange).

Promotionsprogramm/*PhD-Program* *“Hannover School for Nanotechnology”*

Die hsn wurde in einer gemeinsamen Festveranstaltung zusammen mit dem Programm MARIO am 11.10.2013 feierlich im LNQE-Forschungsbau eröffnet.
The hsn has been opened in a joint ceremony together with the program MARIO on 11/10/2013 solemnly in LNQE Research Building.

Das Niedersächsische Ministerium für Wissenschaft und Kultur (MWK) hat die „Hannover School for Nanotechnology“ (hsn) als Niedersächsisches Promotionsprogramm mit Partnern aus dem Forschungszentrum Laboratorium für Nano- und Quantenengineering der Leibniz Universität Hannover und aus der Hochschule Hannover bewilligt. Die Förderung umfasst fünfzehn Stipendien und Mittel für Sach- und Reisekosten der Stipendiatinnen und Stipendiaten, die gesamte Fördersumme beträgt 1.000.000,- Euro für einen Zeitraum von vier Jahren. Das Programm läuft von 01.10.2012 bis 30.09.2016.

Die Nanotechnologie gilt als eine der aussichtsreichsten Schlüsseltechnologien, die zur Lösung vieler Probleme der Menschheit beitragen kann. Eine der wichtigsten Fragen der heutigen Zeit ist hierbei den immer weiter steigenden Energiebedarf bei zu Ende gehenden Ressourcen zu decken und gleichzeitig die Umwelt zu schonen. Die Wandlung, der Transport und die Speicherung von Energie sind grundlegende Fragen für die Zukunft unserer Gesellschaft. Das Gebiet der Nanotechnologie kann hier wichtige Beiträge leisten, durch verbessertes Grundlagenverständnis, durch neue Anwendungen und marktfähige Produkte. Energieprozesse müssen auf der Nanoskala verstanden werden. Mit Nanomaterialien und durch Nanoengineering werden diese verbessert werden und revolutionär neue Wege zur Energiewandlung, Energiespeicherung oder Energietransport gefunden werden.

Die Nanotechnologie ist eine sehr interdisziplinäre Wissenschaft, sie verlangt Kenntnisse in Chemie, Physik, Elektrotechnik und Maschinenbau. Die Hannover School for Nanotechnology führt die interdisziplinäre Ausbildung der Bachelor- und Masterstudiengänge „Nanotechnologie“ der Leibniz Universität Hannover konsequent auf die Doktorandenebene fort.

The Lower Saxony Ministry for Science and Culture (MWK) has granted the “Hannover School for Nanotechnology” (hsn) as a Lower Saxony doctoral program with partners from the research center Laboratory of Nano and Quantum Engineering from the Leibniz Universität Hannover and from the University of Applied Sciences and Arts in Hannover. The funding includes fifteen scholarships and funding for equipment and travel costs of the schoolarship students, the total grant amounts to 1.000.000, - EUR for a period of four years. The program runs from 01.10.2012 to 09.30.2016.

Nanotechnology is regarded as one of the most promising key technologies that can contribute to the solution of many problems of humanity. One of the most important question of our time is here to meet the ever-increasing energy demand with on the other hand ending resources and to protect the environment at the same time. The conversion, transport and storage of energy are fundamental issues for the future of our society. The field of nanotechnology can here make important contributions through improved fundamental understanding, through new applications and marketable products. Energy processes must be understood at the nanoscale. With nanomaterials and nanoengineering this will be improved and revolutionary new ways for energy conversion, energy storage and energy transport will are found.

Nanotechnology is a very interdisciplinary science; it requires knowledge of chemistry, physics, electrical engineering and mechanical engineering. The Hanover School for Nanotechnology leads the interdisciplinary training of bachelor and master programs “Nanotechnology” at the Leibniz Universität Hannover consistently to doctorate level.

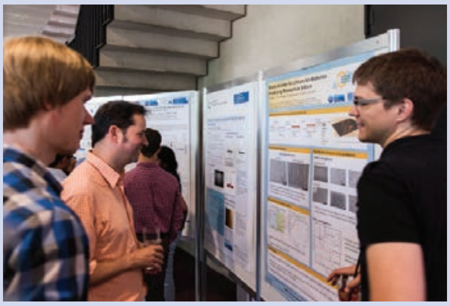
Die hsn richtet sich gezielt an exzellente junge Studierende aus der ganzen Welt, um diese bestmöglich auf dem Gebiet der Nanotechnologie auszubilden. Ein wichtiges Ziel ist, eine möglichst kurze Promotionsdauer auch für internationale Studierende zu erreichen und gleichzeitig Spitzenforschungsresultate zu erzielen. Das Programm hat flexible Einstiegszeitpunkte: direkt nach dem Bachelor-Abschluss, während der Masterzeit oder mit Master-Abschluss, um so exzellente Studierende auf allen Stufen aufnehmen zu können.

Neben dem eigentlichen Promotionsthema wird den Stipendiatinnen und Stipendiaten ein maßgeschneidertes Lehrangebot geboten. Dies beinhaltet Nanotechnologie-Kurse, Seminare, Kolloquien, Kurse zur Förderung von persönlichen Fähigkeiten, und insbesondere spezielle Veranstaltungen, die einen verantwortungsvollen Umgang mit Nanotechnologie lehren. Ein besonderer Schwerpunkt von hsn ist darüber hinaus die Förderung von jungen Wissenschaftlerinnen. Für die besten Stipendiatinnen und Stipendiaten bietet die hsn nach einer Evaluation eine Fast-Track Option an, mit der die Förderung mit einem Stipendium bereits während der Masterzeit beginnt. Es wird dann der Masterabschluss erworben und nach zwei Jahren dann mit Promotion abgeschlossen.

Die hsn vereint Partner aus dem LNQE und der Hochschule Hannover (HsH). Hierdurch wird es möglich, auch exzellenten Absolventen der HsH den Zugang zur Promotion zu ermöglichen. Die Betreuung der Doktorandinnen und Doktoranden wird gemeinschaftlich durch Partner aus der Leibniz Universität Hannover und der Hochschule Hannover übernommen. Die im LNQE gewonnen Grundlagenerkenntnisse werden durch die Partner in der HsH in Anwendungen überführt. Darüber hinaus kann die hsn auf ein exzellentes Netzwerk sowohl regionaler als auch internationaler Kooperationspartner zugreifen.

The hsn is aimed at outstanding young students from around the world to train them in the best possible in the field of nanotechnology. An important goal is also for international students to achieve the shortest possible time to doctorate while achieving cutting-edge research results. The program has flexible entry points in time: immediately after the bachelor's degree, while the master time or with master's degrees to accommodate such excellent students at all levels.

Apart from the actual thesis topic the scholarship holders a customized curriculum is offered. This includes nanotechnology courses, seminars, colloquia, courses to promote personal skills, and in particular, special events that teach the responsible use of nanotechnology. A particular focus of hsn is beyond the promotion of young female scientists. For the best scholars offers the hsn after an evaluation a fast-track option, with the promotion starts with a scholarship during the master time. It is then acquired the master's degree and then completed after two years with a PhD.

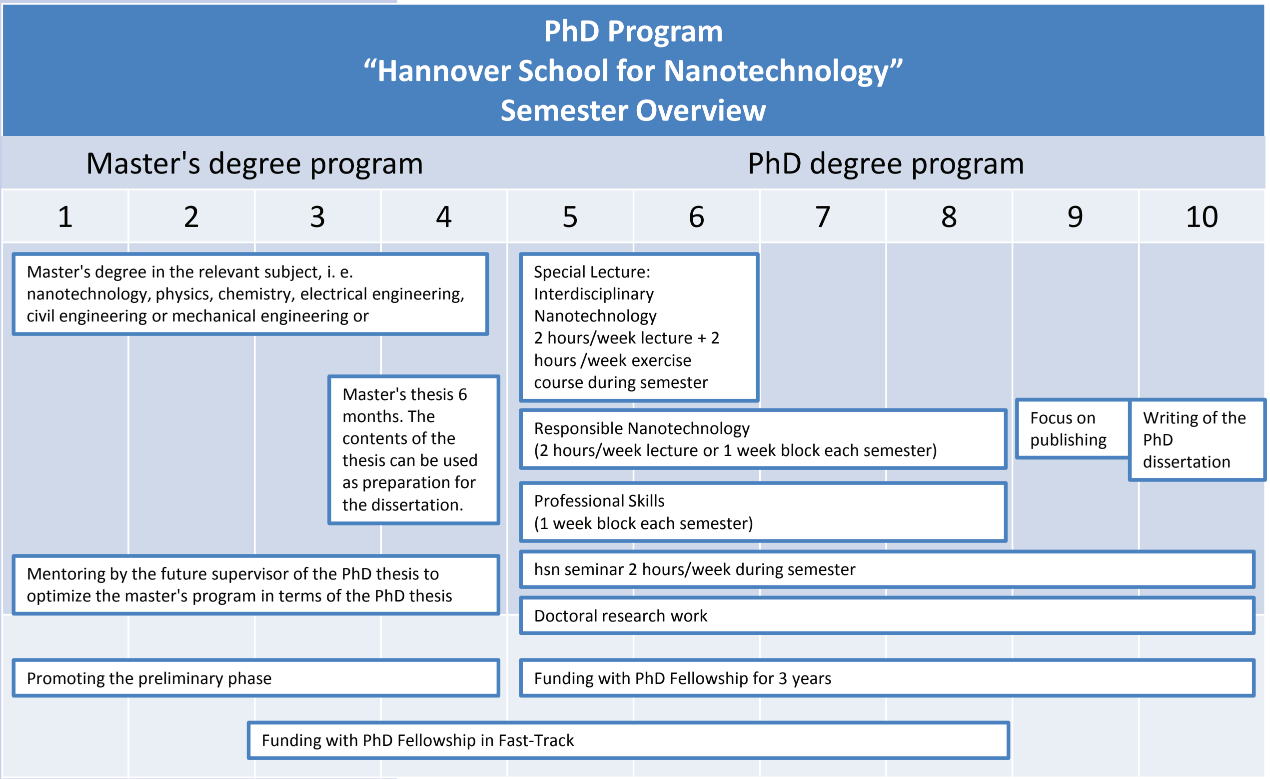


Bei halbjährlichen Statustreffen (hier am 03.07.2015) stellen die Doktorandinnen und Doktoranden den Fortschritt ihrer wissenschaftlichen Arbeiten vor.
In semi-annual status meetings (here on 03.07.2015) the doctoral students present the progress of their scientific work.

Auf die hsn-Stipendien gab es insgesamt 159 Bewerbungen. Die Bewerbungen wurden von einem Auswahlausschuss gesichtet und bewertet. Hier sind wir besonders froh, dass wir Prof. Dr. Stephanus Büttgenbach aus Braunschweig als Mitglied für den Aufnahmeausschuss gewinnen konnten. In einem zweiten Schritt wurden die besten Kandidatinnen und Kandidaten durch Ihre möglichen Erstbetreuer interviewt. Von den 15 Besten, die dann ein Stipendium erhalten haben, stammen sechs aus dem Ausland. Etwa die Hälfte der Stipendien konnte an Wissenschaftlerinnen vergeben werden. Zusätzlich wird das Programm durch weitere exzellente Doktorandinnen und Doktoranden aus den beteiligten Arbeitsgruppen verstärkt.

The hsn brings together partners from the LNQE and the University of Applied Sciences and Arts in Hannover (HsH). This makes it possible to enable excellent graduates of HsH the access to doctoral studies. The supervision of doctoral students is taken jointly by partners from the Leibniz Universität Hannover and the HsH. The in the LNQE won basic findings are converted by the partners from HsH into applications. In addition, the hsn has access to an excellent network of both regional and international cooperation partners.

On the hsn scholarships there were a total of 159 applications. The applications were screened and evaluated by a selection committee. Here we are particularly pleased that we were able to win Prof. Dr. Stephen Büttgenbach from Brunswick as a member of the Admissions Committee. In a second step, the best candidates were interviewed by your potential supervisor. Of the top 15, who received a scholarship, are six from abroad. About half of the scholarships could be awarded to female scientists. The program is also strengthen by other excellent PhD students from the participating research groups.



PhD Program
"Hannover School for Nanotechnology"
Semester Overview

Master's degree program

PhD degree program

1 2 3 4 5 6 7 8 9 10

Master's degree in the relevant subject, i. e. nanotechnology, physics, chemistry, electrical engineering, civil engineering or mechanical engineering or

Special Lecture: Interdisciplinary Nanotechnology 2 hours/week lecture + 2 hours /week exercise course during semester

Master's thesis 6 months. The contents of the thesis can be used as preparation for the dissertation.

Responsible Nanotechnology (2 hours/week lecture or 1 week block each semester)

Focus on publishing

Writing of the PhD dissertation

Professional Skills (1 week block each semester)

Mentoring by the future supervisor of the PhD thesis to optimize the master's program in terms of the PhD thesis

hsn seminar 2 hours/week during semester

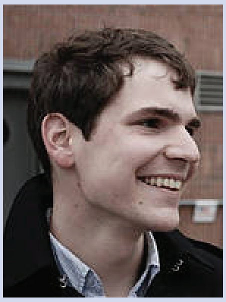
Doctoral research work

Promoting the preliminary phase

Funding with PhD Fellowship for 3 years

Funding with PhD Fellowship in Fast-Track

Hannover School for Nanotechnology: PhD-projects



Tobias Birr

Investigation of surface functionalized nanooptical and plasmonic systems for use as bionanosensors

Supervisor: B. Chichkov
Researcher: T. Birr

In this project, multipole-particle and plasmonic systems will be designed and optimized. Metallic and dielectric films will be structured with different optical lithographic approaches to assemble plasmonic systems. The linear and nonlinear optical properties of multipole-particles embedded in plasmonic systems open new possibilities for fundamental and applied research in ultrafast nanooptics. Their response to optical and surface plasmon-polariton fields will be studied by Fourier-transform microscopy and temporally resolved interferometric leakage radiation microscopy, respectively. Ultrafast switching of optical properties of multipole-particles and particle systems will be studied, using excitation of interband transitions and adiabatic metallization effects induced by ultrashort laser pulses. In plasmonic systems embedded ordered and random hybrid nanostructures with functionalized surfaces can be applied as novel highly sensitive sensor elements. Of special interest is the study of magnetic dipole interactions, providing unique possibilities for novel low-intensity switching elements and for probing magnetic fields at optical frequencies.

Atasi Chatterjee

Chemisorbed single molecules as electronic switches

Supervisor: P. Pfnür, F. Renz
Researcher: A. Chatterjee

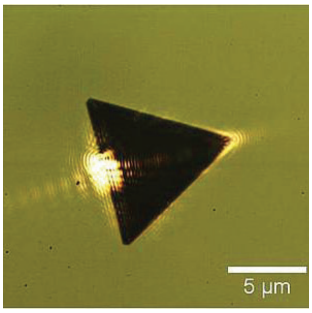
The aim of this project is the direct investigation of the electrical conduction properties of single molecules with extended electronic π-systems, which are chemically bound to metallic contacts. We want to investigate the structure and the adsorption geometry at the atomic scale and finally want to functionalize these molecules and induce switchability by electric fields via the substrate or by additional electrodes. As a starting point we are planning to use silver electrodes and coordination compounds, such as functionalized ferrocene and phenyl substituted molecules (the latter as reference systems). For this purpose laterally open contact structures will be used, which allow direct access to the contact together with the adsorbed molecules. By use of the combination of a 4-probe STM with an SEM all steps like generation and characterization of contacts and molecules at the atomic scale can be carried out in situ, as well as electrical transport measurements. We further plan to vary chemical end groups and temperature in order to study the influence of coupling of the molecule to its environment on transport properties.

Parva Chhantyal

Nanoparticles for Enhanced Photovoltaics, Nanoheating and Sensors

Supervisor: B. Chichkov, C. Reinhardt
Researcher: P. Chhantyal

The main property of metal and semiconductor nanoparticles is their resonant responses as a reaction on external optical fields, concentrating energy inside and around the particles and making them very attractive for different practical applications, e.g. sensor technology, surface-enhanced Raman spectroscopy, and efficiency enhancement in photovoltaic devices. Additionally, Joule heating of plasmonic nanostructures by the induced currents leads to localized heat sources on the nanometer scale, enabling new concepts for nanoscale medicine and chemistry. These topics attract great attention from both experimental and theoretical points of view in the last two years. In this work, metal and semiconductor nanoparticles with adjustable diameters in the range of 40 – 200 nm and periodic nanoparticle structures will be generated by use of femtosecond lasers systems. The nanoparticle structures and their applications for sensing, photovoltaics, and nanoheating will be studied.



Andreas Grimm

Relaxed germanium films on off-oriented silicon wafers as substrates for epitaxial III-V solar cells

Supervisor: T. Wietler, J. Osten
Researcher: A. Grimm

Off-oriented germanium wafers are the common substrates for high-efficiency multi-junction III-V photovoltaic cells for space applications and terrestrial concentrator photovoltaic systems. A miscut of 6° with respect to the [001]-orientation provides a Ge surface formed solely by double atomic steps which is mandatory to avoid anti-phase boundaries in subsequent III-V growth. This project is dedicated to the replacement of Ge wafers with epitaxial Ge films grown on miscut Si wafers. This solution could be cost-efficient because Si wafers are much cheaper than Ge wafers. Further cost reduction potential is at hand due to the larger wafer sizes available for Si. The growth of smooth relaxed Ge films with low defect densities on on-axis Si substrates can be accomplished by controlling the strain relaxation during epitaxy using surfactants. Thus, the application of surfactant-mediated epitaxy to 6° off-oriented Si(001) substrates could provide cheap Ge substrates for epitaxial III-V films.

Lars Heyer

Molecular Switches Based on Iron(II) Coordination Compounds

Supervisor: F. Renz
Researcher: L. Heyer

The aim of this project is the design, development, and investigation of switchable nanoscopic coordination compounds for storage and transformation of energy. The compounds exhibit concerted and sequential electronic molecular switching upon thermal or electro-magnetical excitation. The investigation of the associated conversion and transport of the thermally or optically injected energy is the main focus. A milestone is the synthetical modification of the switchable multinuclear compounds. Such modification is based on electronical or sterical substitutions in the organic framework as well as in the metal centers. The switching of the compounds will be investigated in powder and / or crystalline states.

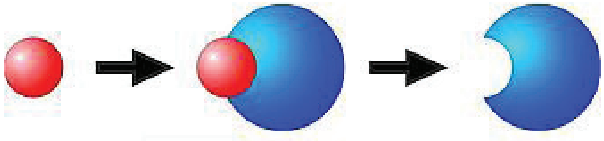
Dominik Hinrichs

Semiconductor nanoparticles with concave morphologies for sensory key-lock applications

Supervisor: D. Dorfs, N. Bigall
Researcher: D. Hinrichs

The properties of nanoparticles are not just influenced by their composition, size and surface functionalization but also by their shape. In general crystals grow in a convex morphology but new synthetic strategies opened access to concave structures. These concave structures show promising features for e. g. sensory key-lock applications.

We want to transfer the so called “cast mold” approach to a variety of materials. In this approach a semiconductor is grown on a nanoparticle e. g. a metal nanoparticle. Afterwards the latter is etched to receive a concave shaped semiconductor nanoparticle. *The so obtained cave can interact size-sensitive with other nanoparticles, which could be exploited for sensory applications.*



Nanocrystalline Electrodes for (Solar) Photoelectrochemical Water Splitting

Supervisor: D. Bahnemann, J. Caro
Researcher: M. Jami

Photoelectrochemical (PEC) Tandem Cells with anodes and cathodes both of which are consisting of suitable semiconducting materials ensuring watersplitting into molecular oxygen and hydrogen, respectively, upon solar illumination are ideally suited for the conversion and storage of solar energy. Employing materials with sufficient abundance such as hematite (iron oxide) and pyrite (iron sulphide) n- and p-doped crystalline nanoparticles with suitable bandgap energies and band positions shall be synthesized employing wet chemical bottom-up methods and bandgap engineering, i.e., utilizing the quantum size effect. Sol/Gel synthesis methods will then be used to prepare the respective photoanodes and -cathodes for the PEC cells. While the overall performance of these cells will be investigated under (simulated) solar illumination, the project will focus on a detailed understanding of the involved individual reaction steps at both photoelectrodes. The latter processes will be studied combining suitable (photo)electrochemical analysis with time-resolved techniques (e.g., laser flash photolysis) and spatially resolved spectroscopic methods (e.g., ATR-FTIR spectroscopy). It is another important target of this project to develop – in close collaboration with other teams of the HSN – suitable models to describe the processes involved thus enabling the development of scale-up PEC assemblies for the anticipated industrial utilization.

Maryam Jami

Preparation and properties of gadolinium oxynitrides

Supervisor: J. Osten, T. Wietler
Researcher: A. Joseph

For the continued scaling of metal oxide semiconductor (MOS) devices to achiev high performance and good integration, ,the thickness of silicon dioxide gate dielectrics must be decreased. As the thickness of gate dielectrics decreases, direct tunneling current increases exponentially,therefore,high-k gate dielectrics have recently received much attention,because tunneling current can be reduced by increasing physical film thickness. On this concept the idea mainly focusses on the preparation and detailed analysis of Gadolinium oxynitrides.

Anit Joseph

Hybrid semiconductor/metal nanoparticles produced by colloid chemistry for photo catalytic conservation of energy

Supervisor: J. Caro, D. Dorfs
Researcher: T. Kodanek

With today’s strong focus on renewable energy sources, also the conversion of e.g. solar energy into chemically bound energy comes into the focus of recent research activities. Very popular examples are e.g. fuel cells as energy conversion units which relay on chemically stored energy in form of hydrogen. This hydrogen could e.g. be produced exploiting solar energy via the photo catalytic splitting of water. In the framework of this project, novel metal semiconductor/metal hybrid nanoparticles shall be synthesized via means of colloid chemistry and their performance for various photocatalytic reactions will be evaluated. Apart from simple (quasi) spherical nanoparticles, also more elaborately shaped nanoparticles like rods and branched nanoparticles shall be synthesized and their photocatalytic performance will be compared to spherical ones. A focus will be put on structure property correlations with specific focus on size and shape of the nanocrystals, their crystal faceting and the character of the metal/semiconductor interface.

Torben Kodanek

Imme Kretschmer

Photocatalytic watersplitting at hematite nanostructures

Supervisor: D. Bahnemann
Researcher: I. Kretschmer

Hematite (α-Fe_2O_3) is discussed to be a promising material for the fabrication of photoanodes for the oxygen evolution from water in photoelectrochemical (PEC) cells. To overcome inherent limitations of this material nanostructuring has been proposed. Thus, the optimization of the morphology of hematite photoanodes is the ultimate goal of this project. Hematite with controlled ordered mesoporosity, large surface areas and highly crystalline walls will be synthesized by a novel sol-gel approach ("brick and mortar"), electrochemical deposition and deposition in a 3D-mesoporous conductive indium-tin oxide (ITO) network. All the obtained nanostructures will be photo-electrochemically characterized in detail and charge carrier dynamics will be studied employing laser flash photolysis and stopped-flow techniques. Since it is known that under irradiation with light of wavelengths smaller than the band gap energy of hematite photodissolution of iron(II) can occur and this might possibly alter the morphology of the photoanode and their photoelectrochemical characteristics, the dissolution-precipitation mechanism will be analyzed and methods to improve the long-term stability of the anodes will be elaborated.

Manish Kumar

Energy transfer and -conversion by functionalized nano-bio-fibers

Supervisor: R. Sindelar, F. Renz, A. Otten, H. Widdecke
Researcher: M. Kumar

In the frame of the project functionalized nano-fibers are developed and their energy transmitting and conversional properties are investigated and applied to technical cases. Energy, e.g. photonic or electric or magnetic nature, can be transferred by nano-scaled fibers produced by electro-spinning. Especially fibers made of bio-polymers are of interest in the field of lifesciences and medical engineering. Functionalization by coordination compounds allows localized energy conversion for various applications such as signal transmittance. The project covers production, characterization and functionalization of the nano-fibers.

Brij Mohan
Mundotiya

Nanocrystallite electroplated softmagnetic layers

Supervisor: L. Rissing, M. Wurz
Researcher: B. M. Mundotiya

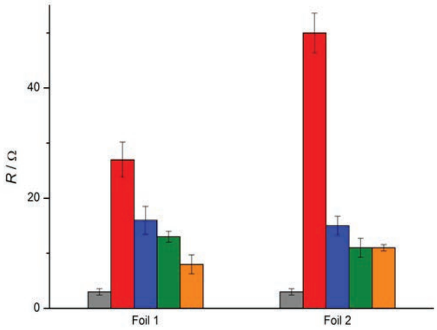
In magnetic sensors and actuators soft magnetic layers serve as flux guides. The experience shows that bulk materials have mostly better magnetic properties than thin film layers. Today materials and their alloys based on Ni, Fe and Co are in use. These materials are deposited by thin film processing using vacuum processes. An alternative procedure is to deposit layers by electroplating. The magnetic properties are depending on numerous influences. One property is the size of the crystals in the magnetic layers. The aim of this project is to adjust the size of the crystallites during the electroplating process and reduce them to nanoscale. By this approach the permeability can be increased. The necessary equipment for the electroplating process is installed at the IMPT. The project should start with collecting information from papers concerning the state of the art and develop a new approach to nanocrystallite softmagnetic layers.

Novel materials for zinc-air batteries

Supervisor: P. Behrens, N. Guschanski
Researcher: D. Nettelroth

The volumetric and specific energy density of Zn-air batteries is higher than that of lithium ion batteries. The aim of this project is to develop economically viable and environmentally friendly solutions for several problems which still have to be overcome for these batteries. The cathode is an electrode with a three-phase boundary (air-electrolyte-solid). Employing carbon nanomaterials (nanotubes, graphene, graphite oxide) the properties of this gas diffusion electrode shall be improved, possibly avoiding expensive noble-metal catalysts.

The electrolyte shall be adapted by rather using neutral solutions instead of the commonly employed aggressive alkaline solutions which also lead to the undesired formation of carbonates. In this way, laboratory models of secondary Zn-air batteries shall be developed which will be tested electrochemically and with regard to cycle stability, lifetime and for their suitability for daily use in industrial applications.



Electrical resistance for nickel foils (grey) and the carbon coated nickel foils. Red: amorphous mesoporous carbon; blue: TG = 700 °C; green: TG = 800 °C, yellow: TG = 900 °C. TG stands for graphitization temperature

Dennes Nettelrodt

Untersuchungen zu den Eigenschaften von weichmagnetischen Dünnschichten auf Polymersubstraten am Beispiel eines flexiblen Sensorarrays

Supervisor: L. Rissing
Researcher: J. Rittinger

Im Rahmen dieser Arbeit soll ein flexibles Sensorarray, an dessen Beispiel der Substrateinfluss auf die Eigenschaften von weichmagnetischen Dünnschichten untersucht wird, entwickelt und hergestellt werden. Die Fertigung dieses Sensorarrays erfolgt dünnfilmtechnisch.

Als flexibles Trägermaterial bzw. Substrat sollen verschiedene Polyimid-basierte Dünnschichten in die Untersuchungen einbezogen werden. Diese werden in Bezug auf vorherrschende Eigenspannungen, Oberflächenqualität und mechanischen Eigenschaften charakterisiert.

Weiterhin muss ein geeignetes Design des zu realisierenden Sensorarrays entwickelt werden. Die zur Fertigung des Sensorarrays benötigten dünnfilmtechnischen Prozesse müssen ermittelt und im Anschluss durchgeführt werden. Am realisierten, flexiblen Sensorarray werden die Eigenschaften der aufgebrachten Sensor-Dünnschichten eruiert. Die durchzuführenden Untersuchungen umfassen die morphologischen, mechanischen und magnetischen Eigenschaften dieser Schichten.

Johannes Rittinger

Johannes Rode

Graphene for Energy Storage and Conversion

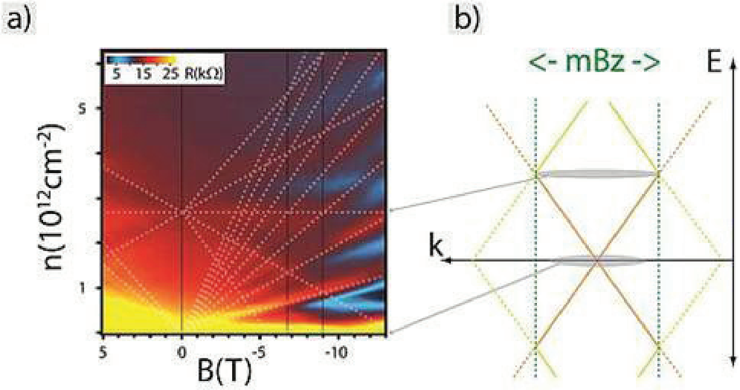
Supervisor: R. Haug, P. Behrens

Researcher: J. Rode

Only for a decade now, we know that it is possible to investigate a single layer of graphite which is called graphene. Nevertheless, it is already clear that graphene is one of the most fascinating materials ever found. Due to its unique mechanical and electronic properties it is suggested to be extremely interesting in applications concerning storage or conversion of energy.

The focus of this project lies on double-layered graphene systems of a certain rotational mismatch also called twisted graphene bilayers. These exhibit exiting novel properties in electronic structure like second generation Dirac points due to long wavelength superlattices (see publication list). The twisted bilayers are prepared by folding of a single layer thereby creating another interesting subject of research in the folded edge, which will be probed in magnetotransport measurements.

As a related topic the photoreduction of graphene-oxide as a promising precursor to graphene is investigated in collaboration with the Institut für Anorganische Chemie (Prof. Behrens) and Laser Zentrum Hannover (Dr. Reinhardt). Precisely defined devices of different degrees of reduction are planned to be investigated in terms of electronic transport.



(a) Longitudinal resistance measurement of a twisted graphene bilayer vs. charge carrier density and magnetic field, exhibiting a satellite Landau fan. (b) Schematic of the folding back of graphene´s dispersion on the superlattice mini Brillouin zone (mBz)

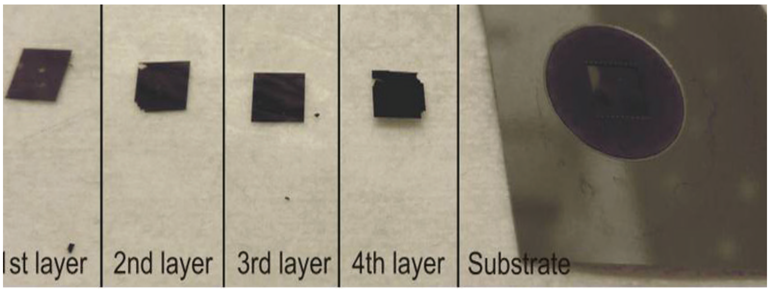
Sören Schäfer

Fabrication and Characterization of Macroporous Silicon and its potential for solar cell application

Supervisor: R. Brendel

Researcher: S. Schäfer

First goal within this project is to develop a method to detach multiple thin macroporous layers from Czochralski grown silicon substrate on an area of 1cm^2. The electrochemical process used therefore has to be optimized. Cylindrical holes are etched into the substrate´s surface. In a depth of 20 to 30 µm - the thickness of the absorber layer (see figure) - the pore diameters are widened in order to create a defined breakage point. Afterwards the pore diameter is decreased again. The process repeats several times and potentially allows an optimal material use of the Si substrate. For further electrical and optical characterization of the absorber layers, the process shall be transferred to a larger area. The long term goal is to qualify the absorber layers as active material for thin film solar cells.



Impact of virtual substrates on the growth of rara earth oxides
Supervisor: J. Osten
Researcher: Jan Schmidt


Jan Schmidt

Das MBE-Institut beschäftigt sich seit mehreren Jahren mit dem epitaktischen Wachstum von kristallinen Seltenen-Erden-Oxiden auf Si-Substraten. Als Modellsysteme werden dabei die Sesquioxide Gadoliniumoxid (Gd2O3) und Neodymoxid (Nd2O3) untersucht. Beide Oxide treten in dergleichen kristallografischen Struktur auf, wobei Gd2O3 einen kleineren Gitterabstand als Silizium aufweist während Nd2O3 größer als Silizium ist. In der Vergangenheit wurden ternäre Mischschichten der Form $(Gd_{1-x}Nd_x)2O3$ (mit x = 0…1) auf Silizium gewachsen, d.h. die Gitterfehlanpassung konnte durch die Wahl der Zusammensetzung durchgestimmt werden. Auf diese Weise konnten erste Informationen zum Einfluss der Gitterverspannung auf dielektrische Eigenschaften von ternären Schichten gewonnen werden [1]. Alternativ kann der Spannungszustand von binären Oxiden durch den Einsatz von virtuellen Substraten mit größerer in-plane Gitterkonstante eingestellt werden. Hierbei bieten sich insbesondere relaxierte $Si_{1-x}Ge_x$-Schichten auf Si an.

Im Rahmen der Promotion „Einfluss von virtuellen Substraten auf das Wachstum von Seltene Erden Oxiden“ werden zwei Themenkomplexe bearbeitet:
Im ersten Teil wird eine Methode entwickelt, um glatte, relaxierte Silizium-Germaniumschichten mit unterschiedlichen Zusammensetzungen auf Siliziumsubstrate mit einer (001)- als auch einer (111)-Orientierung zu wachsen. Dafür wird der Ansatz der Kohlenstoff-unterstützten Epitaxie verwendet, der bereits für die Epitaxie von Germanium auf Si(001) Substraten vorgestellt wurde. Diese Schichten sollen für den zweiten Teil der Arbeit als virtuelle Substrate dienen. Die Schichten werden mittels Molekularstrahlepitaxie hergestellt und anschließend auf ihre strukturellen Eigenschaften untersucht
Im zweiten Abschnitt werden Seltene Erden Oxide auf die virtuellen Substrate aufgewachsen und anschließend bezüglich ihrer strukturellen und elektrischen Eigenschaften charakterisiert. Dabei sollen sowohl binäre Gd2O3 als Nd2O3 Schichten strukturell und elektrische untersucht werden.
Ziel der Arbeit ist ein vertieftes Verständnis des Zusammenhangs von Struktur und dielektrischen Eigenschaften der dünnen Schichten durch das Einbringen einer definierten Verspannung in das Kristallgitter des binären Oxids. Dies wird durch die Wahl des virtuellen Substrates realisiert, wobei insbesondere für Nd2O3 sowohl eine Druck- als auch eine Zugspannung in das Gitter des Seltene Erden Oxids eingebracht werden kann.

[1] D. Schwendt: Charakterisierung von binären und ternären Seltene Erden Oxiden, Dissertation, Gottfried-Wilhelm Leibniz Universität Hannover, 2012.

Camilla Sehring

Near-infrared reflective coatings for cool roof applications

Supervisor: D. Bahnemann, P. Behrens
Researcher: C. Sehring

Cool roofs can mitigate the growing Urban Heat Island effect as well as the increasing energy consumption for air conditioning. By reflecting the solar radiation very efficiently the amount of energy absorbed by the building can be minimized making the interior of the building cooler.

White roofs are already able to reflect high amounts of solar energy. As many homeowners prefer nonwhite roofs, there is a need for cool colored roofs.

The purpose of this project is to develop coatings for tiles which reflect high amounts of invisible near-infrared (NIR) sunlight while keeping the same spectral response of traditional tiles or being transparent in the visible region. Taking into account that the sun emits about 58% of its energy as NIR radiation, a significant improvement in building passive cooling can be achieved, even for dark colors.

In particular, this project deals with the preparation and investigation of NIR reflecting coatings by adding appropriate “cool” nanopigments. This pigments could be new inorganic colored nanopigments, which offer improved NIR-reflecting capabilities while keeping the optical properties in the visible spectrum unchanged. Another kind of promising particles for that purpose could be highly doped transparent conductive oxides (TCOs), which are transparent to visible light but still NIR-reflective.

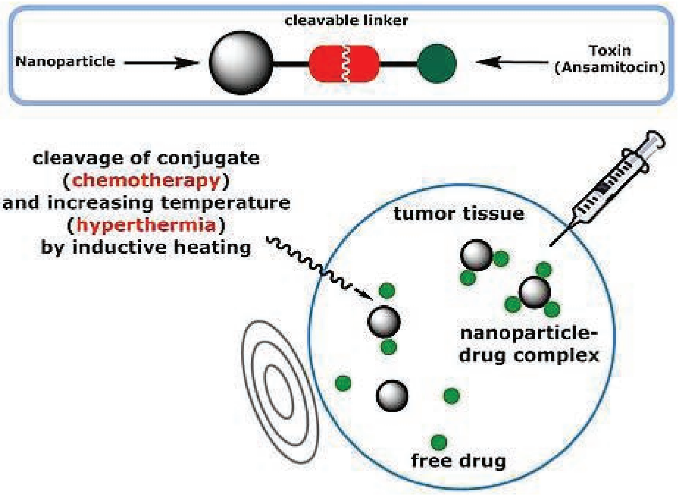
The desired properties are planned to be achieved by tuning the crystal size and distribution of selected nanostructured oxides, as well as by choosing suitable doping materials and ratios. The developed coatings are examined for their IR reflectance properties, surface temperature and the thermal emission to evaluate the effect of different pigments/particles, binders and coating thicknesses. The results are compared to coatings prepared with commercially available pigments.

Katja Seidel

Superparamagentic core-shell nanoparticles as inductive heatable tools for release of chemotherapeutics in medical hyperthermia

Supervisor: A. Kirschning, F. Renz
Researcher: K. Seidel

One of the largest challenges in current cancer therapy based on cytotoxic drugs is the quest for reducing the side effects on healthy tissue and organs. This research topic pursues a new concept that is based on the chemical functionalization of superparamagnetic nanoparticles with a cytotoxic drug such as ansamitocin to achieve a temperature dependent magnetic-drug-targeting system. By combining hyperthermia with a highly cytotoxic drug it is expected to address solid tumors more specifically and with higher efficacy. Optimization of iron oxide silica core-shell nanoparticles for functionalization with complex drugs is the principal topic of the Ph.D. thesis. The Ph.D. thesis is carried out in close collaboration on nanoparticle design and characterisation with the LNQE. The in vivo experiments of the conjugate are currently done with the collaboration of the workgroup of Prof. Dr. Ott (Twincore, Medical University of Hannover).



Experimental and Computational Characterization of Elastomer-FabricsProduced by Electro-Spinning

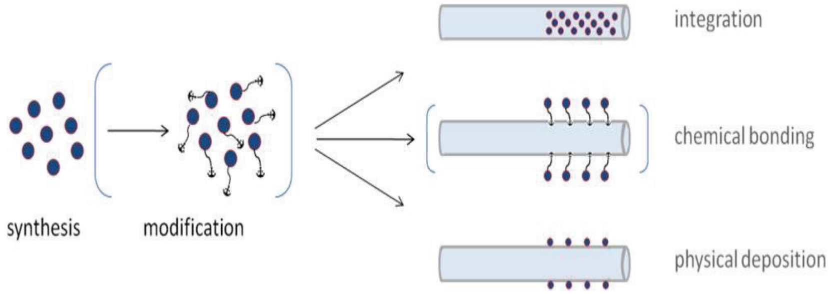
Supervisor: U. Nackenhorst, R. Sindelar
Researcher: Christian Thomas
The overall goal of the thesis is the development of a computational mechanics framework for the prediction of the mechanical behavior of fabrics produced from electro-spinning of elastomers. The computational model will be based on the Finite Element Methods within the framework of non-linear continuums mechanics, including large deformation theory and inelastic constitutive material models. In parallel, goal oriented experimental setups will be designed to produce well defined probes and related experiments for the characterization of the mechanical behavior of single fibers in dependency of their basic material composition as well as their geometrical length scale.

Christian Thomas

Concerted and sequential switching in nanoscopic compounds

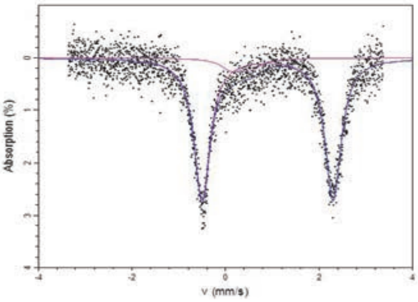
Supervisor: F. Renz, M. Oestreich, R. Sindelar
Researcher: D. Unruh
Concerted and sequential switching in nanoscopic compounds The aim of this project is the design, development, and investigation of switchable nanoscopic coordination compounds for storage and transformation of energy. The compounds exhibit concerted and sequential electronic molecular switching upon thermal or electro-magnetical excitation. The investigation of the associated conversion and transport of the thermally or optically injected energy is the main focus. A milestone is the synthetical modification of the switchable multinuclear compounds.

Daniel Unruh

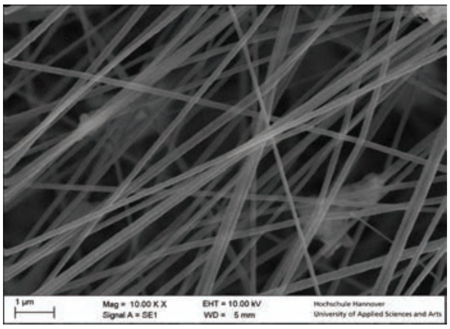


Schematic incorporation of switching molecules in polymer fiber.

Such modification is based on electronical or sterical substitutions in the organic framework as well as in the metal centers. The switching of the compounds will be investigated in powder, crystalline and anisotropic matrix oriented states. The dichroism in the matrix is achieved by incorporation in nanoscopic polymer fibers produced by electro-spinning. Potential applications will be investigated.



Mößbauer-spectrum of an iron(II) spin crossover compound



SEM-picture of functionalized nanoscopic polymer fiber

Julia Susan
Wiegand

Ultrafast optical spectroscopy of interactions and energy transfer in single molecules

Supervisor: M. Oestreich, F. Renz
Researcher: J. Wiegand

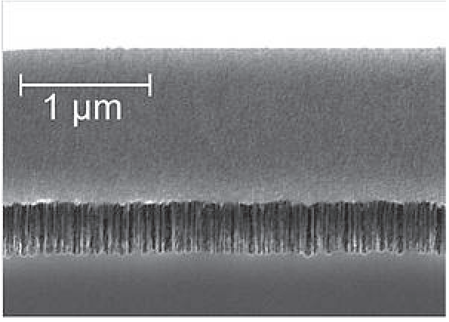
Abstract: The aim of this project is the investigation of concerted and sequential molecular switching in nanoscopic coordination compounds under optical energy injection by ultrafast optical spectroscopy. The compounds comprise multinuclear single molecules which show a distinct switching and interaction behaviour upon thermal or electro-magnetical excitation. The vast majority of all reactions occur within a sequential mechanism, whereas concerted inorganic reactions are not yet understood. The exploration of the associated conversion and transport of the optically injected energy and of the nature of this concerted reaction is the main focus. The importance of the excited states and their lifetimes and spin-flip mechanisms of the macro molecules will be addressed via ultrafast magnetooptical spectroscopy.There is a close collaboration with the project “Concerted and sequential switching in nanoscopic compounds” in which the design, synthesis and characterisation of such compounds will be performed. The two projects will feed-back on each other and allow optimizing the synthesis and exploring the nature of the switching and interaction behaviour.

Sascha Jozsef
Wolter

Nano porous silicon for electricity storage

Supervisor: R. Brendel, D. Bahnemann
Researcher: S. Wolter

Low cost electricity storage is important to cope with the volatile nature of solar energy and wind energy. Crystalline Si is an attractive material not only for Si solar cells but also for storing electricity. It is known from the literature that Si nanostructures exhibit a ten-fold storage capacity for Li ions when compared with conventional graphite anodes. This project evaluates nanostructured porous Si as an anode for Li-ion batteries. The porous Si layers are prepared by an electro chemical etching procedure. The project aims at optimizing the electrochemical etching conditions for achieving a large and stable storage capacity. With the technological equipment available at ISFH (www.isfh.de) it will be possible to investigate new porous Si modifications. The candidate shall measure and model the interplay of the etching chemistry, the porous Si structure, and the storage performance. At ITC the candidate shall investigate the reaction steps for charging and discharging of porous nanostructures. The project will be co-supervised by a physicist and a chemist.



Scanning electron micrograpf of a double layer of meso-porous silicon. The porosity of the top layer is 20% andthat of the bottom layer is 50%

Aktivitäten in 2015
Actvities in 2015

Chalcogenide-type nanostructures: Topological insulator nature versus thermoelectric performance LNQE-Kolloquium Kornelius Nielsch Institute of Applied Physics University of Hamburg	14.01.2015
Status Meeting 2 PhD-program „Hannover School of Nanotechnology“	23.01.2015
Wirtschaftsempfang 2015 Feierlicher Empfang der Leibniz Universität Hannover	23.04.2015
Status Meeting 3 PhD-program „Hannover School of Nanotechnology“	03.07.2015
Hochschulinformationstage: Studiengang Nanotechnologie Informationsveranstalltung und Führung	15.-16.09.2015
NanoDay2015 Workshop Der elfte NanoDay des LNQE	01.10.2015
Niedersachsen-Technikum für Frauen - im LNQE Informationsveranstalltung und Führung	05.10.2015
Begrüßungsveranstaltung Erstsemester Nanotechnologie Feierliche Eröffnungsveranstalltung Start des Wintersemesters 2015/16	12.10.2015
Herbstuniversität Nanotechnologie Informationsveranstalltung und Führung	19.10.2015
NanoSaTox: Workshop on Nanosafety and Nanotoxicology Workshop	27.10.2015

Wissenschaftliche Projekte/*Scientific Projects*

Eine Auswahl von Projekten aus den Arbeitsgruppen des LNQE.
A selection of projects from the working groups of LNQE.

Oxidations of Allylic and Benzylic Alcohols under Inductively-Heated Flow Conditions with Gold-Doped Superparamagnetic Nanostructured Particles as Catalyst and Oxygen as Oxidant

Sangeeta Roy Chaudhuri, Jan Hartwig, Lukas Kupracz, Torben Kodanek*, Jens Wegner, Andreas Kirschning*

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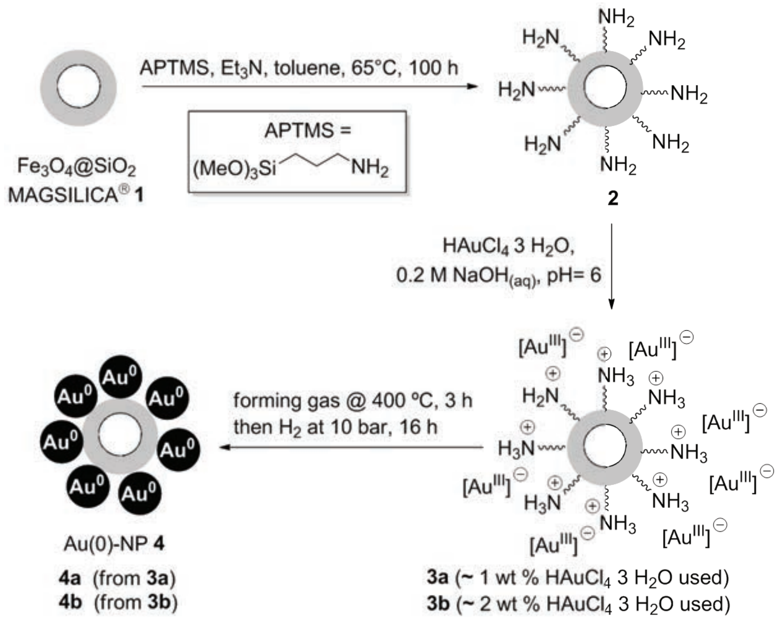
**Laboratorium für Nano- und Quantenengineering (LNQE), Leibniz Universität Hannover, Schneiderberg 39, 30167 Hannover (Germany)*

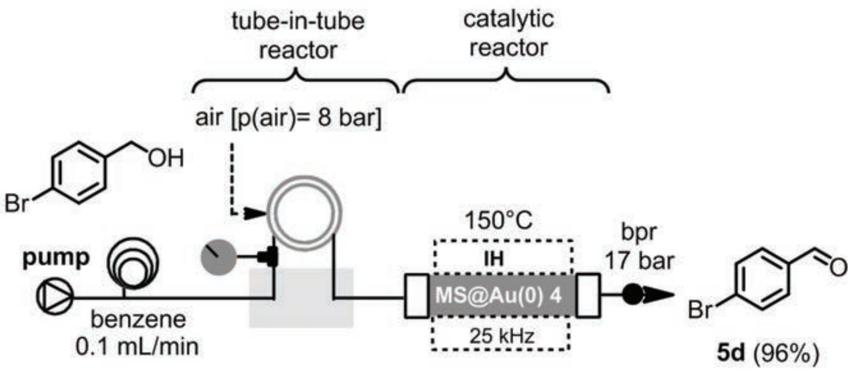
Abstract: A continuous flow protocol for the oxidation of alcohols to aldehydes and ketones, respectively, using oxygen gas or atmospheric air is reported. The key features of this work are gold nanoparticles that are attached to the surface of nanostructured core shell particles composed of an Fe_3O_4-containing core and a silica shell. These nanostructured particles exert superparamagnetic properties and thus inductively heat up in an external oscillating electromagnetic field, conditions under which the gold catalyst is able to perform these oxidation reactions.

In our research, we relied on the uptake of Au^{3+} ions from an aqueous $HAuCl_4$ solution onto amino-functionalized, silica-coated nanostructured magnetic particles **2**. The loading was achieved at pH = 6 and yielded nanostructured particles **3**. This was followed by metal reduction under forming gas at 400 ºC and further reduction in an autoclave under hydrogen atmosphere to furnish the desired gold-doped core-shell particle **4** (Scheme 1). We prepared two different types of particles that differed in the amount of $HAuCl_4$ employed during immobilization (**2** → **3**). Catalysts **4a** and **4b** differed in the amount and size of gold nanoparticles present on the silica surface. We used nanostructured, superparamagnetic nanoparticles **1** as supporting material, composed of an Fe_3O_4-containing core and a SiO_2 shell. These particles were functionalized by coupling of (3-aminopropyl) trimethoxysilane (APTMS) to the silica coating. The basic amino groups in **2** facilitated loading of the anionic Au complex $[Au(OH)_xCl_{4-x}]^-$ to yield **3**. In our hands this protocol was superior to the adsorption of gold on SiO_2 surfaces. From X-ray absorption near edge structure analysis, Rossi et al. concluded that amino groups grafted on solid supports interact more strongly with metal ions than gold that is simply adsorbed on the surface of non-functionalized supports.

Essentially, we aimed to carry out a scale up study to demonstrate the practicability of this catalytic system. Therefore, a PEEK reactor was filled with 2.0 g of catalyst **4a** (24.0 mg Au) and 1.0 g of MAGSILICA® **1**. Thus, 4-bromobenzyl alcohol (2.5 g 13.37 mmol) was dissolved in 50 mL benzene and the solution was pumped through the reactor at a flow rate of 0.1 mL/min. Several reaction parameters were changed towards higher productivity The concentration of the reaction mixture was increased threefold and the flow rate was doubled while catalyst loading was only increased by a factor of four. The desired product was isolated in 92% yield. The same transformation was repeated using pressured air instead of oxygen gas. Gratifyingly, the catalyst also showed high activity with atmospheric oxygen as oxidant and the product was isolated in 96% yield (Scheme 2).



Scheme 1: *Preparation of nanostructured, gold-doped particles 4 (MAGSILICA®).*



Scheme 2: *Oxidation of 4-bromobenzyl alcohol with atmospheric oxygen as oxidant.*[a,b] *Reaction conditions:* [a] *4-Bromobenzyl alcohol (100 mg, 0.54 mmol) in benzene (4 mL);* [b] *catalyst* ***4a*** *(2.0g, 24.0 mg Au), 150 °C and MAGSILICA® (1.0 g).*

In conclusion, we report on the design of nanostructured core shell particles based on iron oxide (primarily Fe_3O_4) and a silica shell that are doped with gold nanoparticles (< 10 nm). This nanostructured architecture allows rapid heating in direct proximity of the heterogenic catalytically active gold nanoparticles under inductive heating conditions and using them in O_2-promoted oxidations of primary and secondary alcohols, which provided aldehydes and ketones, respectively.

The catalytic samples were mixed with nanostructured core-shell iron oxide and used as catalytic fixed bed materials in mesofluidic PEEK reactors. The processes were conducted under high pressure/high temperature conditions and provided in almost all cases complete conversion in a single pass. The catalytically active nanoparticles show excellent distribution across the nanostructured surface of the core shell nanoparticles with sizes below 10 nm and low polydispersity. Catalyst leaching is negligible with less than 0.0015% over 12 hours of operation. The high activity of the catalyst was demonstrated after upscaling as well as when exchanging oxygen gas by atmospheric oxygen as oxidant. It is important to note that no overoxidation occurred during the flow-process. We are certain that the catalyst architecture and the technical set-up has potential applications for continuous oxygen-promoted oxidations in technical processes.

Micro- and Mesoporous Silica and Titania for Catalysis, Biomedizin, Photonics

Carsten Reinhardt[1], Boris Chichkov[1,*], Peter Behrens[2,*]

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[2] *Institut für Anorganische Chemie, Leibniz Universität Hannover, Callinstraße 9, D-30167 Hannover, Germany*
[*] *Laboratorium für Nano- und Quantenengineering, Schneiderberg 39, 30167 Hannover, Germany*

Abstract

A combination of laser-based 3D structuring and chemical bottom-up processes to prepare hierarchical pore structures is presented. Polymer templates with dimensions in the micrometer regime are fabricated by two-photon polymerization and are subsequently infiltrated with mesostructured silica and titania. Calcination to remove both, the macro-templating polymer and the nano-templating surfactant molecules, has been carried out, delivering mesoporous constructs which correspond to an inverse replica of the initial polymer structure. As the two-photon polymerization allows controlled construction of various shapes, mesoporous materials can be constructed with practically any desired morphology on the micrometer scale. The dual pore system of macro- and mesopores classifies these materials as hierarchical pore systems with applications in catalysis and sorption. In addition, the versatility of silica and titania surface chemistry opens new venues for the fabrication of photonic crystals. The general biocompatibility of silica and titania further allows the construction of scaffolds for biomedical applications.

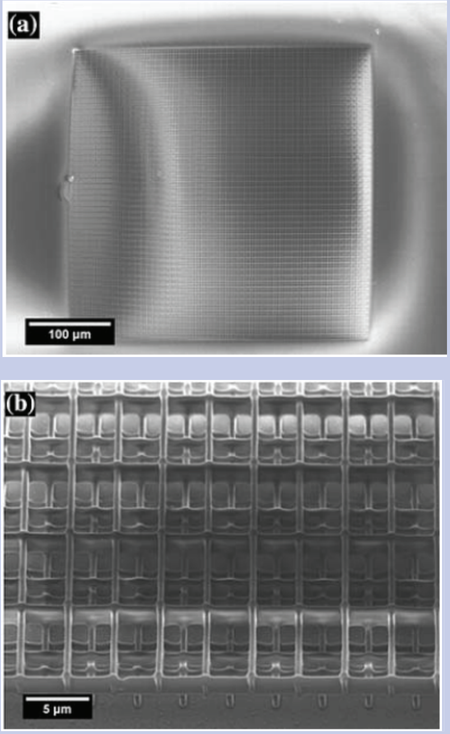

Fig. 1: *3D woodpile temples fabricated by 2PP. a) A four layer 350 µm x 350 woodpile polymer crystal. b) Magnfied image showing sub-µm polymer rods*

Article

Femtosecond laser technology is nowadays widely used for the realization of three-dimensional (3D) micro- and nanostructured materials. Nonlinear polymerization processes allow the fabrication of 3D microoptical and micromechanical devices [1,2] as well as photonic crystals and photonic crystal templates [3]. This photo-fabrication process is accomplished by 2-photon absorption of visible or near-infrared femtosecond laser pulses from ultrashort pulse laser systems. The two-photon polymerization (2PP) technique allows the fabrication within the volume of the photosensitive resins. When femtosecond laser pulses are tightly focused into the volume of a photosensitive material (or photoresist), 3D structures with resolution below 100 nm have already been realized [4]. This gives the possibility for the fabrication of any computer-generated 3D microstructure by direct laser-“writing” into the volume of a photosensitive material and especially for the realization of specially designed microporous media (see Fig. 1) for chemical, biomedical, and photonic applications.

On the other hand, the class of ordered mesoporous silicas has widely been investigated since such materials were first presented by the Mobil Oil Co., in 1992 [5,6]. Reasons for this interest are the large surface areas of these ordered mesoporous silicas and their applications in sorption processes and catalysis. Besides the development of different mesoporous bulk materials like MCM-41 or SBA-15, there was an early and profound interest to obtain ordered mesoporous silicas as a film on a substrate for use in biomedical devices [5].

Here, the realization of hierarchical micro- and nanopores structures in mesoporous silica and titania is described. The scheme of the strategy for the construction of these replicas is shown in Fig. 2. In short, after the preparation of a template by 2PP of a suitable polymer, the sample is coated by a layer of ordered mesostructured silica or titania from which the organic substances are finally removed by calcinations to yield materials hierarchically structured on the micrometer and on the nanometer scale.

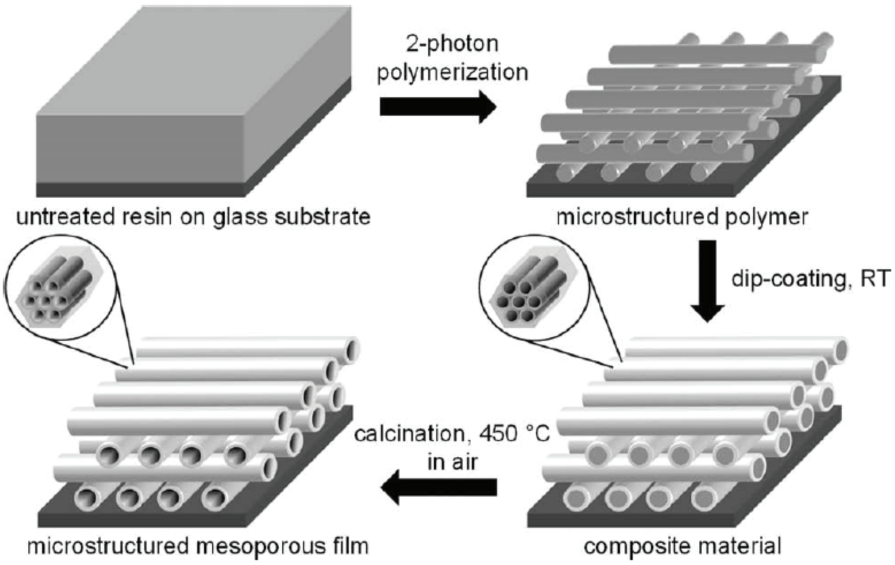

***Fig2:** Synthetic strategy for the combination of 2-photon polymerization and formation of mesoporous coatings.*

The possibility to combine sub-µm top–down construction with the bottom-up self-assembly of nm-structured materials gives rise to a variety of applications. Such materials are of considerable interest in chemistry, as the system of large pores can facilitate transport to the smaller pores where sorption or catalytic reactions can take place.

Such catalytic converters and chemical adsorbers based on hierarchical structures might thus find wide ranges of applications in industrial emission control and automotive industry. For applications as biomaterials, large pores of hierarchically ordered porous materials could allow for the ingrowth of cells into a scaffold material, while the storage capacity of the mesopores can deliver signalling molecules, drugs or nutrients.

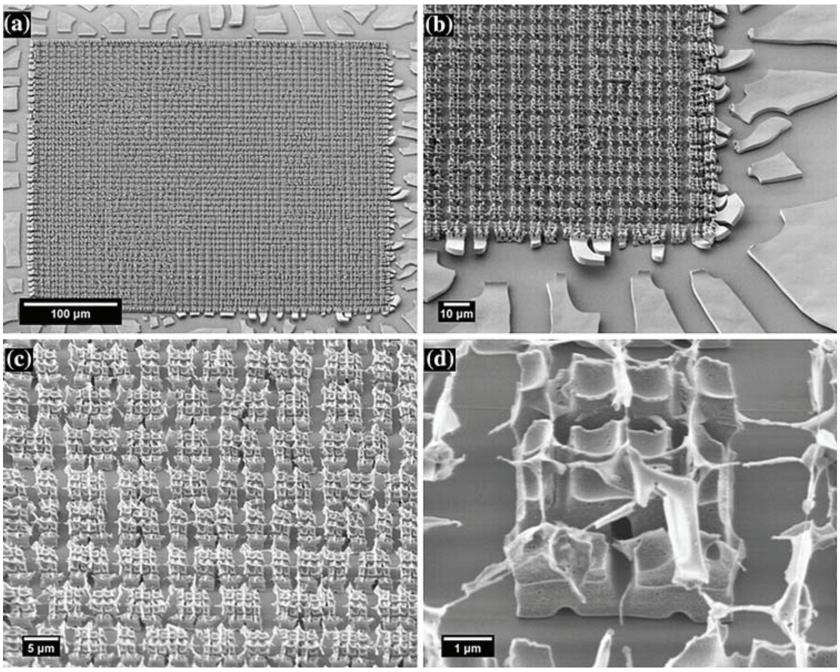

***Fig. 3:** SEM images at different magnifications of a inverse woodpile structure in mesostructured titania.*

The construction of specified 3D structures is also of interest for the realization of photonic crystals providing 3D stop bands. To realize photonic crystals with a full photonic bandgap, 3D structuring of high refractive index materials is required. An example of a realized inverse woodpile titania structure is shown in Fig. 3. It has been shown that after calcination the amorphous titania has been transformed into crystalline anatase. Noteworthy, the refractive index of anatase of 2.6 and is thus large enough for opening complete optical band gaps [6].

The results presented here show novel possibilities to combine the laser-based top-down approach of structuring materials on the micrometer scale by 2PP with a chemical bottom-up self-organization process for producing artificial hierarchically ordered porous media for applications in chemistry, biomedicine, and photonics.

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Microfabricated atom traps for quantum information science and precision measurements

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Motivation

Microfabrication holds great promise for a new class of atomic and molecular quantum systems based on scalable and compact trapping structures. These systems have found applications both in quantum information science, novel types of quantum sensors and precision experiments. We design, fabricate, characterize and operate microfabricated neutral atom and ion chip-scale traps both at LNQE and in the PTB cleanroom facility.

Surface-electrode ion traps

Trapped ions are currently one of the most advanced scalable experimental systems for implementing elements of quantum information science. Single ions can be trapped in UHV conditions using combinations of static and time-dependent electric and magnetic fields for time scales of hours to months. The internal atomic states of the ions serve as a quantum bit or “qubit”. In order to implement interactions between qubits (“quantum logic gates”), one exploits the repulsive Coulomb interaction between ions trapped in a common potential, combined with additional external driving fields, which are typically implemented using focused laser beams [1]. In a scalable architecture [2,3], multiple ion-qubits would be held in different individual zones of a trap array and physically transported between dedicated gate, manipulation and readout zones. A scalable way of realizing such a “quantum CCD” device is given by surface-electrode traps, where all the electrodes sup-plying the trapping potentials lie in a plane and are produced using standard microfabrication techniques [4]. We design and fabricate surface-electrode traps for single 9Be+ ions, where the external control fields for multi-qubit gates are realized using microwave conductors integrated into the trap structure [5,6]. This holds great promise for scalability and operation fidelity. Towards this end, we perform high-quality numerical simulations of microwave current flow in integrated wave-guide structures and analyze the emanating magnetic near-fields [7,8]. We have recently trapped single ions in such a structure and are currently characterizing the magnetic near-fields experimentally using the ion itself as a field probe.

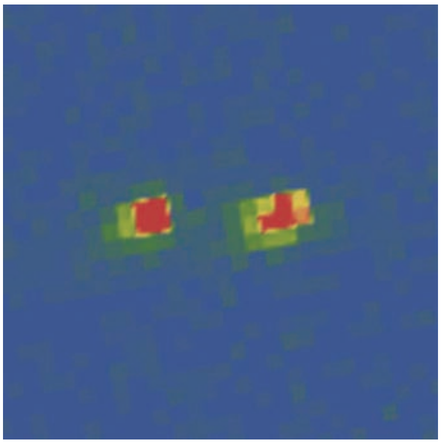

Figure 1: *False-color image of the fluorescence from two 9Be+ ions in a surface-electrode trap.*

Neutral atom chip traps

Since the first demonstration of Bose-Einstein-Condensation (BEC) in 1995 [9,10], different approaches for an efficient creation of this new state of matter have been investigated. One approach is to use microfabricated current-carrying wire structures to produce high-gradient magnetic fields, needed for trapping and efficient cooling of the neutral atoms to BEC [11]. This compact and robust atom chip technology has enabled the development of highly compact, robust and low power consuming BEC machines [12] to make use of the beneficial properties of BECs for e. g. atom interferometry for inertial sensing. By using the coherence properties of the atomic ensemble in an interferometry scheme, inertial forces such as accelerations and rotations can be measured extremely accurately. This leads to the development of new devices to per-form fundamental tests of physics or for earth observation in geodesy. Based on recent advances in atom chip technology, we have developed BEC apparatuses which operate in harsh environ-ments like the drop tower Bremen [13] or on sounding rocket missions performing atom interferometry in space. Furthermore, a new type of portable atom interferometer using BECs for gravity sensing is under investigation.

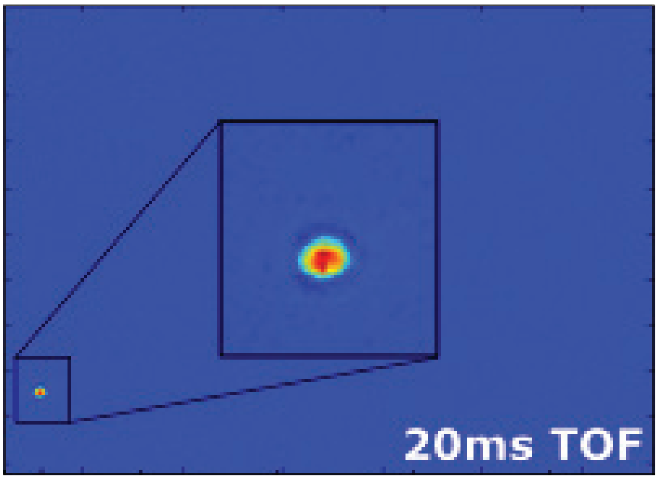

Figure 2: *Absorption image of a BEC with 4x105 atoms created with an atom chip after 20 ms of free expansion.*

Sample fabrication and implementation

We fabricate neutral atom and ion traps using a combination of metal deposition, photolithography, electroplating and etching steps. Our standard wafer is polished Aluminum Nitride because of the high thermal conductivity at room temperature. We first deposit a layer of 20 Å of Titanium as an adhesion layer on top of the substrate. We then evaporate a 500 Å seed layer of gold. On top of this seed layer, we spin photoresist with a typical thickness exceeding 10 µm. The photoresist is exposed and developed. Using electroplating, on top of the exposed seed layer, we grow a film of up to 10 µm of gold in the gaps between the remaining resist structures. The resist and the remaining seed and adhesion layers between the areas where we have grown the gold film are then removed using a series of etching steps. This produces a set of electrically insulated gold conductors, separated by minimum gaps about 4 µm wide. We assemble these structures and align the whole setup within a vacuum system under cleanroom conditions. We connect the chips to a set of vacuum feedthroughs, close and leak test the system before implementing the pumped out vacuum system in an experimental apparatus

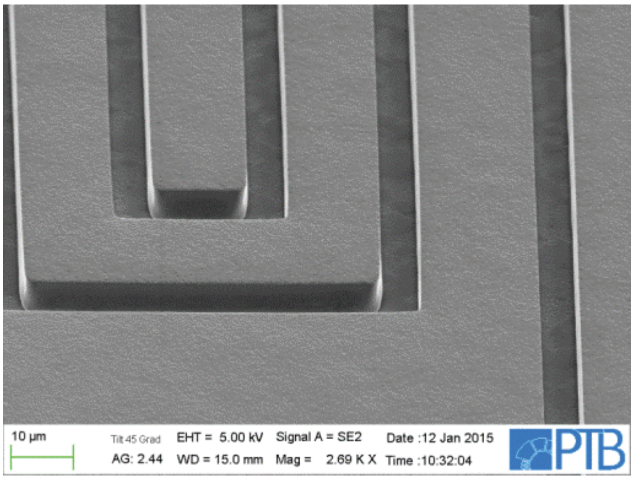

Figure 3: *SEM picture of microfabricated surface-electrode ion trap structure.*

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Superlattice Structures in Twisted Bilayers of Folded Graphene

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The electronic properties of bilayer graphene strongly depend on relative orientation of the two atomic lattices. Whereas Bernal-stacked graphene is most commonly studied, a rotational mismatch between layers opens up a whole new field of rich physics, especially at small interlayer twist. We investigate magnetotransport measurements on twisted graphene bilayers, prepared by folding of single layers. These reveal a strong dependence on the twist angle, which can be estimated by means of sample geometry. At small rotation, superlattices with a wavelength in the order of 10 nm arise and are observed by friction atomic force microscopy. Magnetotransport measurements in this small-angle regime show the formation of satellite Landau fans, which are attributed to additional Dirac singularities in the band structure.

The electronic structure of bilayer graphene can significantly differ from that of a single layer, depending on the interlayer stacking order. Apart from the common Bernal-stacked variety, twisted graphene bilayers (TBGs) constitute a whole new field of their own: Layers of large rotational mismatch effectively decouple, exhibiting reduced Fermi velocities for decreasing interlayer twist in many cases[1,2]. At the smallest angles, totally different electronic structures are expected[3,4]. While TBGs of various angles have been grown and optical studies as well as scanning tunnelling spectroscopy were performed on samples of different interlayer twist, we here present a study on magnetotransport in high-quality folded monolayers of small interlayer twist[0], revealing novel transport features in the form of satellite Landau fans, caused by twist-induced long-wavelength superlattices (Fig. 1).

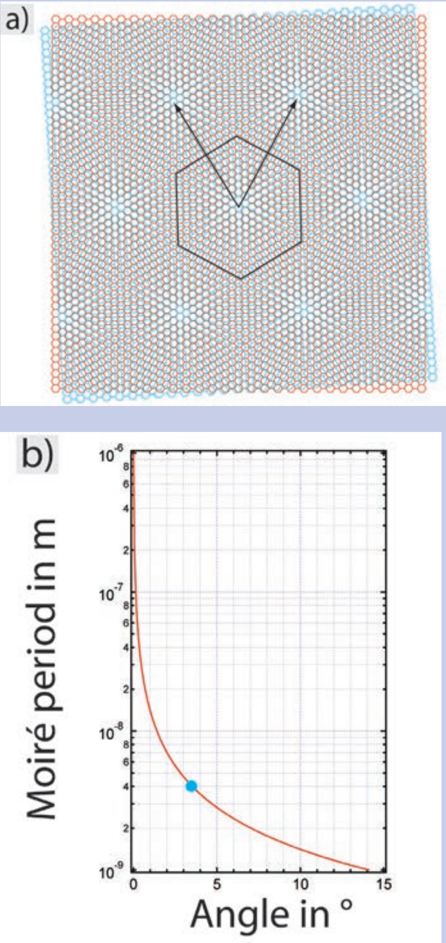

Fig. 1: *(a) Two rotated honeycomb lattices arranging in a moiré superstructure. (b) Dependence of the superlattice periodicity on the twist angle*

Our folded layers are obtained by mechanical manipulation via atomic force microscope (AFM) or incidental flip-over during the exfoliation of natural graphite. As graphene is most commonly terminated by armchair- or zigzag-edges, according crystallographic reference directions in relation to the folded edge (relative angle φ) can be used to estimate the interlayer rotation by $\Phi = 2\cdot\varphi$. In case of the shown example (Fig. 1a), the twist angle can thus be narrowed down to 1.5°±0.5° (projected into the range of $0° < \Phi \leq 30°$ due to graphene's sixfold symmetry). The two rotated lattices may now arrange in periodic superstructures reproducing the original honeycomb pattern on a twist-dependent length scale of $\lambda(\Phi) = a/[2\sin(\Phi/2)]$, a being the length of graphene's lattice vector. Figure 1c shows a lateral force microscopy scan on the TBG area. The dashed white star marks three distinct symmetry directions in the friction force plot, which are clearly confirmed by the prominent hexagonal pattern in the Fourier transform (Fig. 1c) pointing to a trigonal lattice of period $\lambda = 9\,\mathrm{nm}$. The corresponding moiré twist angle of 1.6° fits the geometrically estimated value of 1.5°±0.5° very well.

To investigate the electronic properties of graphene bilayers with different stacking, magnetotransport measurements in perpendicular fields up to $B = 13\,\mathrm{T}$ were performed. For several samples of small rotational mismatch ($\Phi < 3°$), systematic satellite Landau fans could be observed in longitudinal resistance, as depicted in the example in figure 3a (main fan originating at charge neutrality, secondary fan origination at n = 2.75 ´ 10^{12} cm^{-2}). This indicates the generation of secondary Dirac singularities in the band structure comparable to observations on heterostructures of closely aligned graphene on hexagonal boron nitride [5]. This phenomenon can be attributed to a large wavelength moiré pattern between the two rotated hexagonal lattices. Bragg scattering by the correspondingly small superlattice Brillouin zone (mini Brillouin zone, mBz) will lead to replica satellite Landau fans at higher energies (Fig. 3b), while periodically alternating interlayer coupling should result in a more complex electronic spectrum [3,4], as discussed in [0].

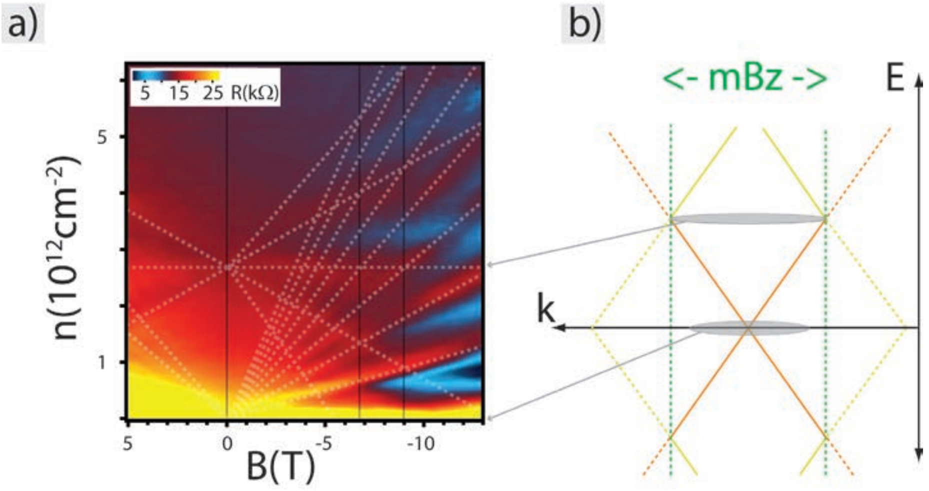

Fig. 3: *(a) Longitudinal resistance vs. magnetic field and charge carrier density for a twisted bilayer of small rotation. Dashed white lines trace main and satellite Landau fan. (b) Schematic of graphene´s low energy dispersion (orange). Reflection on the mini Brilloun zone (green) leads to replica Dirac points at higher energies.*

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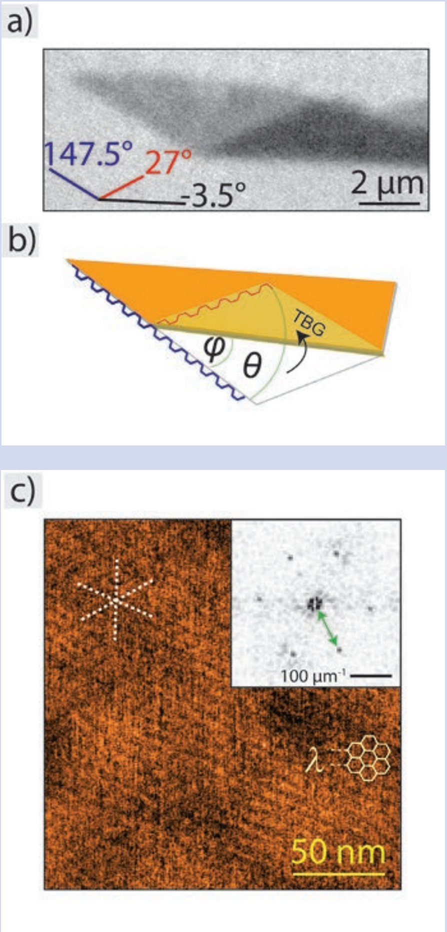

Fig. 2: *(a) Optical picture of a folded graphene sample. The orientation of edges can be used to estimate interlayer twist, as illustrated in the schematic in b. (c) AFM scanning image of the TBG in friction force mode and Fourier transform in the inset.*

Site-Selective Noble Metal Growth on CdSe Nanoplatelets

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Abstract

Au, Pt, and Pd noble metal domains have been grown site-selectively onto 5 monolayer (ML) thick CdSe nanoplatelets (NPLs). Depending on the metal and also on the reaction conditions, metal domains are found to grow only at the corners, shorter side edges and also all around the edges of the NPLs. The marriage of metal and semiconductor NPLs generates a novel class of materials which has potential application possibilities in the field of optoelectronics, photocatalysis, and fabrication of photovoltaic devices or as a sensors for chemical detection.

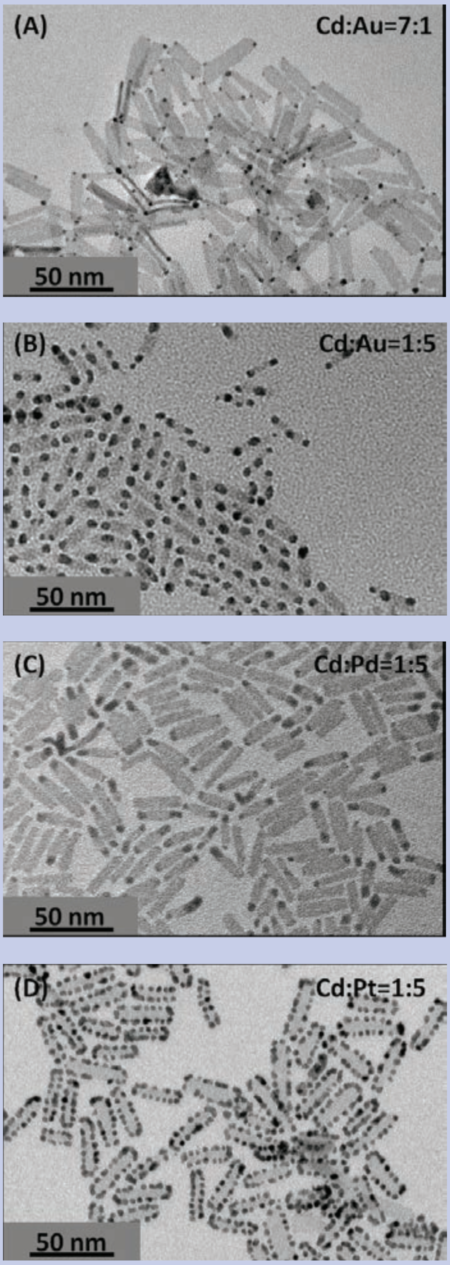


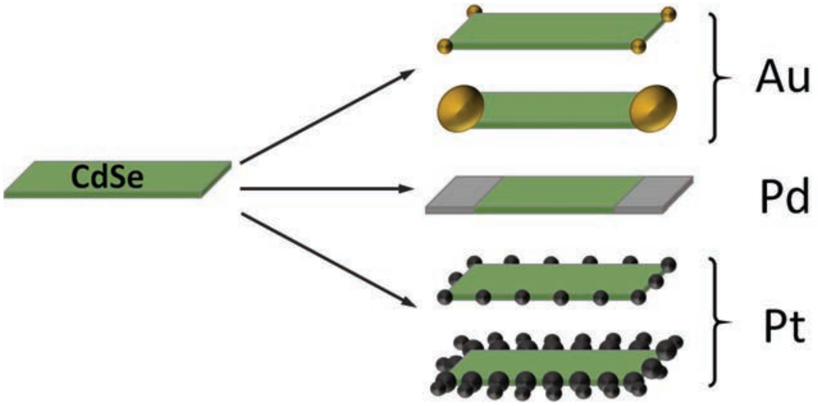
Figure 1: *TEM micrographs of Au, Pd, and Pt decorated 5 ML CdSe NPLs. (A) and (B) are platelets with Au domains on 5 ML CdSe NPLs with a Cd:metal molar precursor ratio of 7:1 and 1:5, respectively. (C) and (D) are Pd and Pt domains on CdSe NPLs from a Cd:metal molar precursor ratio of 1:5.*

Introduction

The combination of metal and semiconductor materials in a single component helps the researchers to manipulate the properties of both the metal and the semiconductor in the same segment. Such nanoheterostructures have a broad range of possible applications, e.g. in pollutant degradations, solar to chemical energy conversion, photocatalytic water splitting.[1-3] Since the pioneer work of Prof. Banin to grow gold domains on CdSe nanorods and tetrapods, scientists have successfully extended metal domain growth (mainly Au, Pt, Co) on CdSe, CdS, PbSe, Cu_2ZnSnS_4,TiO_2 and many more systems.[1, 4-5] Recently, CdSe NPLs of few monolayer thicknesses (~1.2 to 1.8 nm) have attracted attention of many nano-researchers due to their unique optical properties such as extremely narrow photoluminescence emission spectra (full width at half maximum as narrow as ~9 nm), high quantum yields, and also ultrafast fluorescence radiative lifetimes leading to exciting applications in polarized light emitters and electroluminescence emitters even in room temperature lasing with very low energy thresholds.[6-7] However, to the best our knowledge there was no report so far regarding nanoheterostructures with these few monolayer thick, quasi 2 D II-VI semiconductor CdSe NPLs and metal domains. Therefore, we focused on the development of synthetic strategies to grow noble metal domains (Au, Pd, Pt) site selectively on 5 ML thick (~1.5 nm) CdSe NPLs. From transmission electron microscopic characterization of the nanoheteroplatelets, it can be inferred that depending on the type of metal precursors and also on the reaction parameters, quasi spherical domains have grown at the corners and the shorter side edges (in case of Au) along with all around the edges of CdSe NPLs (in case of Pt). Pd domains are found to grow only at the two shorter edges of the CdSe NPLs with a quasi flat rectangular morphology.[8] We believe that this novel class of nanoheteroplatelets will catch significant attention of material scientists to imply them in usable optoelectronic devices or in sensors.

Results and discussions

Figure 1 shows the different growth behavior of Au, Pd and Pt metal domains on the CdSe NPLs. When the Au precursor concentration is low (molar precursor ratio Cd:Au = 7:1,) the quasi spherical domains are mainly observed at the corners, while with Cd:Au = 1:5 the domains are at the shorter edges of the NPLs. In the case of Pd with molar precursor ratio Cd:Pd = 1:5 the domains are quasi flat, having similar thickness as of the NPLs and have grown at the shorter edges of the NPLs. However, using Pt(acac)$_2$ as the precursor for Pt with Cd:Pt molar precursor ratio of 1:5 the quasi spherical Pt domains are found to grow all around the edges of the NPLs. Our findings are summarized in scheme 1 representing the various morphologies obtained by metal decoration on 5 ML thick CdSe NPLs.



Scheme1: *Morphologies of Au, Pd, Pt domains on the 5 ML thick CdSe NPLs.*

Conclusion

In this work, we have grown Au, Pd, and Pt metal domains site-selectively on quasi 2D CdSe NPLs of 5 monolayer thickness. Au and Pd domains are found mainly at the corner and at the shorter edges of the NPLs, whereas the Pt domains are all around the edges of the NPLs. The different morphologies obtained for different metals are attributed to the type of metal precursor and to the varied reaction parameters.

Acknowledgement

N.C.B., S.N., J.F.M and A.S. are grateful for financial support from the German Federal Ministry of Education and Research (BMBF) within the framework of the program NanoMatFutur (support code 03X5525).

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Raman spectroscopy and tunneling microscopy on epitaxially grown graphene nanoribbons

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Motivation

Graphene nanoribbons (GNR) are an essential building block of future graphene based electronic devices due to their unique electronic properties, such as a band gap scaling with the width of the ribbon in armchair type ribbons [1,2] or the presence of topologically protected edge states in zig-zag GNR [3]. Unfortunately, GNR produced by standard lithography methods were shown to suffer severely from the initial patterning process revealing rough and disordered edges [4,5]. The growth of graphene and graphene nanosturctures by means of the so-called sublimation epitaxy on silicon carbide (SiC) samples turns out to be a promising alternative. As shown recently by our group, sidewall GNR grown on pre-stucured SiC-nanofacets exhibit room-temperature ballistic transport properties with electronic mean free paths up to 15 µm [6]. However, roughness besides that of the mesa structure itself is highly detrimental. Despite the intensive characterization of sidewall GNR [6,7] the physical origin of the exceptional transport properties is still unknown. In this joint project, we intended to gain a deeper insight into the growth process of sidewall epitaxial graphene nanoribbons. Besides AFM and TEM, scanning tunneling microscopy (STM/STS) as well as Raman spectroscopy were used to characterize the GNR structures. Thereby, we addressed three main questions regarding the potential growth of multilayers, doping, and the orientation of the ribbons.

Results & Discussion

After a predetermined thermal treatment of the SiC(0001), basically to remove residual scratched from former polishing steps, and subsequent mesa-structuring by means of optical lithography and RIE etching (for details see Ref. [8]), a final high temperature step around 1500 °C for 10 min. results in selevtive growth of GNR at the edges of the SiC-mesa. For the case of uniaxial mesa structures with a pitch widths of 2 µm the corresponding AFM image is shown in Fig.1a. The selective growth is nicely demonstrated by electrostatic force microscopy (EFM) seen as white strips in the lower part of Fig.1a. As mentioned above, the orientations of the edges of these GNR structures are crucial for the electronic transport prop-erties. Figure 1b) shows an atomically resolved STM image taken in the center of a sidewall GNR. As obvious the sidewall ribbon is oriented in zig-zag direction as expected for a mesa orientation along the <-1100>-direction. Most likely also the edges should reveal this zig-zag type orientation. However, their direct imaging with atomic resolution failed most likely due to the strong local inhomogeneity with respect to the morphology and band structure. Subsequently, tunneling spectroscopy was carried out with the same tip on the same sample area, leading to the spectra in Fig.1c). The dI/dV versus bias voltage exhibit the typical V-shape expected for graphene. Tunneling spectra recorded besides the ribbon on the mesa top (bottom) show band gaps of 1.3 eV (0.8 eV) indicating the presence of buffer layer growth and ensuring that the ribbon is electronically isolated from each other. Most importantly, the minima of the dI/dV of all spectra taken on the sidewall ribbon are precisely located at zero bias indicating charge neutrality which an important requsite for the ballistic transport behavior [8]. The method of choice for answering the question of multilayer contributions is Raman spectroscopy. A typical Raman spectrum of a sidewall GNR is shown in Fig.1d). All three visible peaks D (1382 cm^{-1}), G (1606 cm^{-1}), and 2D (2735 cm^{-1}) are characteristic for graphene. The peak positions are fully consistent with those for epitaxial monolayer graphene [9] From the ratio I(D)/I(G) = 0.14 the mean distance between defects was estimated to be larger than 40 nm [10]. The 2D peak can be fitted with a single Lorentzian with a line width of 40 cm^{-1}, a clear signature for monolayer graphene [11]. The mapping of the 2D peak shown in the inset confirms agai the growth of graphene only at the mesa sidewalls.

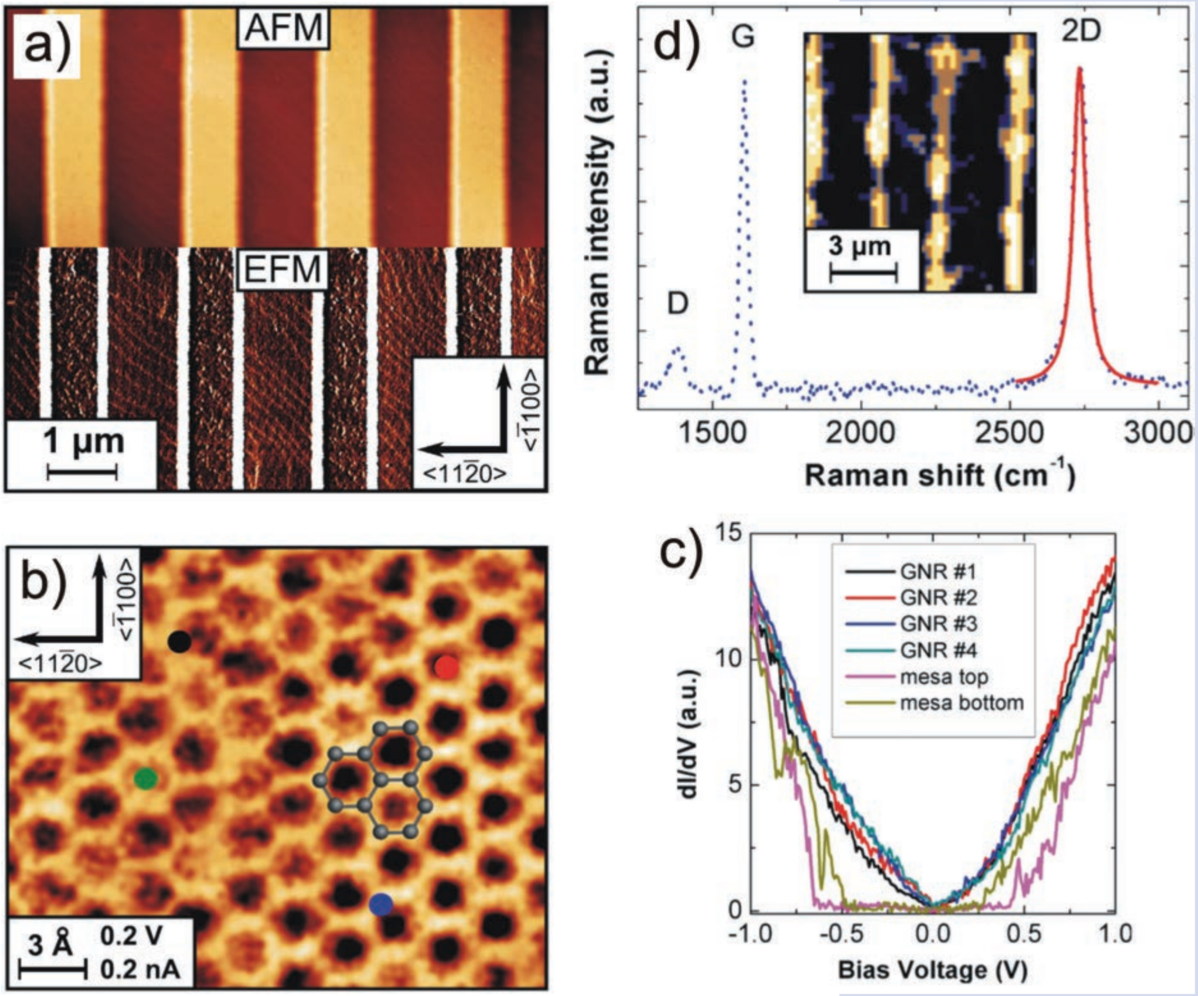

Figure 1: *a) AFM (top) and EFM image (bottom) of SiC samples after mesa structuring (1µm spacing)and graphene growth at the edges. b) Atomically resolved STM image of the nanoribbon. The points mark the positions of the tunneling spectra shown in (c). (c) STS of a sidewall GNR and of the surrounding buffer layer. d) Raman spectrum of sidewall graphene nanoribbons. The inset shows a mapping of the 2D peak intensity.*

To summarize we have characterized in this joint collaboration GNRs, grown selectively on the sidewalls of SiC mesa. The identification of charge neutrality, monolayer thickness as well as the zig-zag orientation is important and a prerequsiste for the ballisitic transport behavior.

Moreover, we measured in this context (not shown here) also single-channel ballistic transport by means of local 4-point probe experiments. Thereby, the mean free path of the ballistic ribbons was shown to be limited by the terrace width of the substrate. Additionally, a transition from diffusive to ballistic transport dependent on the roughness of the mesa sidewall was observed. Therefore, both the careful control the substrate roughness as well as the smoothness of the mesa sidewalls is essential for the synthesis of ballistic sidewall nanoribbons. For more details, the interested reader is referred to: J. Baringhaus et.al., Applied Physics Letters 106, 043109 (2015)

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[1] M. Eazwa, Phys. Rev. B 73, 045432 (2006). Figure 1: a) AFM (top) and EFM image (bottom) of SiC samples after mesa structuring (1µm spacing) and graphene growth at the edges. b) Atomically resolved STM image of the nanoribbon. The points mark the positions of the tunneling spectra shown in (c). (c) STS of a sidewall GNR and of the surrounding buffer layer. d) Raman spectrum of sidewall graphene nanoribbons. The inset shows a mapping of the 2D peak intensity.

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Aerogels from CdSe/CdS Nanorods with Ultra-long Exciton Lifetimes and High Fluorescence Quantum Yields

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Abstract

Hydrogels and aerogels from CdSe/CdS nanorods have been fabricated. By precisely controlling the gelation process, gels with high photoluminescence quantum yield and ultra-long exciton lifetime can be obtained. Thus, this type of assemblies represents a very promising way to fabricate materials that present new or improved characteristics with respect to both the colloidal solution and the bulk.

Introduction

Nowadays, it is possible to produce a huge variety of nanoparticles (NPs) in colloidal solution with different interesting properties and a wide variety of sizes and shapes, but the fact of being in solution is sometimes a limitation for the envi-sioned applications. Assembly methods serve as a powerful tool to connect nanoscale materials into macroscopic materials, giving rise to superstructures, such as hydrogels and aerogels that retain the original nano-properties [1].

In our work, we use semiconductor NPs, specifically CdSe/CdS nanorods, as building blocks for the fabrication of gels. This asymmetric core-shell system consisting of a CdSe core surrounded by a rod-shaped shell of CdS [2] is characterized by a high photoluminescence quantum yield (PLQY), due to the larger band-gap material in the shell that will force the exciton generated after illumination to recombine in the core [3].

The general methodology we follow to produced the gels consists of three main steps. The first one is a phase transfer of the NPs from the organic solvent to aqueous solution. Original TOP-TOPO ligands are exchanged by mercaptopropionic acid [4]. After the phase transfer, the NPs are subjected to a controlled oxidative process with hydrogen peroxide (H_2O_2) that removes part of the ligands in the surface of the NPs, they will interact with each other and they will form the hydrogels (Figure 1). In a last step the solvent in the pores (water) is removed by supercritical drying (SCD) to form aerogels (Figure 1). SCD is done in four main steps: the water in the gels is first replaced by acetone and then by liquid CO_2. Afterwards, the CO_2 is taken over its critical point and finally the gas is released. The gels were characterized by several techniques giving rise to very interesting results.

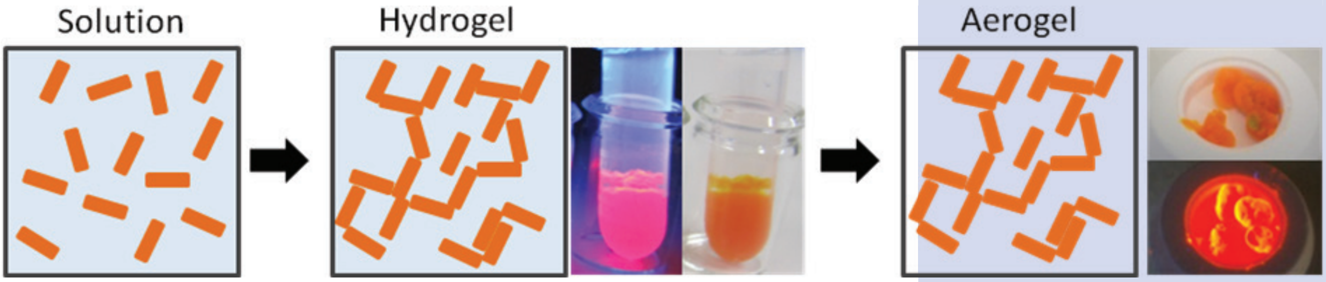

Figure 1: *Scheme of the general methodology followed for the preparation of the gels.*

Results and discussion

After analyzing the morphology of the gels by SEM and TEM it can be concluded that the gels have a highly porous structure, with pores ranging between 2 and more than 50 nm, and a nanoscopic morphology with connections between the rods mostly tip to tip, forming this network (Figure 2A).

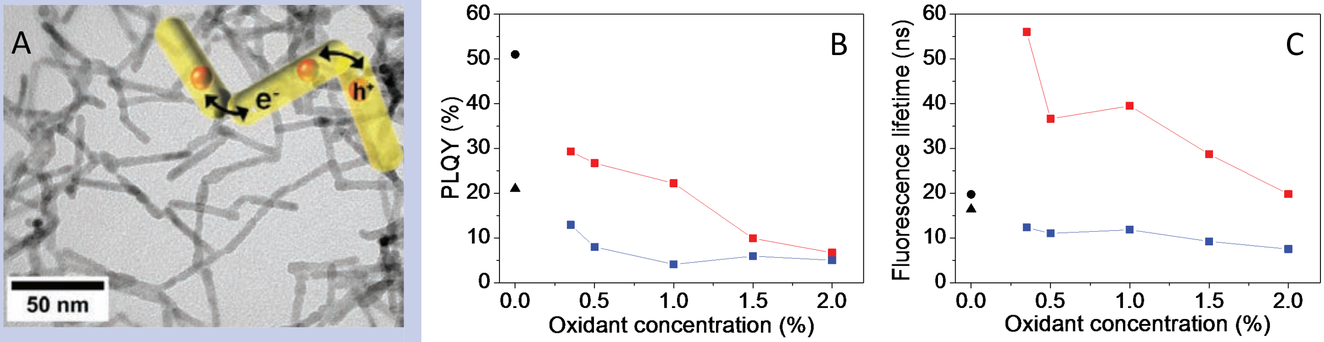

Figure 2: *TEM image of an aerogel and a sketch of the corresponding model (A). PLQY (B) and fluorescence lifetime (C) of hydrogels (blue) and aerogels (red) generated with different H2O2 concentrations. 0% H2O2 corresponds to the organic (black circle) and aqueous (black triangle) solution of the nanorods.*

The PLQY and the lifetime of the structures were measured as a function of the oxidant concentration (Figure 2B and C). It should be noted here that to our knowledge this is the first report on gels from CdSe/CdS nanorod system and moreover, that this is the first work reporting the PLQY of these structures, which due to their scattering nature are difficult to char-acterize. We observed that in all cases the PLQY of the aerogels is not only higher than the corresponding hydrogel but is also higher than the aqueous solution (at least for the three lower amounts of H_2O_2). Surprisingly, although we measure these high values of PLQY in the case of aerogels the values for the lifetime are extremely long. We have first a decrease in the non-radiative processes when going from hydrogel to aerogel and also the recombination process is slowed down in the aerogels. Taking all these things into account, we propose a model in which the NPs, that in colloidal solution are isolated, in the gels they form this network in which the inorganic parts are connected, creating a continuous structure in which the excited electron can be delocalized (sketch in Figure 2A). Consequently, lifetimes are strongly increased. The results of this work are published in Advanced Materials [5], work to which the reader is encouraged to read for a more detailed information.

Conclusions

In this work we have fabricated gels from CdSe/CdS nanorods with high PLQY (up to 29% for the aerogel generated with 0.35% H_2O_2) and long lifetimes (56 ns for the aerogel generated with 0.35% H_2O_2), in comparison to those of the nanoparticle building blocks. When assembling nanoparticles into macroscopic superstructures, new interparticle interactions arise and fascinating changes of physical properties are expected, confirming the famous axiom “The Whole is Greater than the Sum of the Parts”. Hence, CdSe/CdS nanorods gels are very promising as high-tech materials in light emitting diodes (LEDs), optical gain and sensors applications.

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