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MAX-PLANCK-GESELLSCHAFT

No. 8 FOCUS on Materials

MAX PLANCK INSTITUTE FOR METALS RESEARCH STUTTGART

Order in Disorder

Researchers of the Department "Low-Dimensional and Metastable Materials" uncovered hidden local symmetries in disordered matter by X-ray speckle cross correlation

Disordered matter, such as glasses and liquids, does not exhibit translational symmetry. A particular system is able to accommodate sequentially different local symmetries, among them the icosahedral local order, which belongs to the forbidden motifs in periodic structures. This mysterious and so far experimentally inaccessible localized order within disorder has been fascinating scientists for many decades, as it is held responsible for the undercooling of liquids and the existence of the glass state.

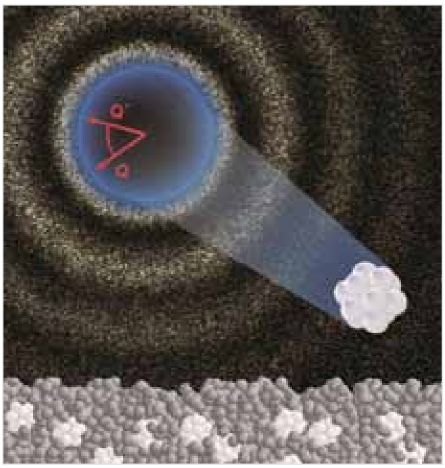


Figure 1: Schematic image of the X-ray speckle cross correlation analysis and how it describes local symmetries in disordered matter.

Researchers in the Department "Low Dimensional and Metastable Materials" (former Department Dosch) and their collaborators from DESY (Hamburg) and ESRF (Grenoble) have found a way to characterize localised order quantitatively. They scattered a coherent X-ray beam, like in a snapshot, from the instantaneous positions of all the atoms in the disordered sample. This way they overcame the limits of conventional diffraction, which yields only orientationally-averaged information. In addition, they analyzed the resulting speckle pattern (Fig. 2), which is a fingerprint of the local disorder, for angular correlations by calculating a newly developed 4-point correlation function $C_Q(\Delta)$.

In this study, highly concentrated glassy suspensions of sterically stabilised PMMA particles with an average diameter of 0.1 µm were investigated (Fig.2). Most fascinating is that $C_Q(\Delta)$ (Fig. 3) clearly reveals a very pronounced anisotropy with 5-fold symmetry, which points to a so far hidden local symmetry in the colloidal system. The emerging picture is that clusters of

continued on page 2

EDITORIAL

Dear Readers,

During the past 30 years, the Max Planck Institute for Metals Research has evolved from investigating basic phenomena in metals into a broadly-based materials science institute. Nowadays, scientists are interested in how the functions of materials at the atomic, nanoscopic and microscopic length scale influence their macroscopic behavior. The knowledge about the processes at the interfaces of two materials will help to design materials with specific properties.

This issue of Focus on Materials presents again the research activities of the different departments and groups illustrating the wide range of very interesting and successful materials research at the MPI for Metals Research. Enjoy Reading!

With best regards,

Joachim Spatz

Prof. Dr. Joachim Spatz
Acting Director

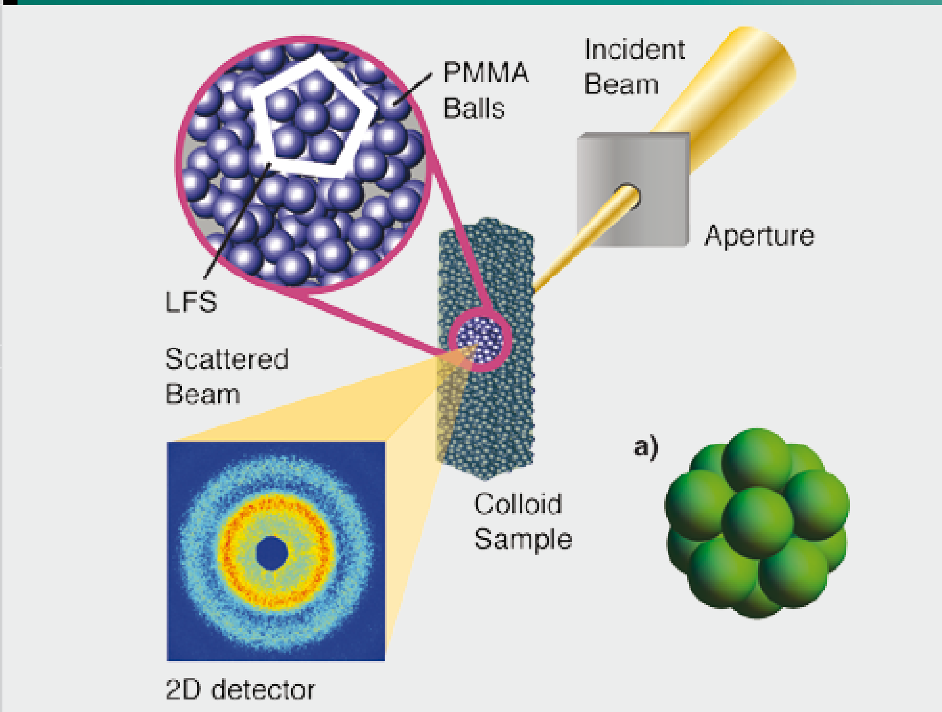


Figure 2: Sketch of the setup where a speckle diffraction pattern is generated in the far field when coherent X-rays illuminate a disordered sample. a) illustrates the local icosahedral symmetry.

Figure 3 a: Angular averaged structure factor, which is the standard radial intensity distribution.

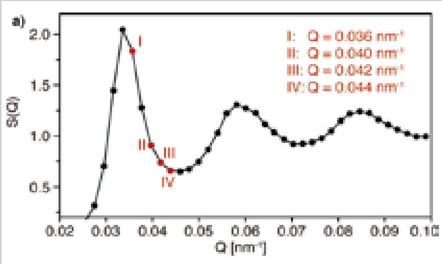
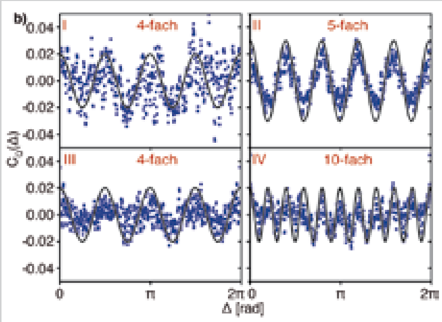


Figure 3 b: Experimental results after applying the cross-correlator $C_Q(\Delta)$ to the data at different Q values indicated in (a). Solid lines are a guide to the eye.



icosahedral order reorganize themselves and are formed either in nano-crystalline environments or out of complete disorder, all of which involves breaking and formation of bonds. Clearly, there is a wealth of new information about the kinetics and the origin of the glass transition to be mined from such experiments. The availability of short-pulse XFEL radiation in the 0.1-nm regime and with sub 100-fs pulse length will open up the fascinating option to analyze the local structure of liquids (in particular water) by applying the new concept of X-ray cross correlation analysis (XCCA) to single laser shot speckle diffraction patterns.

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P. Wochner, C. Gutt, T. Autenrieth, T. Demmer, V.N. Bugaev, A. Díaz Ortiz, A. Duri, F. Zontone, G. Grübel and H. Dosch
X-ray cross correlation analysis uncovers hidden local symmetries in disordered matter
Proc. Natl. Acad. Sci. **106**, 11511-11514 (2009). (Online: http://www.pnas.org/content/106/28/11511.full)

PEOPLE & NEWS

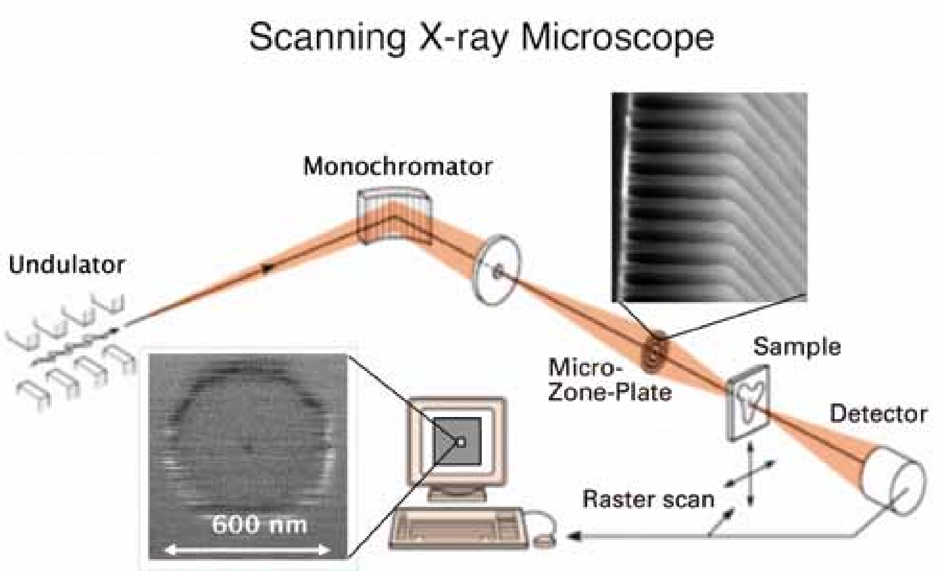
Boards Get New Members

The "Scientific Advisory Board" and the "Board of Trustees" guide, advise and support our Institute. Both have been re-constituted in 2009.

The Scientific Advisory Board (SAB) is an independent review board. It plays a key role in the evaluation process all Max Planck Institutes have to undergo regularly to ensure the sustained high quality and scientific research output. The SAB is made up of experts in materials science from all over the world who are appointed by the President of the Max Planck Society for a six-year term. In October 2009, the eleven members of the re-constituted SAB were in session for the first time. Professor Dr. Itamar Willner from The Hebrew University of Jerusalem, Israel, is the new chairman of the SAB. The complete list of members of the current SAB can be found on our homepage: The Institute > Organization > Committees.

The Board of Trustees bridges the gap between research and industry, society and politics. It consists of renowned personalities in these areas; some members of the Board of Trustees are alumni of the Institute. The Board of Trustees was re-constituted last year in autumn when the 17 members started their five-year term. Just as in the preceding term, Professor Dr. Winfried Huppmann from Liechtenstein once again chairs the Board. The list of members can also be found on our homepage: The Institute > Organization > Committees.

The Institute thanks the members of the Boards for their valuable support!



The principle of X-ray microscope: the highly intense, polarized and monochromatic undulator radiation is focused by means of a zone plate onto the sample and the transmitted beam intensity is measured with a detector system. The zone plate consists of concentric rings with thicknesses of about 20 nm that absorb the incident radiation. The required high aspect ratio (right figure above) is a challenge for the production by means of electron beam lithography. Using the circularly polarized radiation, small magnetic structures of about 10 nm such as a magnetic vortex core (figure on the left below) can be resolved with good contrast.

Perspectives of Nanostructures by X-rays

MAXYMUS – The most advanced scanning X-ray microscope

Optical and electron microscopes are now standard equipments in many areas of modern research and easily fit into a normal laboratory. In contrast, X-ray microscopes, which can be found at big research institutions like the synchrotron laboratories, are much less known. There is only about a dozen of such kind in the world. The researchers at the Department "Modern Magnetic Materials", headed by Professor Schütz, have developed such a device called MAXYMUS (MAgnetic X-raY Microscope with UHV Spectroscopy) in cooperation with Bruker ASC and the Helmholtz-Zentrum Berlin. Since mid-last year it has successfully begun its operation at the storage ring BESSY II in Berlin.

Here we use the absolutely parallel aligned (high collimated) and highly intense synchrotron X-ray radiation in the short-wavelength range. With a micro lens, which is based on the Fresnel Zone plate principle, we focus them onto the X-ray transparent sample. The width of the outermost concentric ring of the zone plate produced by the electron beam lithography limits the resolution of the system to 15 nanometer (nm) up to now. Worldwide, there are a number of approaches to drive this value down to the wavelength-limited resolution.

Another great possibility in addition to the spatial information and element selectivity is provided by the time structure of synchrotron radiation. This allows a temporal resolution of up to 10 picoseconds (10^{-12} seconds, 1000 picosecond = 1 nanosecond). With the use of polarized radiation that is uniquely available at the synchrotrons, the magnetization distribution and its dynamics can be mapped in addition to the morphological structures.

The new X-ray microscope MAXYMUS of the MPI for Metals Research is a worldwide novelty. While so far only X-ray transparent samples on a thin silicon nitride membrane could be studied in transmission mode, this particular system operating under high vacuum also allows investigating the non-transparent systems. This expands its spectrum of applications significantly in diverse research fields, especially in materials science.

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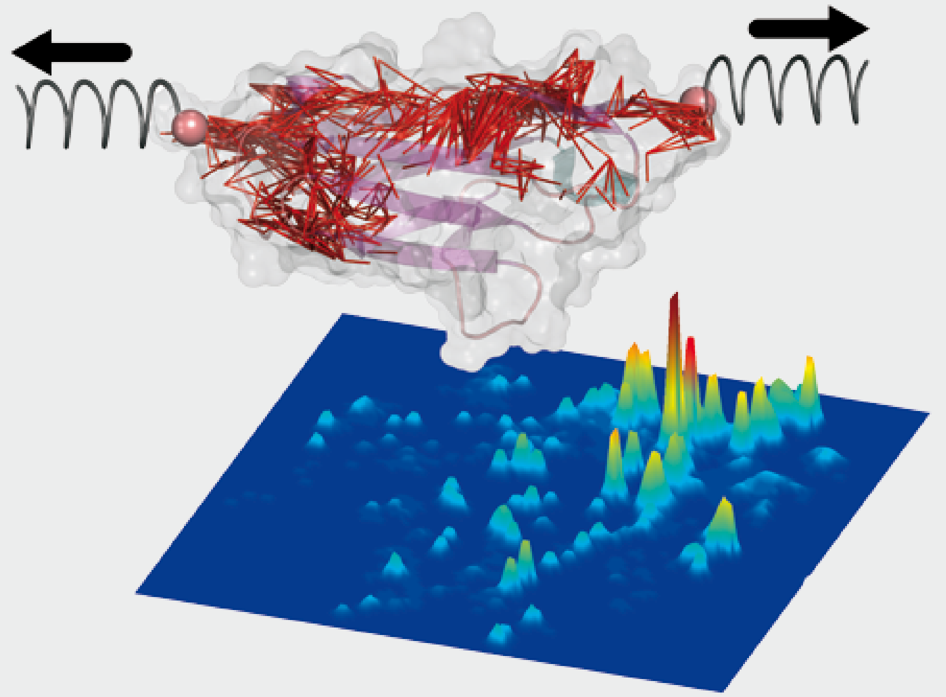
Aerial view of the electron storage ring BESSY in Berlin Adlershof that belongs to the Helmholtz-Zentrum Berlin.

The hutch of MAXYMUS at the helical undulator beam line.

Interior of MAXYMUS. The beam enters from the left and is detected with a detector system at the right.



A muscle protein being subjected to a crash test:
The force-bearing structure of an immunoglobulin domain found in muscle is shown in red. The springs indicate where the mechanical force has been applied to the protein. The same data on the distribution of stresses in the protein is shown in the diagram below as a 2D-projection.

Protein in the Crash Test

A bridge between Shanghai and Heidelberg

From 2007 to 2009, Dr. Frauke Gräter was an Independent Junior Research Group Leader at the MPI for Metals Research and the Partner Institute for Computational Biology, Shanghai. In the meanwhile, her group "Molecular Biomechanics" has moved to the Heidelberg Institute for Theoretical Studies (HITS). The following text gives an insight into her interdisciplinary research activities.

All living organisms react on mechanical forces with sophisticated mechanisms which are able to translate mechanical signals into biochemical signals and vice versa. The junior research group headed by Frauke Gräter aims at revealing the principles that allow proteins, the crucial players in this game, to respond to forces as they occur in muscle cells, silk fibers, or the shear flow of blood. High-performance simulation techniques and continuum mechanics models are developed and employed to identify and engineer the stress-bearing structural elements in complex biological materials. For describing the proteins of the size of a few billionth of a meter, Frauke Gräter and her co-workers make use of methods conventionally applied to meter-sized objects in mechanical engineering or the car industry, as for example for crash tests. On the long-term, this is expected to enable, among others, the design of polymer materials which are as tough as spider silk, but can be more readily synthesized.

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Honors & Awards

Prof. Dr. Eric J. Mittemeijer, Director of the Department "Phase Transformations", was honored with the IFHTSE Medal 2010 of the International Federation for Heat Treatment and Surface Engineering. The conference took place in Rio de Janeiro, Brazil, in July 2010.

Prof. Dr. Manfred Rühle, Acting Director of the Department "Low-Dimensional and Metastable Materials", was appointed Honorary Member 2009 of the Japan Institute of Metals as well as Fellow of the European Academy of Sciences.

Dr. Theobald Lohmüller, former member of the Department "New Materials and Biosystems", won the Klaus Tschira Award for the Public Understanding of Science in 2009 with his contribution "Die Motte hat den Durchblick" (The moth sees it all).

Dr. Christoph Koch received the Günter Petzow Prize 2009 during the Paul-Peter Ewald Colloquium on July 17, 2009. Mr. Koch has autonomously developed a new method for the calculation of the electric potential on internal interfaces in ceramic materials.

Last year, the Otto Hahn Medal was awarded to two Junior Researchers of the Institute: **Dr. Hendrik Hansen-Goos**, former member of the Department "Theory of inhomogeneous Condensed Matter" and **Dr. Markus Mezger**, former member of the Department "Low-Dimensional and Metastable Materials". The awards were presented during the annual general meeting of the Max Planck Society in June 2009.

Dr. Hendrik Hansen-Goos was also honored with the "Preis der Freunde der Universität Stuttgart" (Award of the Friends of the University of Stuttgart) for his outstanding scientific achievements.

Dr. Claudia Pacholski, Department "New Materials and Biosystems" has been admitted into the "WIN Kolleg" (Junior Academy for Young Scholars and Scientists) of the Heidelberg Academy of Sciences and Humanities in 2009.

Prof. Dr. Manfred Fähnle, Department "Modern Magnetic Materials", was awarded the 2009 Faculty Teaching Prize of the University of Stuttgart.

Dr. Ralf Richter, Junior Research Group "Model systems of glycan-rich cellular coats", received the "Ramon y Cajal – Advancement Award" from the Spanish Ministry of Science and Innovation.

In 2009, **Dr. Sylvie Roke**, Max Planck Research Group "Nonlinear Spectroscopy of Bio-Interfaces", received one of the coveted European Research Council Starting Independent Researcher Grants valued at 1.1 Mio. Euro.

Kyung Sub Jung, Department "Phase Transformations", won the Young Scientist Award 2009 of the European Materials Research Society.

During the Paul-Peter Ewald Colloquium on July 17, 2009, Professor Günter Petzow (right) and Professor Joachim Spatz (left) awarded Dr. Christoph Koch (middle) the Günter Petzow Prize 2009. Dr. Christoph Koch received this award for his internationally acclaimed work on the development of a new method for the calculation of the electric potential at internal interfaces in ceramic materials.

Günter Petzow Award 2009 for Dr. Christoph Koch

New methods for the measurement of the electric potential at internal interfaces

Since 2005, the Institute has awarded the Günter Petzow Prize to a junior researcher of our Institute for his or her outstanding research. The awardee presents his research activities during the Paul-Peter Ewald Colloquium and receives 2.000 Euros in prize money.

In 2009, Dr. Christoph Koch, scientist at the Stuttgart Center for Electron Microscopy (StEM), was honored with this award. Mr. Koch investigates internal boundaries in ceramic materials, working at the frontiers of what is currently experimentally possible. During the last three years, Dr. Koch has been developing a new method which allows very precise measurements of the time it takes for an electron in the transmission electron microscope (TEM) to traverse a very thin, only several nanometers thick specimen (Ultramicroscopy 108 (2008) 141-150). This information allows one to make inferences on the distribution of charges and magnetic fields within the sample and can even be used to significantly extend the resolution of a TEM. Together with Burak Özdöl, a PhD student at the StEM, he has also applied this method for measuring very precisely the mechanical strain of transistor structures in most recent technology computer processors with very high spatial resolution (Applied Physics Letters 96 (2010) 091901).

The performance of solid oxide fuel cells is often limited by the ion conductivity of the ceramic membranes within them. The method developed by Dr. Koch now provides the necessary precision for measuring the electrostatic potential and the charge distribution associated with it at internal boundaries within such ceramic materials (International Journal for Materials Research 2010/01 (2010) 43-49).

The applications of this method and the software developed for it have already left the walls of this Institute. Examples of current collaborations include the characterization of the electrical properties of defects in solar cells at the Helmholtz-Zentrum Berlin für Materialien und Energie and the investigation of intergranular glassy films at metal-ceramic interfaces at the Technion in Haifa.

EVENTS CALENDAR

Mondays, 5:00 pm, during semester
Materials Science Colloquium
Werner Köster Lecture Hall 2R4

Tuesdays, 5:15 pm, during semester
Physics Colloquium
Universität Stuttgart:
Lecture Hall V57.01
Pfaffenwaldring 57
MPI Campus: Lecture Hall 2D5

November 17, 2010
5:30 p.m., 2 R4
(Werner Köster Lecture Hall)
Public Lectures by Young Scientists of the Institute (in German):

Dr. Max Nülle
"Collaborative Research Initiative between Institutes of the Max Planck Society: Neutron Reflectometer N-Rex^{+} at the FRM II (Garching)"

Sairamudu Meka, M. Tech.
"Unusual phase-transformation phenomena during nitriding of iron-based alloys"

Preview 2011:

April 02, 2011
10:00 a.m., Max-Planck-Campus
Open House/Science Day; more information and invitation will follow.

July 07/08, 2011
The Institute will celebrate its 90th anniversary in Stuttgart-Büsnau; more information and invitation will follow.

For more details see: www.mf.mpg.de > News

Island of Mainau I

Neither Lake Constance nor the flower island of Mainau could have presented themselves in a more picturesque fashion on July 3, 2009: The sun was shining brightly in the clear blue sky and a fresh wind was blowing across the water. It was the most perfect weather for the boat trip from Lindau to the Island of Mainau on the occasion of the 59th Lindau Nobel Laureate Meeting. Aboard the ship guests from all over the world – Nobel prize laureates and young scientists – got to know the State of Baden-Wuerttemberg as well as the state's "research in chemistry". About 20 institutions of higher education, research facilities and companies presented their research activities on the ship chartered by the Ministry of State of Baden-Wuerttemberg. Our Institute was represented by Lisa Maus, Lindarti Purwaningsih and Dr. Roberto Fiammengo, Department "New Materials and Biosystems". Thanks for the commitment!

Island of Mainau II

Exhibition "Discoveries 2010 – Energy"; the MPI for Metals Research presented: "A spatial miracle: MOFs as hydrogen storage"

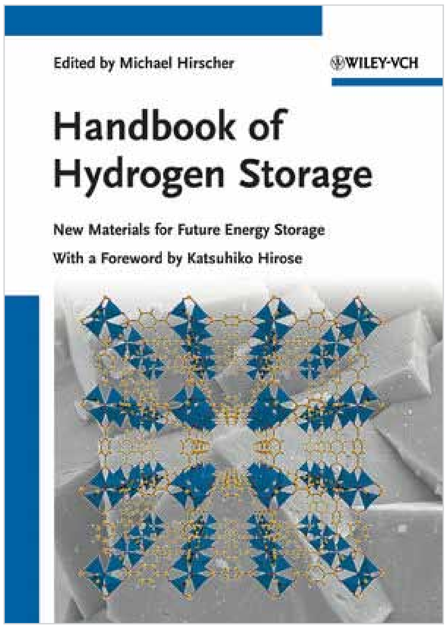
Within the context of the Year of Science 2010, "The Future of Energy", the Island of Mainau in Lake Constance showed the exhibition "Discoveries – Energy". The Max Planck Society presented three fundamental research projects showcasing some of its activities in energy-related research. Besides the MPI for Metals Research, the MPI for Solid State Research and the MPI für Kohlenforschung took part in the event. Our Institute was represented by the research group of Dr. Michael Hirscher, Department "Modern Magnetic Materials". The Group introduced its research activities on the material class of so called MOFs (metal-organic frameworks) for hydrogen storage.

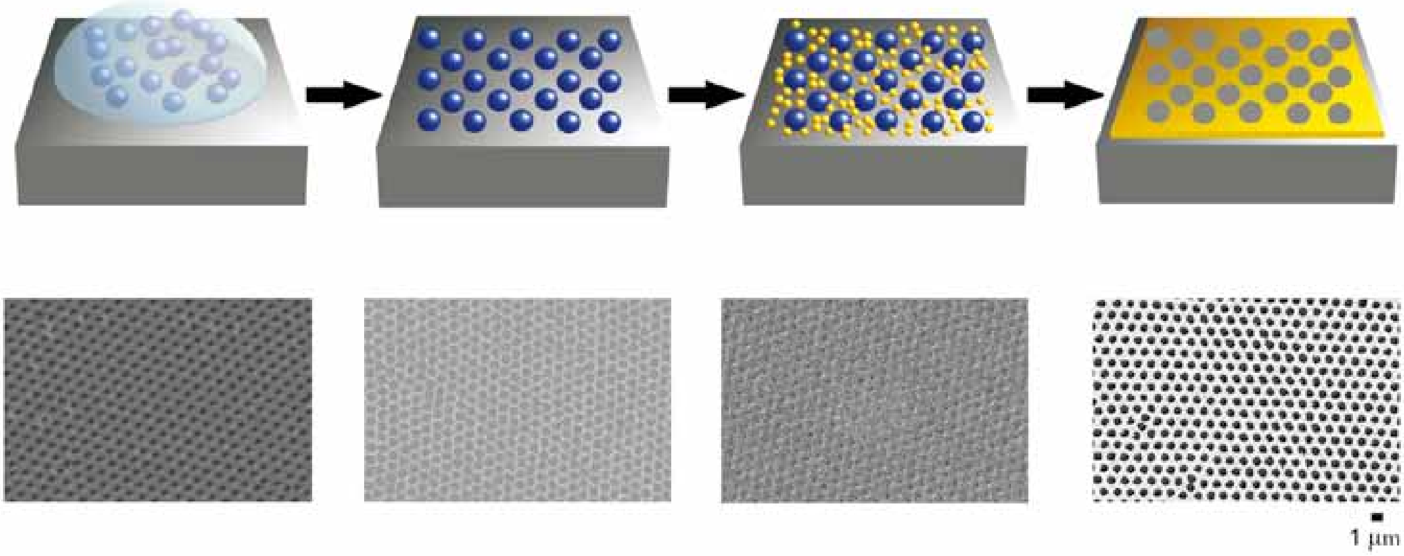
At room temperature and normal atmospheric pressure, hydrogen (H_2) is a very light and volatile gas. This is what makes storing it one of the greatest challenges facing the hydrogen energy industry. Large quantities of H_2 can be stored relatively well in liquid form at very low temperatures (-253°C). However, this is very energy-intensive and requires a certain type of specially insulated tanks. It is also possible to store hydrogen at very high pressure (up to 700 bar), but the achievable storage density is low: a fuel cell car with a range of 400 km would need to have a special, expensive high-pressure tank with a volume of about 200 l. The yardstick for hydrogen storage is the fuel cell car. But if we are to use hydrogen as a fuel on a large scale, a "tank" still needs to be developed that is lightweight and small in volume, but that can store large quantities of hydrogen, as well as absorb and release it again at a fast enough rate.

MOFs are a new class of crystalline solids currently being studied at the Max Planck Institute for Metals Research. Within the MOFs, clusters of metal and oxygen with organic molecular linkers form a threedimensional lattice. This hollow network structure, which makes the MOFs very light and exceptionally porous, means that there is an extremely large internal surface: a piece of the MOF the size of a sugar cube possesses about the surface area of a soccer field. The enormous surface offers space for a great many hydrogen molecules to attach at low temperatures of "only" -196°C due to Van der Waals Forces. Through this process of cryo-adsorption hydrogen can be stored efficiently and in a technologically utilizable manner since in this way H_2 can be packed more densely than in a gaseous state.

MOFs were one of the topics presented at the exhibition "Discoveries – Energy" by the Max Planck Society, May 20 to August 29, 2010. Further research activities concerning energy in general and fuel cells and hydrogen storage in particular were also presented on the Island of Mainau in Lake Constance.

You can find further detailed information on hydrogen storage in the "Handbook of Hydrogen Storage" published recently. The book offers a comprehensive overview on the most current approaches to hydrogen storage in solids and illustrates their advantages as well as their limits.
Editor is Dr. Michael Hirscher,
ISBN-10: 3-527-32273-6, Wiley-Verlag.





On the Track of Tumor Cells

Members of the Department "New Materials and Biosystems" develop optical biosensors for the detection of tumor cells in cooperation with the University of Stuttgart

Schematic representation of the fabrication process of optical biosensors (top row) and scanning electron microscope images of the respective steps (bottom row). Highly ordered hole arrays in gold films are achieved using solely simple chemical methods.

For physiological processes, as for instance wound healing or immune response, the active locomotion of single cells or cell structures within an organism is essential. Additionally, this so-called migration is a key characteristic of tumor cells: They first break out of the primary tumor tissue; then they invade the extracellular matrix via proteolysis, i.e. controlled local degradation; finally they enter the blood and lymphatic system. In cooperation with the University of Stuttgart (Dr. Angelika Hausser, Institute of Cell Biology and Immunology), Dr. Claudia Pacholski and Stefan Quint developed an optical biosensor for the fast and easy detection of the invasive potential of tumor cells.

Biosensors consist of two principal components: a sensitive recognition element and a signal-gathering element. The latter transforms the effect contained within the sensitive, biological layer into a measurable signal. For the detection of tumor cells, we use extracellular matrix components (collagen) as the sensitive recognition element and a gold film with highly ordered hole arrays as an optical signal converter. Using this diffraction grating, the surface plasmon resonance of the gold film, which reacts particularly sensitive to changes of the refractive indexes, can be stimulated even in transmission.

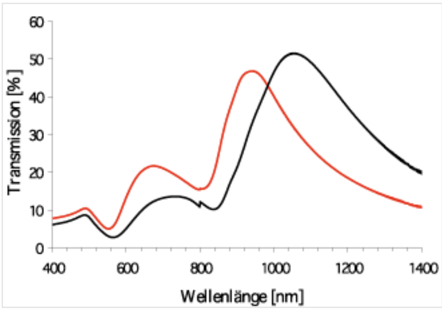
To date, such structures in gold films have been produced by elaborate physical processes. The new method only consists of chemical processes. First, a mask of hydrogel spheres is produced on a glass substrate. The self-assembly properties lead to a two-dimensional array of polymer disks with defined spacing. The polymer discs serve as a mask for the deposition of a gold film by selective electroless plating.
After the removal of the polymer mask, the optical biosensor becomes operational.
This project is supported by the Heidelberg Academy of Sciences and Humanities.

Contact: pacholski@mf.mpg.de

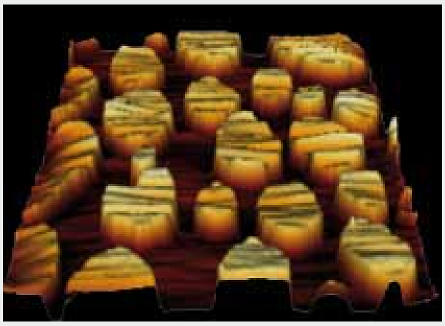
Sources:

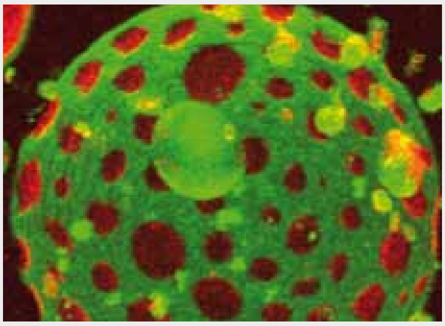
S. B. Quint, C. Pacholski, **A chemical route to sub-wavelength hole arrays in metallic films**, J. Mater. Chem., 2009, T19, 5906-5908

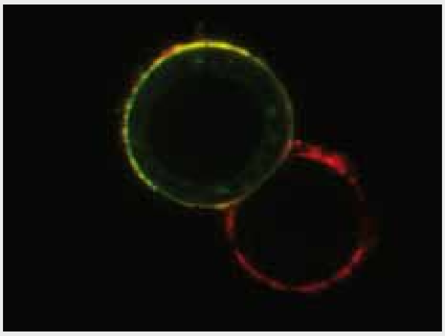
A. Hausser, C. Pacholski, **Detektion extrazellulärer Matrixdegradation durch einen Biosensor**, Biospektrum, 2008, 5, 485-487

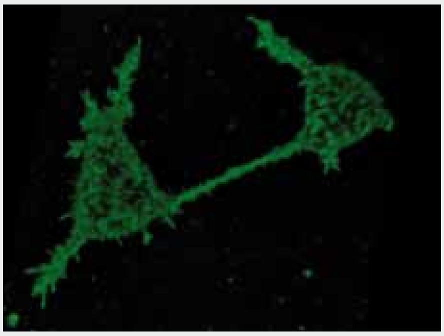


Transmission spectra of an optical biosensor before (red) and after (black) adsorption of a protein at the surface of a sensor. The transmission changes because of the change in refractive index and thereby detects adsorbed or bound bio molecules.









Membrane Biophysics

The Research Group "Membrane Biophysics", headed by Dr. Ana Garcia-Saez, applies fluorescence correlation spectroscopy, atomic force microscopy and single particle tracking to in vitro reconstituted systems in order to characterize the complex interaction networks between the members of the Bcl-2 proteins.

The pictures show images obtained in different membrane model systems. From top left to bottom right: scanning microscope image of a lipid bilayer; 3D picture of a huge liposome (GUV); vesicle of a cell membrane marked by fluorescence; living cell marked by fluorescence.

Pictures: Dr. Ana Garcia-Saez

New Junior Research Group at the Institute – Cooperation with Heidelberg

Membrane Biophysics

Since the beginning of this year, there is a new Junior Research Group at our Institute. The group is headed by Dr. Ana Garcia-Saez and works together with the German Cancer Research Center (Deutsches Krebsforschungszentrum, DKFZ) at the BioQuant in Heidelberg. The investigations are on protein-protein- and protein-membran-interactions via biophysical methods.

To remove damaged or even dangerous cells from the body, cells use a special kind of programmed cell death called apoptosis. The initiation of apoptotic cell death needs a strict regulation as increased or decreased cell death both can also be dangerous or even lethal for the organism.

The apoptotic death of a mammalian cell can be forced by the immune system or the cell itself can induce it after sensing potentially dangerous changes (e.g. DNA damage or increased concentration of reactive oxygen species). At later stages, apoptotic cells develop into vesicles that contain the cellular components, called "apoptotic bodies", which can be engulfed by macrophages and thus removed from the tissue. This procedure allows a complete removal of the dying cell without any inflammatory reaction or tissue damage.

A critical role in cell death is played by mitochondria, which are known as the powerhouses of the cell. The permeabilization of the outer mitochondrial membrane is an early step in apoptosis, which enables several proteins to relocate to the cytosol leading to the activation of special proteases called caspases. Their activation is a unique hallmark of apoptosis, responsible for activation of several key components in the pathway as well as for the digestion of the cell interior.

The proteins of the Bcl-2 family are key players in the control of mitochondrial membrane permeabilization. Due to their function, the Bcl-2 proteins have an important role in tumor formation and in cellular responses to anti-cancer therapies. Although their mechanism of action and the interaction among the family members is of great therapeutic interest, it is still not fully understood.

The group of Dr. Ana Garcia is studying dynamic membrane processes and has a special interest in the Bcl-2 proteins. Furthermore, investigations on the interplay between the Bcl-2 proteins and proteins regulating mitochondrial fusion and fission are planned, as Bcl-2 proteins are shown to affect mitochondrial morphology. To follow all these protein interactions quantitatively an in vitro system has been established.

The Institute wishes Ms Garcia-Saez and her colleagues an enjoyable and successful research.

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IMPRINT

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