empa News

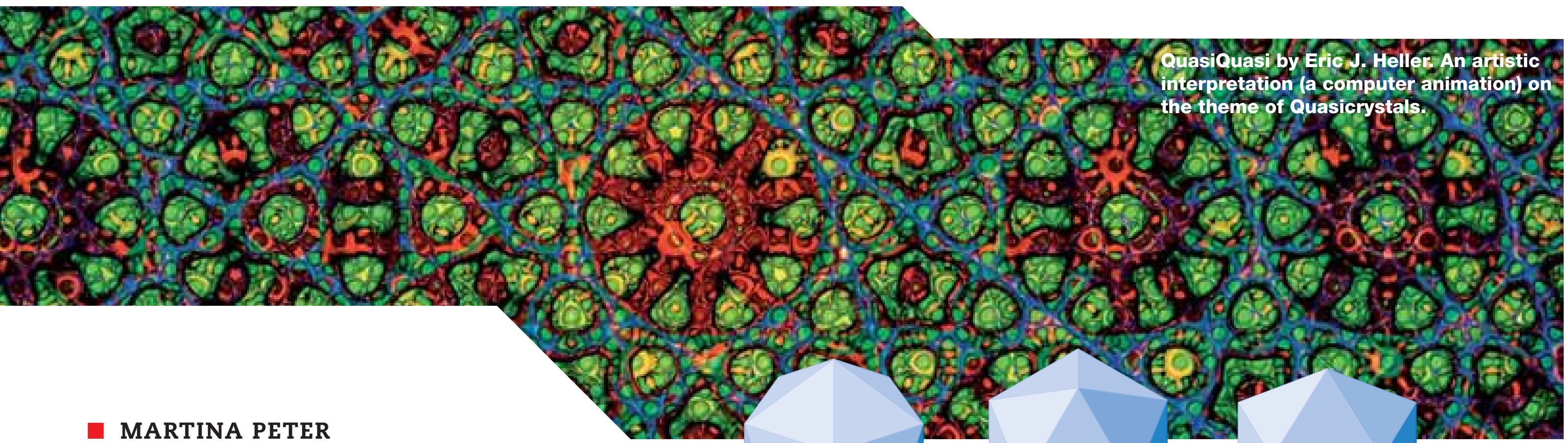
Empa, an Institution of the ETH Domain for Materials Research and Technology

Quasicrystals

Basic research

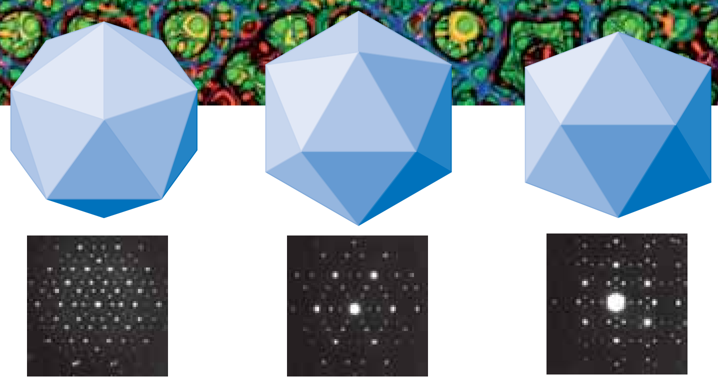
Mysterious metal alloys with great potential

Quasicrystals have exotic-sounding physical properties. Researchers at Empa are attempting to understand them by deciphering the laws that govern the structure of quasicrystals with the aid of a low-temperature scanning tunnelling microscope. This knowledge could be used in the future as the basis for developing alloys with customized properties.



QuasiQuasi by Eric J. Heller. An artistic interpretation (a computer animation) on the theme of Quasicrystals.

■ MARTINA PETER



Shown on the left: the electron diffraction pattern of a quasicrystal of aluminium-manganese. The icosahedron views on theright-hand side show how the quasicrystalline symmetries correspond to those of the icosahedra.

In the 1980s scientists discovered a new class of materials, which actually ought not to exist at all. The materials in question occurred in abruptly cooled aluminium-manganese alloys. When the researchers examined the alloys using X-ray diffraction, they found regions with a regular spatial arrangement of atoms. However, in contrast to the classic crystalline structure of 2-, 3-, 4- or 6-fold rotational symmetry, these regions exhibited a 5-fold structure. 5-fold symmetry was thought to infringe the laws of crystallography – for the same reason that 5-sided floor tiles don't exist: it's impossible to tile a floor with equilateral pentagonal shaped tiles without leaving gaps. Although a 5-fold rotation symmetry precludes a periodic structure, experiments did reveal regular diffraction patterns. This is why the structure became known as «quasicrystalline».

New class of solid with astounding properties

It quickly emerged that the new materials have exiting and exceptional physical properties. Although they are metal alloys, quasicrystals behave electrically and thermally more like semiconductors. They are hard yet elastic at the same time. Their low coefficients of friction and exceptionally low surface energies in combination with their remarkable hardness make them ideally suited for applications in tribology where it is desirable to keep friction and wear on reciprocating bodies as low as possible.

Finding out why quasicrystals are stable at all, accurately defining their physical properties and identifying the laws that govern the structure of quasicrystals could be the key to producing alloys with customized properties at some point in the not too distant future. Empa scientists are involved in studies of the local electron structure of quasicrystals, which aim at elucidating these enigmatic solids.

Atypical electron structure of quasicrystals

Nearly all physical properties of solids can be attributed to their valence electrons, which physicists describe with what is known as the electron band structure. This provides information about every single possible energy state of all electrons in a solid body, usually in the form of an energy wave number vector diagram. Depending on the profile of this band structure, it is possible to draw conclusions, for example about a material's metallic-conducting, semi-conducting or insulating electrical properties.

The electron band structure of a crystalline solid is determined by the periodic arrangement of the atoms in the crystal lattice. Quasicrystals, which reveal specific rotational symmetries but are not periodic, would not, strictly speaking, be expected to have a band structure of this type. Theory merely predicts relatively strongly localized electron states. Physicists speak of «critical» electron states. However, so far it has not been possible to obtain experi-

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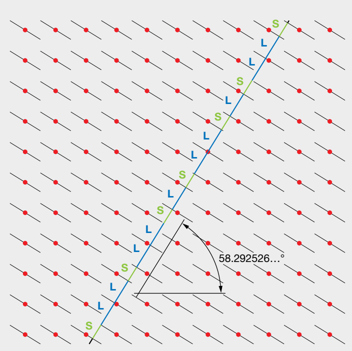
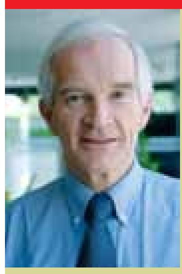
Quasicrystals can be justified mathematically

A periodic crystal lattice can be constructed in a **6-dimensional** space, which, when projected onto 3D space at a specific angle (58.29°), results in the quasicrystalline structure. This can be illustrated using a **2D lattice** of dots through which lines of equal length are drawn. If this regular lattice of rods is intersected by a line at an inclination of 58.29°, the result is a sequence of short (S) and long (L) sections on the **1D line**. The sequence of these sections is aperiodic and is never repeated. The Fibonacci sequence (0, 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89, 144 etc.) can be seen in the «1D quasicrystal»: both the ratio between the lengths of the L and S sections as well as the ratio of the number of long and short sections correspond exactly to the golden mean.

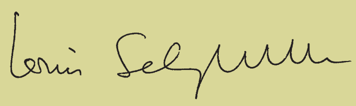


Editorial



Opportunities, yes! But what about the risks?

Innovations are based on new technologies, which, in turn, often originate from new materials. New materials are thus increasingly becoming the very engine of innovation. In this context, nanotechnology is one of the most promising fields of activity. However, every new technology is accompanied by potential risks, which must be evaluated as carefully and as early as possible. This was the case with the introduction of electricity as a source of power, and with the automobile as a widespread means of transport. With the increasingly popular application of techniques and materials using nanoscale effects things will be no different. The aim of the economic world is to find and nurture profitable innovations derived from new technologies. The duty of the state is to pass legislation, when necessary, to ensure the safe handling of the new materials. Both these tasks – developing innovations and dealing with potential dangers in a responsible way – demand in-depth knowledge. This is Empa's role: to acquire the knowledge in question and to transfer it to the relevant stakeholders. Empa fulfills this obligation of course also in the field of nanotechnology.



Louis Schlapbach, CEO Empa

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mental proof of these electron states, which are unknown in «genuine» crystals with «normal» rotational symmetry.

Indications of the existence of critical states

Empa was the first research institution to successfully measure the local electron structure of quasicrystals in the subnanometer range with a low-temperature scanning tunnelling microscope. At temperatures of -268° Celsius they found evidence pointing to the existence of «critical states». The studies showed that they are localized to regions with a volume of about 1 x 1 x 1 nm^3.

There are plans to investigate the electron structure of other quasicrystals in order to achieve an even better understanding of these awkward materials. Models developed from this research will then make it possible to accurately characterize and maybe even predict the physical properties of this «new» type of crystals. ■

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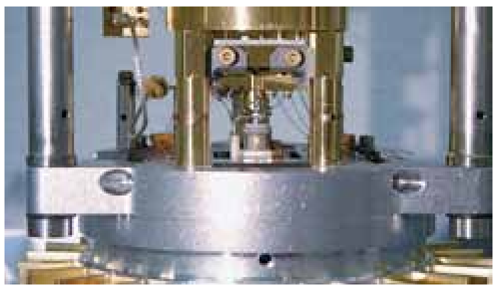

A look into the low-temperature scanning tunnel microscope (LT-STM), which operates at a temperature of 5 Kelvin (-268°C). The instrument operates at a temperature of 5 Kelvin, achieving a spatial resolution of about 0.01 nm and an energy discrimination of 5 meV.

A significantly better understanding of quasicrystals

Empa was one of the co-initiators of the «smart quasicrystals» project in the 5th Framework Programme financed by the EU. In this project scientists produced metal alloys and investigated both their properties and their use in thin layers. Empa researchers participated by studying the local electron structure of quasicrystals and by precipitating quasicrystals in ultra-thin layers. The project lead to the Network of Excellence «Complex Metallic Alloys» in the EU's 6th Framework Program, in which the Empa holds one of the three coordinator positions.

Nanotechnology is more than just Nanoparticles

Nanotechnology deals with the use of materials composed of nanometer-sized constituent elements, the exploitation of novel material properties in this dimension, and physical, biological and chemical phenomena on the nanometer scale. Every individual application of the new technology brings with it its own particular opportunities and dangers, which must be assessed on a case-by-case basis. When considering the yet-to-be-evaluated health risk of particles capable of penetrating deep into the lungs, for instance, it must be kept in mind that this refers solely to nanoparticles moving freely in the air, that is, in the form of aerosols (some of which are emitted by automobiles). Nanoparticles, which are bound within a product – for example the magnetic nanoparticles to be found in data storage devices of computers – or those that have agglomerated to form larger «microparticles» can be regarded as harmless in this respect.

Where there is light, there is also shadow

«The world will be a better place thanks to nanotechnology» – that at least is the promise of the marketing departments in the nanotechnology sector. But in contrast to its potential for improving the properties of materials and products, nanotechnology may also involve certain risks. The Empa is involved in the NanoRisk project, which deals with possible negative aspects of various nanoparticles. The aim is to encourage the development of innovative technologies which are safer and more successful in the long term.

■ MARTINA PETER

Nanoparticles hold the promise of numerous new materials with tailor-made functional properties. Already today there are countless nano-products available on the market. But how do nanoparticles behave in the human and animal organisms? Or in the environment? And how should legislative bodies, employers or even consumers deal with these new nanomaterials?

Knowledge helps to assess risks

As the materials science research institution of the ETH-Domain, Empa investigates and exploits the opportunities offered by nanotechnology. In addition, however, it is also one of the few research bodies tackling the question of potential dangers involving the new technology. For example it is investigating the effect of nanoparticles on cells and cell metabolism (see the article «Are Nanoparticles dangerous to Human Cells?» on the Empa toxicity study). In this context the institution initiated the «NanoRisk» project in early 2005.

Empa researcher Claudia Som began to collate existing information on the risks to health and the environment posed by nanotechnology. Data – for example from the toxicity study mentioned above, from testing on animals and from investigations on the distribution of nanoparticles in the environment – are being used to assess the dangers posed by nanoparticles and nanotubes to humankind and the environment. In addition scientists from Empa's «Technology and Society» laboratory are analyzing all studies available performed on the subject of nanotoxicology and are consulting experts to assess the studies' strengths and weaknesses. Preliminary results indicate that there are relatively few reliable investigations covering this field, and they are sometimes contradictory. One reason for this could be that the nanoparticles under consideration were frequently not well defined, and the researchers therefore often did not know exactly what shape and size the particles under study actually possessed.

NanoRisk

Two Empa laboratories, «Technology and Society» and «Materials-Biology Interactions» are involved in the «NanoRisk» project, which is financed by the Swiss Federal Office of Public Health (FOPH), the Innovation Promotion Agency (CTI) and the Federal Office for the Environment (FOEN).

In a second phase of the project, Empa scientists will investigate in depth specific examples of applications using carbon nanotubes, covering manufacture, the fabrication of finished products containing the nanoparticles, as well as their disposal. The aim of this so called life-cycle assessment is to collect data on when nanoparticles are released into the environment and in what quantities. This will enable researchers to develop strategies for avoiding future problems and minimizing risks. ■

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On the trail of the «Black Magic Dust»

When your white terrier all of a sudden has black paws after a stroll through your living room – even without having been outdoors – then something is wrong. When black patches suddenly appear on the ceilings and walls in an apartment this is more than just an annoyance. It is often assumed that soot is the cause, and the finger is then pointed at the fireplace, candles or heavy smokers as the source. Most of the time, though, the problem is not quite that simple.

■ RÉMY NIDERÖST

These dark stains, known as «Black Magic Dust» because of the way they appear so suddenly and unexpectedly, are frequently described as black or dark-gray oily smears. They develop primarily above radiators, on curtains, window frames, synthetic surfaces, electrical devices and on the inside surfaces of external walls. The stains usually appear when the heating is on, with living rooms being most heavily affected.

Black Magic Dust – what is it really?

A rapid and economic way of ascertaining whether these dark stains do really contain soot is to investigate samples with a scanning electron microscope or SEM. Soot particles cannot be identified with a normal optical microscope, but using the much higher magnification of the SEM, Heinz Vonmont of Empa's Analytical Chemistry laboratory can quickly spot them. Soot consists of spherical particles with diameters of 20 – 100 nanometers (nm), which adhere to each other, forming chains or clumps. It is not possible, however, to determine the source of the soot – be it a candle, a diesel motor or an oil-fired central heating system – by visual means alone, since the particle morphologies are practically identical.

To trace the origins of the deposits Empa researcher Markus Zennegg determined the chemical composition of the «Black Magic Dust», investigating samples wiped off stained surfaces in affected rooms. Measurements made with a gas chromatograph – mass spectrometer (GC-MS) revealed that the major constituents were compounds known as «semi-volatile organic compounds», in short «SVOCs». Among other chemicals these include plasticizers, which are used in large quantities to improve the handling and usability of many plastics. Other SVOCs were also identified, such as fatty acids originating from candle wax, leather goods or cosmetics.

Many sources of black dust

The German ministry of health in Berlin, the UBA, has been tackling the problem of «Black Magic Dust» for the last ten years or so. UBA experts have investigated several thousand cases over this period, and they have noticed that this phenomenon occurs most frequently after renovation work or when a new apartment is occupied for the first time. There are many possible sources,

How do human cells react to nanoparticles?

Empa researchers have developed cell assays, which quickly and simply evaluate the toxicity – the poisonousness – of these minute particles. First results show that one nanoparticle is not the same as another – hence not a simple case of: «Seen a thousand, seen them all.»

MICHAEL HAGMANN

Nanoparticles – particles with diameters of just a few nanometers, often consisting of just a couple of molecules – possess different physico-chemical characteristics than larger particles of the same substance. They can be used to make dirt repellent shirts, scratch-proof coatings, better computer hard-disks or more effective sun screens. But how does the human body react to these tiny structures? What effects do nanoparticles have on cells and tissues? Nanoparticles are approximately the same size as the protein molecules in cells. so they should easily be taken up by them.

Cell cultures as guinea pigs for toxicity tests

«If these novel materials are to be used on a large scale, we have to be sure that their new physico-chemical properties do not have unexpected effects on the human organism» says cell biologist Peter Wick. Together with Empa colleagues and scientists from the Institute for Chemical and Bio-Engineering of the ETH Zurich, he has developed a quick and simple test system, which does not involve testing with animals.

An ideal candidate would be cell cultures, such as those already used for the toxicity assessment of chemicals. «We realized rather quickly, however, that it is not so easy with nanoparticles,» admits Wick. «Fortunately we had the help of our material scientists at Empa.» They revealed a few tricks to the biologists as to how to suspend nanoparticles in the culture medium without allowing them to form clumps. Now the scientists always know the shape and size of the nanoparticles they are dealing with. Their ETH colleagues have, in the meantime, even managed to separate nanoparticles depending on their shape and size.

Not all nanoparticle are equally harmful

Wick and his team have investigated the cell toxicity of seven industrially important nanoparticles, which they obtained from their ETH colleagues, from the supposedly harmless silicon oxide (which has long been used as a food additive, for example in ketchup) via titanium and zinc oxides (used in cosmetics) to cerium and zirconium oxides (used in the electronics industry). For comparison, the researchers also tested asbestos fibers, whose toxic effect on cells is well known. As «guinea pigs» they used cell lines of two cell types, namely human lung cells and mouse fibroblasts. The metabolic rate and rate of division of the cells, as well as their appearance under the microscope served as a yardstick to measure their state of health. The conclusion drawn by the study? «Some nanoparticles are more toxic than others,» says Wick.

The scientists created a sort of «toxicity ranking» between asbestos and silicon oxide. While iron oxide and zinc oxide particles caused significant damage to human lung cells, tri-calcium phosphate (which is used on medical implants) proved to be as well tolerated as silicon oxide. Nanoparticles of titanium, cerium and zirconium oxides produced short term effects on cell metabolism but were significantly less toxic than asbestos. «Lung cells proved to be very suitable for this kind of study because they are very sensitive,» says Wick. One further aim is to develop a process which mimics the situation in the human organism as closely as possible. Empa researchers are therefore investigating a whole range of different cell lines.

Carbon nanotubes: the more they stick together, the more toxic their effect

In an as yet unpublished study, Wick and his team have also investigated the effects of carbon nanotubes. In contrast to nanoparticles, nanotubes were most damaging to cells when they stick together to form larger needle-like structures. «These agglomerates mimic asbestos fibers, both in their appearance and their level of toxicity», says Wick. «They cannot therefore be regarded as entirely harmless.»

As a next step, the cell biologist will investigate what exactly occurs in a cell when exposed to nanoparticles. He is analyzing the activity of thousands of genes with the help of so-called DNA chips. Wick: «This lets us see what effect the particles have on the cells, which genetic programs are switched on or off.» ■

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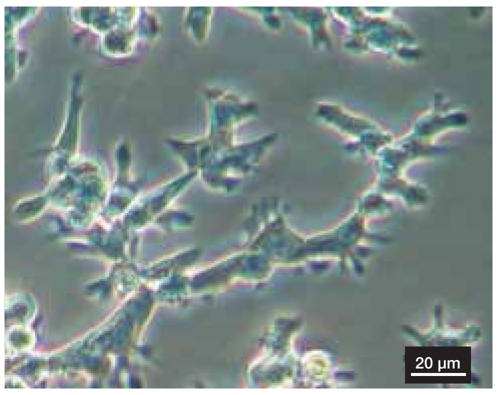
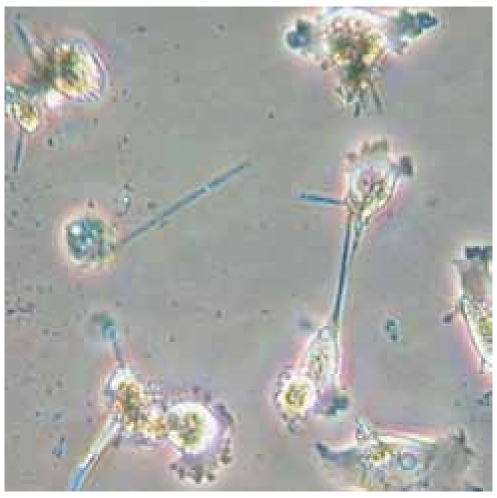
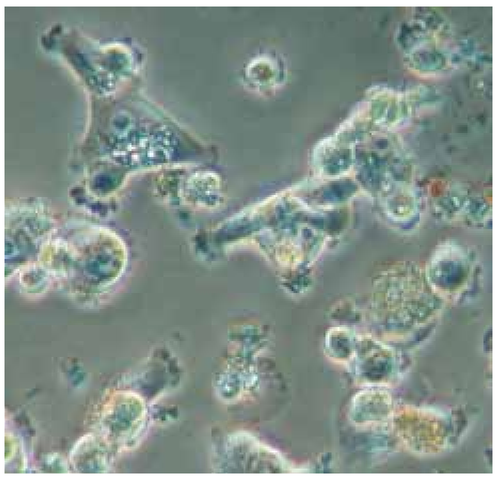


Human lung cells were exposed to harmless silicon dioxide (SiO_2) nanoparticles for three days. The cells stick to the bottom and have a spindle like form. This is how healthy cellular cultures appear. (The beam is about 20 micrometers long.)



Human lung cells were exposed to toxic asbestos fibers for three days. The cells which normally stick to the bottom and are long and stretched out start to agglomarate and separate from the bottom, a signal of stress. Some cells, top left, are close to dying.



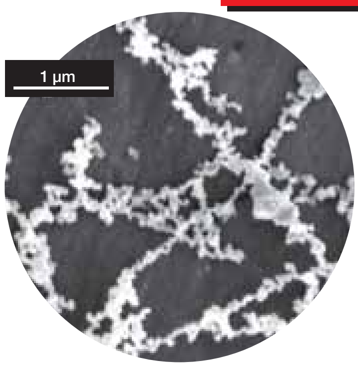
Human lung cells were exposed to iron oxide (Fe_2O_3) nanoparticles for three days. Here too, the cells begin to agglomarate and separate from the bottom.

Reference

Peter Wick et al., In Vitro Cytotoxicity of Oxide Nanoparticles: Comparison to Asbestos, Silica, and the Effect of Particle Solubility, *Environmental Science & Technology*, in preparation.

Environmental Analysis

Typical damage in an apartment. The black staining is clearly visible.



Scanning electron microscope image of soot particles seen on a white plastic ceiling cover taken from a flat suffering from staining. The particles have diameters of 30–80nm (nanometers). Image magnification is 20000.

in particular the increased use of SVOCs in paints and varnishes but also the tendency to use furniture and fittings made of plastic materials, which release plasticizers over time. Aggravating the problem is the fact that today's buildings are very well sealed, so room air is less frequently exchanged. Intensive heating, scented candles and insufficient airing of rooms make conditions even worse. The microclimate in a room and weather-dependent factors also play a role. For example low air humidity leads to increased electrostatic activity, which, in turn, amplifies staining.

Even if, as far as is currently known, these deposits do not cause any health problems, they represent an aesthetic nuisance. This often makes renovation work mandatory, even if the last repairs were only recently completed. To remove the stains it is often necessary to wash down the affected surfaces very thoroughly using detergents or special additives. Simply painting over the greasy stains, on the other hand, generally does not solve the problem. First and foremost, it is crucial to find the source of the problem before beginning the renovation work. ■

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Environment-friendly process developed for the coating of textile fibers

Metal coating makes fibers and textiles functional

A process developed at Empa permits the nanometre-scale coating of textile fibers with metallic particles without the environmentally harmful waste water that is a frequent by-product of conventional coating processes.

RÉMY NIDERÖST

The mediaeval suits of armour on show at castle museums are certainly imposing, but today we can be grateful that we don't have to wear armour or chain mail. Wearing a heavy suit of armour was certainly anything but comfortable. On the other hand, nothing provided better protection against a lance thrust or a stab with a dagger, and even a blow with a sword seldom left more than a dent in the metal.

Today, bullet-proof jackets, firemen's clothing, motorcycle overalls and other protective clothing make do without metal reinforcement, and modern fibers like Kevlar provide equally good if not better protection against mechanical impacts such as thrusts or blows. But what protects us against other dangers such as the invisible electric smog, which occurs almost everywhere? A mediaeval suit of armour would in fact have been very suitable for this because it acts like a Faraday cage*.

Materials that protect against electric smog

For some time now there have been items of clothing, carpets and even curtains, into which metallic threads – made of copper, for example – are woven in order to protect against electric smog. However, since the copper threads have different mechanical properties to the surrounding fibers of the fabric, they impair the functionality of the fabric in certain applications. For example, the addition of metal to closely-woven textiles makes them permeable to water, viruses or bacteria. This can be avoided by coating the synthetic fibers with metal rather than incorporating individual metal threads in the weave. This makes the textile homogeneous and easier to process, without impairing the functionality of the fabric. However, the current coating process using wet chemical methods produces large quantities of polluted waste water, which has to be treated and disposed of at great expense.

New coating technique is environment-friendly

There is an alternative solution, though. Researchers at Empa's «Functional Fibers and Textiles» laboratory have developed a new coating system for synthetic textile fibers, for example with silver. The fibers are fed at a speed of about 10 metres per minute through a complicated system of locks and capillaries, first into a precleaning chamber, then into the coating chamber. The thread is turned round several times while a homogeneous metallic coating is deposited with the aid of a plasma, an electrically conductive gas mixture. The thread leaves the plasma chamber after about four minutes and is then wound onto a reel. The metallic layer deposited has a thickness of about 50 nanometres (nm) or 50 millionths of a millimetre. In a project funded by the Commission for Technology and Innovation (CTI), the researchers recently demonstrated that they can also produce antibacterial as well as electrically conductive fibers using this method.

There are still a number of problems to overcome before it will be possible to apply this new environmentally-friendly method on an industrial scale. For example, the metal layer has to adhere reliably to the fiber even after the fabric has been cleaned or sterilized several times, as in the case of medical textiles. This means that the fibers have to be cleaned as thoroughly as possible before coating in order to remove the sizing agents previously applied to them. These oily substances are used in the spinning process to reduce friction and avoid electrostatic charging.

«The plasma process only has a chance of being used industrially when it is as cost-effective as the wet chemical method,» says fiber specialist Michael Keller. To achieve this, the fiber transport speed will have to be increased to at least 200 metres per minute, a rate which would reduce the price for the end product, the coated fiber, to around 150 Swiss Francs per kilogram. At present the coating plant at Empa's laboratory is being further optimized to achieve the best possible combination of cost-effectiveness and environment-friendliness, a crucial factor – and a potential competitive advantage – for the plasma coating of synthetic fibers. ■

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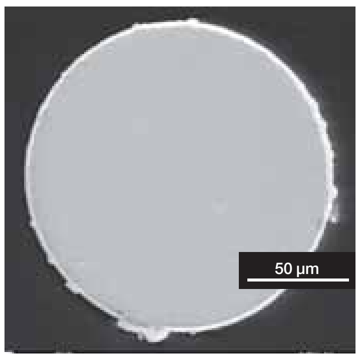
Titanium coating of synthetic fibers in the fiber coating system.



Scanning electron microscope image of a homogeneous, continuous, 3 µm-thick silver coating deposited on a 150 µm-diameter nickel wire by the fiber coating machine.

Fabric made of synthetic fiber coated with silver.

Empa's plasma coating system and fiber specialist Michael Keller.

A multitude of different applications

The Empa experts use their plasma coating system to deposit a metallic coating on synthetic fibers for research purposes. These fibers could be used to produce textiles with considerable market potential such as:

¥ Medical textiles: Silver-coated synthetic fibers prevent the migration of viruses and bacteria through textile such as cloth, covers and gowns used in operations.

¥ Textiles for industrial safety: Electrically conductive fibers incorporated in curtains act as a Faraday cage*

¥ `Healing˝ textiles: Bed covers with silver-coated fibers woven into them alleviate itching in neurodermatitis patients and promote healing of skin lesions.

¥ Sports textiles: Silver-coated textile fibers have an antibacterial effect and reduce odours.

¥ `Sensor shirt˝: Specially developed textile electrodes are incorporated into a shirt or T-shirt in order to record data such as the wearer s heart function and circulation in real time.

* Metal enclosure designed to exclude electrical fields from a limited area.

NIMS-President Kishi Receives 47th Honda Memorial Award

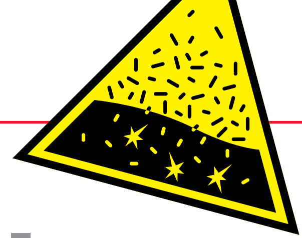
Teruo Kishi, president of Japan's National Institute of Materials Science (NIMS), was honored recently with the Honda Memorial Award, the most prestigious award given to researchers who made significant contributions to the progress of scientific culture based on outstanding achievements in research related to metals and associated materials. The award to Kishi was given in recognition of achievements in research on nondestructive evaluation of materials and research on evaluation of the reliability of structures. The Award Ceremony and Memorial Address were held on May 12, 2006.

Hilti Delegation Visits Empa

A high-ranking delegation of Hilti's research group visited Empa on 12th April to learn about current research projects and the range of services Empa offers to potential customers. Presentations and lab visits provided information for the visitors from Liechtenstein about the developments in progress with a direct link to the company's own interests and offered opportunities to discuss specific problems with various Empa specialists. The Hilti group appreciated the way the day's program was tailored to meet their particular interests. «The breadth of the topics covered, and at the same time the depth of expertise we encountered at the Empa has impressed us,» said Dr. Andreas Bong, Hilti's CTO (Chief Technology Officer) who headed the delegation. While several collaborative projects between Empa and Hilti are already underway, the possibility of additional future cooperation was discussed during the visit.
As host, Empa took advantage of the opportunity to demonstrate its newly created «Portal».
In the future potential partners and clients will be able to link to appropriate contacts within Empa via *portal@empa.ch.*

Empa Research «On the Road»

Last year Empa invited the public into its laboratories to learn more about its research activities with «Open Lab days». This year the institution is itself giving a guest performance, with its traveling exhibition «Empa on the road – research to ease your life». Contacts between Empa, its partners and potential clients in various institutions drawn from the Swiss educational, research and technology fields should now lead to even closer cooperation with high-tech companies – especially SMEs – thus speeding up technology transfer from application-oriented research to innovative new products. «Empa on the road» is oriented primarily towards Swiss industry, technical universities, other R & D organizations and technology parks as well as representatives of the cantonal and federal administration and other politicians. The Empa road show has already premiered at the «Intertech Bodensee'06» trade fair in St. Gall in May. After a summer break, the traveling exhibition will be in Horw from 19th – 20th October. Further stops will be at Biel/Bienne (26th – 27th October), Neuchâtel/CSEM (2nd – 3rd November), Sion (9th – 10th November), Trevano (16th – 17th November) and Buchs (early 2007).



Are new rules for dealing with nanoparticles necessary?

To date no European country has enacted legislation to specifically regulate the handling of nanoparticles. Currently the laws governing the use of chemical substances apply for nanoparticles as well. A social sciences research group at Empa has surveyed decision makers from science, industry and government on their perception of how nanoparticles are dealt with. The key question was whether or not new laws or other regulatory measures were needed to govern the handling of nanoparticles.

MARTINA PETER

Very tiny particles can have toxic effects, as various studies have indicated. So how can technological developments in this area be further advanced without damaging the environment or causing health problems? To address this, Empa researchers Asgeir Helland und Hans Kastenholz have contacted key players from German, British and Swiss science, industry and health authorities as well as EU officials and a representative of a non-governmental organization (NGO). The questions Helland and Kastenholz were interested in were: «Do you support regulatory measures? If so, what measures should be implemented?»

No need for new legislation, say authorities and industry reps

The study's results were published recently. While government representatives are well aware of the fact that the use of nanoparticles carries potential risks, they argue that the current – incomplete – state of scientific knowledge precludes the formulation of adequate legislation. «There have been no scientific results published so far giving cause for alarm,» as one official put it. Industrial representatives were also unanimous. «We support legislative regulation as soon as there is sufficient scientific evidence to prove that nanoparticles are a health hazard.»

The scientists made a point stressing that more research into possible adverse health effects associated with the use of nanoparticles was necessary. «The current laws on handling nanoparticles are outdated,» they maintain. It is also necessary to determine whether other factors need to be considered when drafting new legislation. Any new regulation should be based on the chemical composition of the nanoparticles in question, the surface area of the individual particles and the number of particles a person is exposed to.

In contrast, the ETC Group, an international NGO active in the fields of the environment and human rights, would like to see the manufacture and distribution of nanoparticles strictly regulated. In the absence of such legislation, as is currently the case, ETC supports a moratorium, which would temporarily halt the production of nanoparticles.

Basic research data on nanoparticles should be freely available

In the absence of generally agreed standards, industry is instituting their own in-house rules for handling nanoparticles during production operations as well as in the event of an unintentional release. It is, however, not known how much research on this topic is being conducted by industry, since the resulting data are kept secret. The research necessary to assess potential hazards posed by nanoparticles must, therefore, frequently be funded by the taxpayer.

A greater degree of transparency regarding the publication of research results and the application of environmental precautionary principles would raise not just our level of scientific understanding but also public confidence in the safety of this as yet unknown technology. Empa scientists Helland und Kastenholz are thus in favor of measures that encourage industry to actively share its knowledge about nanoparticles with the research community and the public. ■

Asgeir Helland, asgeir.helland@empa.ch
Dr Hans Kastenholz, hans.kastenholz@empa.ch

Reference

Literatur: Asgeir Helland, Hans Kastenholz et al., Nanoparticulate materials and regulatory policy in Europe: An analysis of stakeholder perspectives, *Journal of Nanoparticle Research*, 2006, im Druck.

Bringing «Nano» closer to society

There was enormous interest among the 2500-plus visitors to the first NanoPubli in 2005. This has encouraged Empa and its co-organizers to hold the public exhibition on the topic of nanotechnology again this fall. NanoPubli 2006 will take place in parallel to the scientific conference and the NanoEurope trade fair; its target audience being the young, technically interested public. Its aim is to inform visitors on the fundamentals and the future potential of nanotechnology. Companies will exhibit their latest nanoproducts involving the new technology.
The Empa, as a research institute and the main organizer of the event, has chosen «Health and Safety with Nanotechnology» as the motto of this year's NanoPubli. Empa scientists will explain, for example, how nanotechnology-based methods in the fields of molecular and cell biology are already being exploited today to improve our health and safety.
The exhibition will run September 12th through 14th at the Olma conference center in St. Gall. On offer are various shows, film presentations and an exhibition, in which visitors will be able to carry out exciting experiments themselves. Entry is free of charge.

www.nanopubli.ch
www.nanoeurope.com

Olma Messen St.Gallen

Tuesday/Wednesday 9 – 18.30
Thursday 9 – 17.00

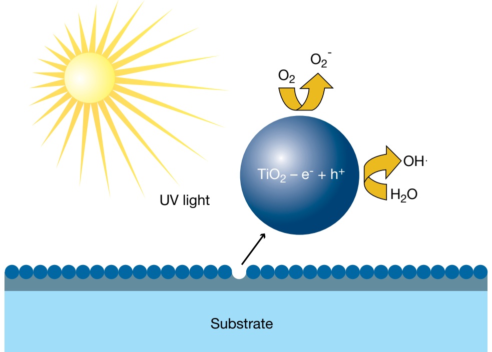
Clean thanks to nanoparticles

Walls coated with titanium dioxide particles prevent layers of dirt building up and stop bacteria becoming established. Thanks to «photocatalysis» they cleanse themselves automatically. In order to make this light-stimulated chemical reaction even more efficient, Empa researchers are developing novel nanoparticles made of tin dioxide and titanium dioxide.

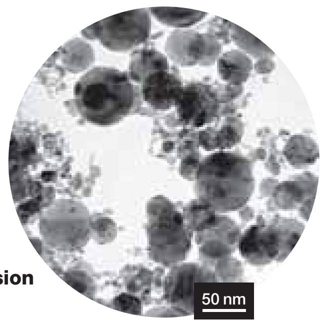
MARTINA PETER

Surfaces coated with titanium dioxide (TiO_2) possess an interesting property: Organic materials that come into contact with them decompose «of their own accord» when exposed to (sun)light. If the coatings consist of nanoparticles they are particularly active. Although it sounds like something out of science fiction, this technique has already been in use in Japan for a number of years. Self-cleansing lamp covers in tunnels and self-sterilizing tiles in hospitals are just two of the ideas that have been successfully turned into reality. Near Milan, a heavily used road was recently refurbished using photocatalytic building materials in order to prevent it being contaminated by air pollution particles. Surfaces coated with nanoparticles also help improve air quality in rooms, they reduce odours and prevent mirrors and glass from steaming up. A team of scientists at Empa's «High Performance Ceramics» laboratory has been investigating the secret of this phenomenon in various research projects.

The aluminium façade of the YKK building in Sendai, Japan, is coated with titanium dioxide, which makes it practically self-cleaning.



Nanoparticles absorb UV light, decompose water to produce reactive OH radicals and react with oxygen to create ozone, which can then decompose organic compounds.



SnO_2/TiO_2 nanoparticles imaged with the transmission electron microscope.

Multifaceted applications

Photocatalysis and titanium dioxide coatings create advantageous properties in many materials, such as:

- Non-misting, self-cleaning, dirt-repellant
- Antibacterial, antiviral and antifungal
- Deodorizing and air cleaning
- Water purifying

Photocatalytic self-cleansing

Many chemical reactions only take place with moderate speed, if at all, at room temperature. However, irradiation by light considerably accelerates some reactions. The best known example of this is photosynthesis. Sunlight provides plants with the energy they need to build organic substances from inorganic materials. With photocatalysis too, it is sunlight – or more precisely its ultraviolet component – that provides the energy needed to stimulate the TiO_2 particles to act as catalysts and to start up a chemical reaction. Organic substances are broken down into CO_2 and water. Light induces electric charges in the semiconductor TiO_2 in the form of electrons and holes. These diffuse to the surface where they produce extremely reactive hydroxyl radicals that break down the organic substances. The TiO_2 acts as a catalyst and therefore remains unaltered; for this reason a surface coated in this way can repel or break down dirt over a long period.

Still not effective enough for industry

TiO_2 is the ideal material – stable, non-toxic, corrosion-resistant and cheap. However, it is not used industrially on a large scale since its photocatalytic efficiency is still too low. The reason is that oxidation and reduction, the twin processes of the chemical reaction, have different reaction velocities. Whereas oxidation takes place within nanoseconds, reduction requires microseconds. Another difficulty is that TiO_2 only reacts to UV light and not to light in the visible range. UV radiation accounts for just 3–5% of our sunlight though. Artificial UV light, which would result in faster photocatalysis, is, however, harmful to humans. There are therefore two options: restricting the radiation to a closed room or increasing the light sensitivity of the TiO_2 particles. Empa researchers are working on precisely this latter aspect.

To fully exploit the wider range of the solar spectrum, the electron excitation energy of the particles must be modified to give a better match to sunlight. To achieve this, an exactly defined quantity of «contaminant» material is added to chemically pure TiO_2. Tin dioxide (SnO_2) has highly promising properties as an additive. Empa researchers are using a process known as flame synthesis to bond the semiconductors SnO_2 and TiO_2 together. «We expect a significantly higher photocatalytic efficiency from the newly designed composite nanoparticles,» says Andri Vital.

The composition of the particles and their size can be controlled via the process parameters. As a starting material metal organic (MO) liquids are evaporated and mixed specifically with oxygen and a combustible gas in the diffusion burner. The flame converts the MO liquids into metal oxides. The combination of high temperatures, short reaction times in the flame and the subsequent very fast cooling results in a nanoparticle composition with phases that are not in a state of equilibrium. These effects create the desired mix of SnO_2/TiO_2 particles with a higher photocatalytic activity than the pure TiO_2 particles. ■

Dr Andri Vital, andri.vital@empa.ch

Reference

K.K. Akurati, A. Vital et al.: One-step flame synthesis of SnO_2/TiO_2 composite nanoparticles for photocatalytic applications, Intern. Journal of Photoenergy, 7/2005, 153-161.

Events

Empa-Academy

3rd July 2006 13.00 – 20.00
Smart Materials, Structures and Systems
Enabling technologies for novel products and applications.
Location: Academy, Empa, Dübendorf

28th August 2006 16.30
In search of the Ideal Wood – Making Violins for the Masters
Science Apéro. No prior registr. necessary
Location: Academy, Empa, Dübendorf

26th October 2006 09.00 – 17.30
Functional Fibers
9th Empa Textile Seminar (in German)
Location: Academy, Empa, Dübendorf

Further events and details at www.empa-akademie.ch

Opinion

Dr Olivier Carnal
Georg Fischer AG
Head of Technology Development

“Internationally operating companies such as Georg Fischer AG grow through cutting-edge innovations. A close business relationship with Empa is therefore of utmost importance. With its strong position in many research areas, including nanotechnology, and its intensive ties to industry, Empa represents the ideal partner for the transfer of technology into products.”

Impressum

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