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1/10 special issue

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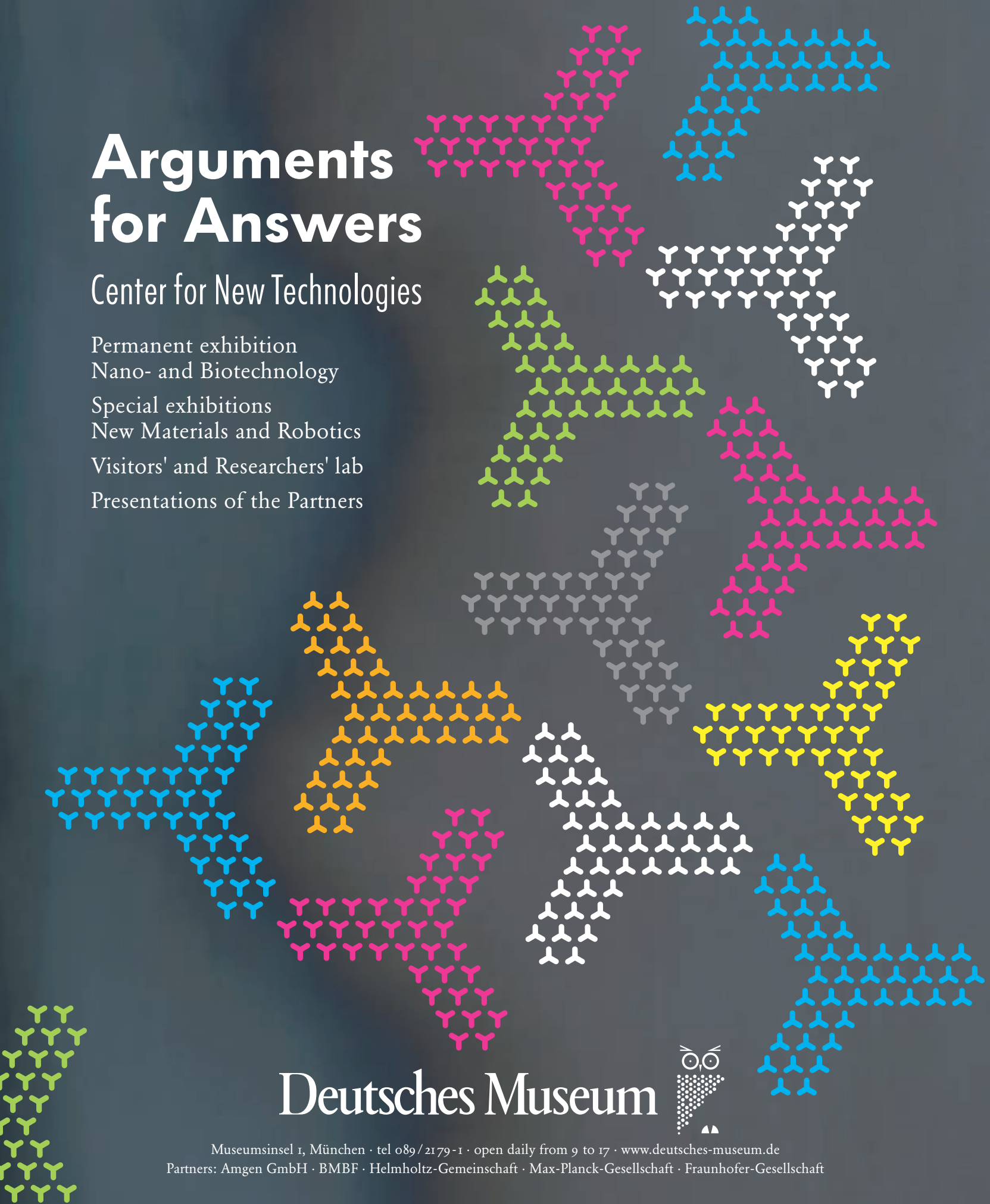

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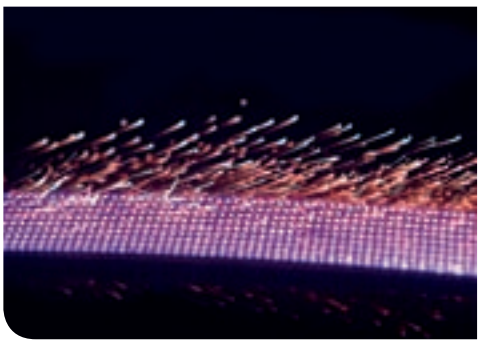
Yielding to electromobility

Prof. Dr. Hans-Jörg Bullinger. © *Bernhard Huber*

For more than a century, the internal combustion engine has been the workhorse of automated motion, or "automobility." Yet limited fossil fuel reserves and the climate change compel rethinking. For the first time, drastic increases in oil prices over the past year made it clear that the inventory of the earth's crude oil is being depleted down to the last few drops. Consumption of fossil fuel-based energy sources harms the environment through carbon dioxide emissions. Passenger vehicle traffic in Germany, for example, accounts for roughly 14 percent of the emissions of those gases responsible for the greenhouse effect. Particulates, exhaust fumes and noise additionally impair the microclimates of urban centers and their agglomerations. No doubt about it: we need new, environmentally sound and resource-friendly solutions, just so we can sustain our mobility in the future. Electromobility offers both the opportunity to diminish our reliance on oil and to minimize the generation of carbon dioxide. Vehicles powered solely or partially by electricity can become affordable and environmentally safer alternatives to diesel or gasoline powered automobiles - especially when energy from renewable resources, like solar and wind energy, is used. Another asset of electric propulsion is its high level of efficiency. Electric motors have an efficiency factor of approximately 90 percent.

By comparison, internal combustion engines actuate only about 35 percent of the energy stored within gasoline or diesel fuels. Last year the German federal government placed the issue of electromobility on its political agenda. Through the "Electromobility" national development plan, the German government is making 500 million euros available as part of "Economic Stimulus Package II," intended for the development of integrated mobility concepts in the public sector. The purpose is to make Germany the leading market for electromobility. Nonetheless, a plethora of additional research and development must still be conducted in order to make electric vehicles a truly viable alternative to their predecessor passenger vehicles, while simultaneously preserving Germany's competitive edge in the automotive engineering world of the future. In the project known as "Electromobility Systems Research," funded by the German federal ministry of education and research BMBF, 34 Fraunhofer Institutes will spend the next two years developing the fundamental components of a system solution for electromobility. In the process, the researchers will be examining the value creation stages of electromobility, and propelling their development on a coordinated basis. These components can include anything from power generation to transportation and energy distribution; the interfaces between the power grid and vehicle; energy storage through to innovative vehicle and power train concepts, all within a new infrastructure – as well as usage and pricing models. In the cover story of this issue, you can find out more about which issues researchers consider to be the main focus areas. The individual electromobility of tomorrow will drastically change transportation and the economy. Fully electric and semi-electric vehicles not only require these new infrastructures, they also foster innovative business models.

To keep a close eye on these challenges, the Federal Research Ministry established the "Electromobility Forum" in Berlin, through Fraunhofer. The forum provides a basis for the promotion of scientific and social discourse on advancing electromobility. Ultimately, a move toward electromobility can only succeed if people, industry and communities share in its ownership.



Content

Window display

Just one click and the window turns into a display screen. The technology involved is based on transparent coatings which conduct electricity, and scientists at the Fraunhofer Institutes for Surface Engineering and Thin Films IST, Solar Energy Systems ISE, Silicate Research ISC, Mechanics of Materials IWM and Photonic Microsystems IPMS have already made some progress in this field. They have, for example, been able to increase the conductivity of the printed coatings fivefold, thus making them suitable for displays; they have also produced initial demonstrators. Now, the researchers are working together to produce novel types of coating in which moving electron holes conduct electricity. By way of comparison, to date it has always been electrons that have produced current flow. Although these new materials do not conduct electricity as effectively and are not as transparent, when electron-conducting and hole-conducting materials are combined within a single element, they can nonetheless be used to make transparent diodes, transistors and solar cells.

Environment-friendly packaging

Consumers generally purchase food and many other products wrapped in plastic film. As part of the EU project "FlexPak-Renew", researchers at the Fraunhofer Institute for Process Engineering and Packaging IVV are currently working on an innovative flexible packaging paper made from renewable raw materials that can be manufactured using an eco-efficient process. To ensure that this packaging paper provides an adequate barrier against water vapor and oxygen, a new laminated structure is being developed. The recyclable and biodegradable material should help to reduce greenhouse gas emissions.

Global demand for flexible packaging materials is increasing by five percent every year. In 2010, the annual requirement will be 16 million metric tons, with Europe representing the largest market, followed by the United States and Canada.

New packaging made of renewable raw materials.
© Fraunhofer IVV

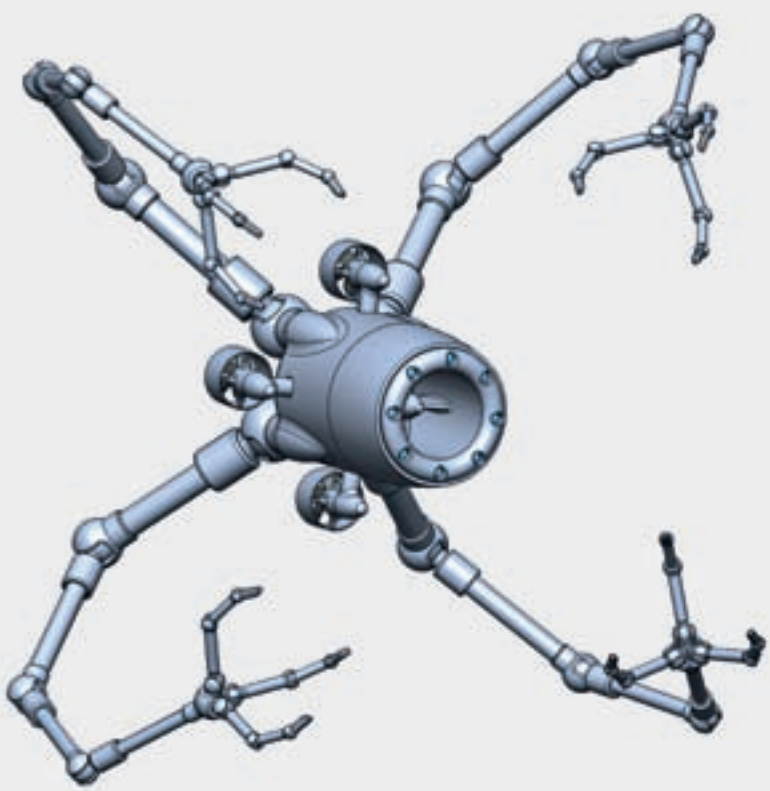
Underwater robots with a sense of touch

Underwater robots perform a number of different deep-sea tasks, including maintenance of offshore drilling rigs and collection of sediment samples. Now researchers are aiming to endow robots with a sense of touch so they can orient themselves better under the sea. Sensors will help them to detect their environment autonomously, even at great depths.

The strain gage is a key component of this tactile capability. The German Research Center for Artificial Intelligence (DFKI) has developed a robot model on which scientists from the Fraunhofer Institute for Manufacturing Engineering and Applied Materials Research IFAM in Bremen have placed numerous strain gages. If the robot touches an obstacle, one or more of these strain gages become deformed and their electrical resistance changes. A special feature of the strain gages is that they are printed onto the substrate, instead of using adhesive. The sensors are encapsulated to protect them from the salt water.

To produce the strain gages, the research scientists atomize a solution containing nanoparticles to create an aerosol. A software system guides the aerosol stream to the right position. Focusing gas shrouds the spray and ensures that it does not fan out.

Model of an underwater robot with a sense of touch.
© DFKI Bremen



Photos for friends

Researchers at the Fraunhofer Portugal Research Center for Assistive Information and Communication Solutions AICOS have developed the "TAnDI beta" software to enable people to share photos via their cell phones by pressing just one key. Specially developed for use with T-Mobile's Android G1 cell phone, it allows the straightforward transfer of personal photographs and other content to the T-Online Media Center, as well as other platforms such as Flickr or Picasa.

The most striking feature of the software is that it even allows digital picture frames or media players, for example, to be connected via an RSS feed, thereby making up-to-date pictures available to friends and family in the twinkling of an eye. The scientists hope TAnDI will help simplify the use of information and communication technology. Further information available at: http://andi.projects.fraunhofer.pt

Locating information more quickly

The world's largest physics laboratory – the Large Hadron Collider at the European Organization for Nuclear Research (CERN) near Geneva – produces vast quantities of data that are evaluated using the combined computing power of several thousand computers at eleven different locations around the world. The user service is coordinated by scientists at the Research Center Karlsruhe, Germany. In order to ensure efficient access to information, they opted for the search function provided by ConWeaver technology, which was developed by the Fraunhofer Institute for Computer Graphics Research IGD.

The teams at the eleven locations take it in turn to provide support services. They do not know each other and work in different time zones around the globe. However, using the system, a help desk employee in Karlsruhe should be able to access a query answered by a colleague in Taipeh a week before – the enhanced ConWeaver search function thus makes it possible to identify best practices and solutions relating to individual problems.

The computer center at CERN. © *Florian Hirzinger*

IT girls: Cyberellas

What do women scientists who work in information and communications technology actually do? What does a normal working day involve? The EU project "Gre@t Careers for Gre@t Women – Cyberellas are IT!" provides schoolgirls with the answer to this and many more questions, giving them the opportunity to shadow a woman scientist, IT specialist or engineer in their workplace for a whole day. The aim of the project is to encourage girls to enter ICT professions.

The Fraunhofer Institute for Reliability and Microintegration IZM in Munich has signed up to the project, and Jeanette Tang, a schoolgirl from the Max-Planck-Gymnasium, spent a day shadowing IZM researcher Anna Ohlander, who is working on a new type of biochip for diagnosing deep vein thrombosis. The system is polymer-based so it will be cost-effective to manufacture, and its researchers hope it will for example provide future passengers on long-haul flights with a quick and easy method of assessing for themselves whether or not they are at risk of DVT after their journey. The schoolgirl, too, was inspired by the project. Her conclusion? Science isn't a dry subject at all! Her report on her taster day evidently convinced the EU as well – she was invited to Brussels.

© *ec*

Driven by electricity

Text: Birgit Niesing

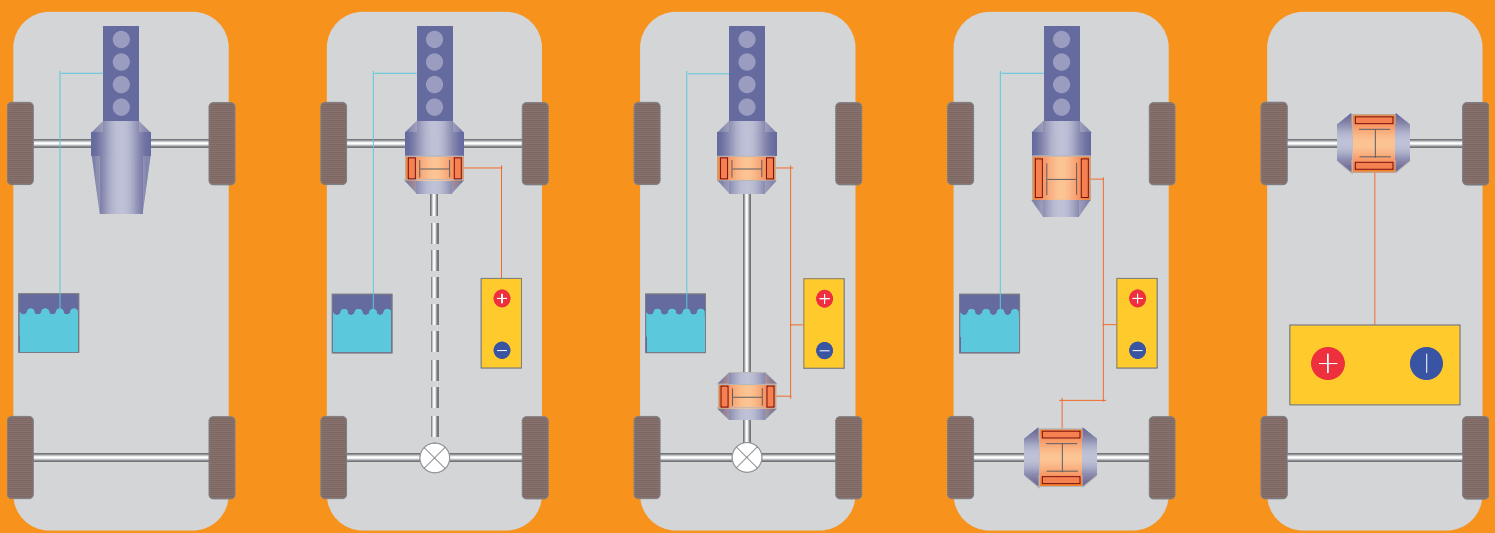
Electric cars are part of the future. However, some research and development work is still left to be done before we can ensure that electric automobiles will become a viable alternative to their vehicular predecessors. Over the next two years, Fraunhofer experts will be defining the core elements of a system solution for electromobility.

On the streets of Berlin, Munich, London, Rome and Amsterdam, electric vehicles are already on the go, flitting through these cities quietly and without spewing exhaust fumes. Automakers, suppliers, utility companies and communities themselves are using various model projects to study how electromobility can be properly adapted to everyday use.

And they are gathering insights that are urgently needed. Because by the year 2020, an anticipated one million electric automobiles will be on the road in Germany, according to federal government plans. Even today, the demand for cars that run on electricity is on the way up. "This year alone, we project sales in Europe of 80,000 vehicles that are p powered exclusively by an electric or hybrid drive train – that corresponds to a market share of 0.5 percent," explains Prof. Ferdinand Dudenhöffer, automotive researcher at the University of Duisburg-Essen. This expert estimates that in 2015, 1.5 million hybrid and electric cars will be sold in Europe. "By the year 2030, there will not be a single new car without an electric or hybrid engine," affirms Dudenhöffer confidently.

Electric power instead of fossil fuels

The internal combustion engine has been the mainstay of automated mobility – "automobility" – for more than a century. Yet limited crude oil resources and the climate change are forcing a change in thinking. In the future, cars are expected to run on electricity instead of gasoline. Electric vehicles have several points in their favor: they convert energy much more efficiently than cars on an internal combustion engine platform; they do not stink and are not a source of noise pollution. What's more, electric vehicles are environmentally sound – especially when the power is attained from renewable sources. Electric vehicles might even serve as energy



Mobility of tomorrow: drive concepts.
© *Fraunhofer IISB*

storage units. On a very windy night, wind parks deliver an overabundance of power. The batteries are recharged. Over the course of the day, when demand hits its peak, this energy is fed back into the power grid.

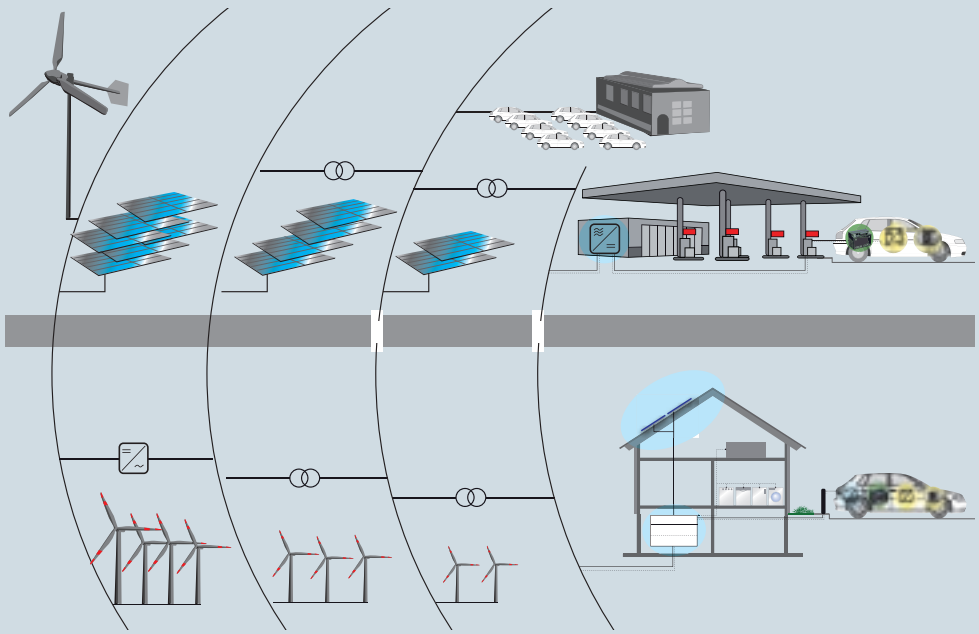
Acting jointly with automobile industry suppliers, battery makers and the power companies, car manufacturers are gridding for the transition. No easy task, considering that the entire value creation chain of the automotive engineering field is being transformed. Internal combustion engines and manual transmissions will be rendered obsolete, but electric drives and high-performance batteries will be needed. Power companies will be forced to revise their business models and adapt pricing structures to accommodate power supplied to cars. Moreover, these electric cars are going to need to feed somewhere: at a recharging station, of course. All major carmakers are contending with the immense pressures to produce electric vehicles. Manufacturers want to bring electrically-driven cars to market within the next two years. The first models already made their debut in the fall at the IAA International Motor Show in Frankfurt.

A panoply of industries – as well as emerging countries – are cultivating the transition to the electric car on a massive scale. Just a few month ago, US president Barak Obama announced a multi-billion dollar economic development scheme to engineer hybrid and electric vehicles. The US government plans on investing a total 2.4 billion US dollars in electromobility. U.S. industries will account for another 2.4 billion dollars. Japan is adding 200 million dollars in support of generating new batteries for electric cars. Three Japanese automakers – Nissan Motors, Mitsubishi Motors and Fuji Heavy Industries – additionally intend to collaborate with power operator Tokyo Electric Power to develop the required infrastructure for Japan. China is also pursuing the targeted growth of electromobility: over the next two years, the government will provide an estimated 2 billion euros to finance the expansion of more than ten pilot regions. A projected 10,000 vehicles will be available for use there. No stranger to electromobility, China has for years relied on the electric drive to power its motor scooters.

Transitioning to electromobility

The German federal government has also set ambitious goals: it would like to make Germany the lead market for electromobility. In August, the cabinet passed the "National Development Plan for Electromobility," an effort to promote research and development, market preparedness and the market launch of battery-driven vehicles in Germany. The government is encouraging applications-based research in this field through the 500 million euros in its Economic Stimulus Package II.

"Germany must press ahead with electromobility through a systematic, holistic approach and



Vehicle to grid: exemplary structure of the power supply for electromobility using renewable energies.
© *Fraunhofer ISE*

from the vantage point of a complex system so we can preserve our competitive edge on the macroeconomic level, especially in automotive engineering and in the energy generation and storage sectors, and so that Germany can play a defining and sustainable role as we help shape international development," as Professor Ulrich Buller, senior vice president for research at Fraunhofer-Gesellschaft, confidently asserts. The Fraunhofer-Gesellschaft therefore launched the collaborative project "Fraunhofer system research for electric mobility", which helps the German automotive industry to preserve and maintain its top position throughout the world in this sector (see sidebar).

A total of 33 Fraunhofer Institutes are collaborating on the project. The federal government is backing the plan, too: its Economic Stimulus Package I had designated 14 million euros for Fraunhofer towards investments in electromobility. Currently, the German federal ministry for education and research is ratcheting up the funding of grants from Economic Stimulus Package II to 44 million euros, thereby pressing ahead with this matter. A constant interexchange with industry is guaranteed by a supervisory board that involves the active participation of representatives from the automotive and supplier industry, the energy companies and electric motor manufacturers.

"The goal of Fraunhofer system research for electric mobility is to generate knowledge and technologies along the entire value chain – especially at interfaces – and then make them available to industry based on Fraunhofer's standard practices," explains Prof. Holger Hanselka. The Director of the Fraunhofer Institute for Structural Durability and System Reliability LBF is coordinating the general plan. "For the last few years, various Fraunhofer Institutes have actively worked on electric mobility. They have designed batteries, lightweight automotive construction materials, power electronics, vehicle models and logistics. Now we are bundling these activities

Fraunhofer Electromobility Systems Research

Through the „Electromobility Systems Research" project, Fraunhofer is tracking all of the value creation stages of electromobility: from energy generation to transport and energy distribution; the interfaces between power grid and vehicle; energy storage and new vehicle and drive concepts using a new infrastructure; usage and pricing models. A total of 34 institutes are collaborating on the project. The plan is divided into four focal points. It is headed by Dr. Ulrich Buller, Fraunhofer senior vice president for research planning; chief coordinator is Dr. Holger Hanselka. The federal ministry for research and education (BMBF) is funding the plan. The four points are being investigated:

Vehicle designs: Wheel hub motors and axle systems; lightweight automotive construction and energy storage systems; fast exchange of power storage units; vehicle testing facility

Energy generation, distribution and conversion: energy generation and network integration; power electronics and drive train technology

Energy storage technology: material development for lithium-ion batteries, innovative hybrid battery storage systems

Technical system integration and sociopolitical issues: passenger vehicle demonstrator; Autotram® demonstrator; sociopolitical issues; meta-project management

into concentrated effort." In the upcoming two years, researchers aim to focus on technology and components, as well as develop two electric vehicle demonstrators: "Frecc0," a passenger vehicle powered entirely by electricity, as well as an electrically-driven Autotram®. "These prototypes are indispensible as tools for open platforms and for modeling experiments – engendering the development of innovative technologies, and enabling us to identify the essential system demands to be met," Hanselka points out.

New vehicle designs

Nevertheless, we must still resolve a series of issues before we will be able to drive our electric cars to work, the store or the local swimming pool everyday: How is the car propelled? How do we construct batteries that are safe, durable and cost-effective? How is energy generated, transported, distributed and stored? Where are the charging stations built? How do the interfaces between power grid and vehicle function? And how does the consumer pay for power use? Fraunhofer scientists are working assiduously on solutions to these and many other aspects of electromobility.

The "Fraunhofer system-research for electric mobility" is divided into four areas of focus: vehicle designs; energy production, distribution and conversion; energy storage technology; and technical systems integration along with socio-political issues. New vehicles must be designed to make the electric car suitable for daily use. The researchers are not only examining the familiar primary engine; they also want to develop high-performance wheel hub motors. "These are motors that are positioned within or around the wheel, and that move the car forward," explains Prof. Matthias Busse, Director of the Fraunhofer Institute for Manufacturing Engineering and Applied Materials Research IFAM, who is coordinating this subproject. The scientists are working on new manufacturing techniques and materials designs for wheel hub motors.

Another challenge: how to construct lightweight, operationally reliable and crash proof batteries. Fraunhofer researchers are developing new materials for this purpose, including metal and fiber-reinforced plastics. Experts are exploring the link between new vehicle components and interfaces at specialized testing centers. Fraunhofer has four vehicle testing facilities. The latest solutions can be tested with regard to a diverse range of aspects – including acoustics, structural durability, electronics and crash safety.

Driving cars powered by the wind and the sun

Vehicles running entirely or partially on electricity are an environmentally prudent alternative to diesel and gas-operated cars. But to succeed as a counterbalance to acute problems – like climate change and limited resources – they have to operate primarily on the basis of renewable power generation. Researchers are coming up with concepts that address this, among other issues, under the „energy production, distribution and conversion" focal point.

The ever increasing proportion of solar and wind energy is leading to severe fluctuations in the energy supply. The eureka moment for the researchers: use the electric car as a mobile energy

Framework vehicle for the "Frecc0" demonstrator.
© *Fraunhofer IFAM*

storage unit for wind and solar power. When the sun appears, the batteries in the electric cars recharge using surplus power. If a dearth of power exists on the grid and the car is not being used, then network operators can tap into the car battery's stored energy. Thus, electric cars can help stabilize the power grid. The impact is substantial: if 10 percent of all cars registered in Germany were plug-in hybrid vehicles or electric cars that could store an energy quantity of one kilowatt hour, the overall energy capacity would soar to 4.6 gigawatt hours. Of signal importance to this new infrastructure are standards – such as a standard to govern the interface between vehicle and power grid. Automotive manufacturers and power companies have already reached agreement on a standard plug to be used for "fueling" the vehicles. A new five-point plug will recharge the batteries faster than an ordinary household plug. Moreover, this applies to more than just the individual components – design engineers from various technical fields are examining the energy system of the car and power supply as a whole.

Electrically-operated cars also require new electronic power transformers. "In order to hold currents that occur at outputs of up to 100 kilowatts and above within manageable limits, a secondary on-board electrical supply system with elevated voltage is indispensible. For the first time, high-voltage and high-capacity electronics are being incorporated into automotive engineering on a massive scale," says Dr. Martin März of the Fraunhofer Institute for Integrated Systems and Device Technology IISB, as he describes the challenge.

Key component: battery

Despite their numerous advantages, electric cars have been unable to penetrate the market so far. One reason for this: a paucity of high-performance, safe, long-lasting and affordable energy storage systems. Nowadays you can travel about 100 kilometers on one battery charge. However, this kind of electromobility comes at a steep price: a suitable battery costs about 15,000 euros. Advanced lithium-ion batteries are considered the key components for electrically-driven cars. However, to date these batteries have one Achilles' heel: organic electrolytes are combustible. Overheat the batteries, and they just might catch on fire. Therefore, Fraunhofer researchers are seeking out new, robust and safe lithium-ion batteries. Another challenge: manufacturers must be able to produce the batteries at an affordable cost to succeed in the market. "We are developing new materials for lithium-ion batteries. This should make batteries safer," explains Dr. Jens Tübke of the Fraunhofer Institute for Chemical Technology ICT. The expert in electrochemistry is coordinating the engineering of „energy storage technology." "Many of the basic principles had already been defined at Fraunhofer Institutes over past years. Researchers designed new anodes, cathodes, electrolytes and separators, and also devised new safety components and management systems. We are now combining these diverse elements in a manner that enables us to realize a unified structure," says Tübke.

But basic questions still demand clarification: Will there be one large battery module, or will there be many small ones? Will the batteries be recharged or exchanged? Gaining in significance are energy management systems that monitor these batteries safely and reliably. The driver will have to know the strength of the battery charge, and how many kilometers he or she can cover with the remaining charge. To help explain the added functionalities such systems may possess, Tübke has an example. "If an electric car is sitting under a broiling sun at noon, then the battery is already warm. Suppose the driver then wants to drive at full throttle right off the bat. That might damage the battery. Here is where battery management comes in."

The researchers are working on more than just the new findings; by the end of 2010, they even want to have built a complete, electrically-driven demonstration vehicle – „Frecc0" – based on an existing vehicle design. "The project findings from all participating Fraunhofer Institutes should be incorporated into the car, thereby demonstrating the basic feasibility of the engineered solutions," explains Prof. Busse. To do so, the researchers are using an existing vehicle as the framework into which the Fraunhofer components are integrated. This platform can then be used for projects with automobile manufacturers and suppliers. Using the Autotram® as an example, the researchers can show how the engineered solutions can be used for individual traffic as well as for public transportation or intra-urban delivery traffic. The newly developed modules are being assembled and integrated into the existing vehicle.

However, a switch to electromobility can only succeed if it is supported by people in general. In order to demonstrate the advantages of electric cars and the possibilities of new drive technologies and new business models, plans are underway in Berlin for establishing a new "forum for electric mobility". It is intended to enable those interested to familiarize or thoroughly inform themselves about electromobility, from the layperson to representatives of automobile manufacturers, suppliers, transportation and energy businesses. Drivers are still approaching this new technology with reservation. Admittedly, about one out of every three individuals surveyed can envision the purchase of an electric car, as revealed by a study sponsored by Aral. Nonetheless, drivers are not ready to spend substantially more for an electric vehicle. Indeed, 77 percent would be prepared to pay only a small premium – up to 2000 euros – over the price of conventional engines.

"An essential point for the future market success is the economic feasibility of these vehicles and customer acceptance," insists Dr. Martin Wietschel of the Fraunhofer Institute for Systems and Innovation Research ISI. "The most intelligent technical solutions will not function if they are not engineered with customer needs in mind." Electromobility may foster the drafting of totally new designs for mobility, such as supplying goods to inner city environmental zones. It is important to structure business models in order to finance, for example, the development of a fueling infrastructure. "The value creation structures between automobile companies and suppliers will shift. The economy has to position itself for this in order to be competitive on an international scale," Wietschel says as he points to yet another aspect of the research efforts.

A few things are going to change over the coming years: soon, electric cars will be on the go not only in Berlin, Munich, London, Rome and Amsterdam, but in virtually all cities. And power fuel pumps will be in demand, replacing the conventional service station. Car manufacturers, suppliers, energy corporations and even communities themselves have to prepare for this transition of the infrastructure and a diverse array of mobility designs. ■

Electricity on tap

Renewable energy needs electricity storage systems to unlock its full potential. Redox-flow batteries, which store energy in tanks, are a highly promising technology that can meet this need.

Text: Bernd Müller

Solar energy and wind power are in strong demand. As more wind farms are built and photovoltaic systems installed, however, there will be an increasing need for balancing and reserve energy to provide power when the wind is not blowing and the sun is not shining. Coal, gas or atomic power plants have to be kept operating to balance out fluctuations. And the problem grows. A leading study on renewable energies conducted by the German Environment Ministry BMU estimates that in 2050 the proportion of fluctuating output in the German electricity grid will amount to 90 gigawatts and be twice as high as the supply of controllable energy. Today fluctuating output only accounts for one sixth.

There is only one way out of this dilemma. When the wind is blowing and the sun is shining energy storage systems must be able to stockpile the energy needed to bridge periods of inadequate supply. Many concepts have been developed but they all have disadvantages: Pumped-storage power plants in the mountains only operate efficiently at high level of energy generation, exceeding 50 megawatt-hours, and they also spoil the appearance of the landscape.

Great hope is invested in compressed-air storage systems but these have not yet been technically perfected and are only viable at even higher levels of output. Conventional batteries on the other hand are too small to store the energy from entire wind farms or large photovoltaic facilities delivering several megawatts of output. The Fraunhofer Institute for Chemical Technology ICT in Pfinztal near Karlsruhe intends to plug this gap with redox-flow batteries. The principle behind them has been known for a long time. Two liquid electrolytes containing metal ions flow through electrodes made of porous graphite fleece, separated by a membrane which is proton-permeable. During this exchange of charge a current flows over the electrodes which can be utilized. At first this seems like a description of a fuel cell – but there is a key difference. "The fuel produced by a fuel cell is consumed, whereas the redox-flow process is reversible," explains Jens Tübke, Head of the Department for Applied Electrochemistry at the ICT. This means that if any surplus energy is generated – for instance during a strong wind – the electricity charges up the ions in the electrolyte, but when energy is needed the chemical reaction is reversed, as often as required.

The two technologies share a common feature in that like the fuel cell, the cell in which the electricity is generated in a redox-flow battery is separated from the energy storage system. The energy generated by a fuel cell comes from natural gas or other fuels, while in the redox-flow battery it comes from two tanks containing liquid electrolytes. Two pumps move the electrolyte evenly through the cell and back into the tanks. The advantage of such a system is that it is scalable. Larger tanks contain more energy, i.e. more kilowatt-hours, and permit longer buffer times. More cells – combined as stacks and modules – produce higher output, which is available within milliseconds. The two requirements of long-time buffering and high output can be combined as required. During darkness a redox-flow battery is suitable as a buffer for photovoltaic electricity, but can also provide high outputs quickly, e.g. when the grid needs balancing energy to stabilize the network. Wind power plants come somewhere in the middle – they need energy reserves for periods of a few minutes up to several hours.

Correct choice of electrolyte

The electrochemists are spoilt for choice as far as the electrolyte is concerned. Various material combinations are possible, such as iron-chromium or vanadium-bromine, in each case with sulfate as the ion partner. The ICT chemists, however, see the greatest potential in a combination of vanadium and vanadium, dissolved in water and sulfuric acid. Because both electrolytes contain the same materials they do not contaminate the cells and the tanks if the electrolytes become mixed.

The electrolytes must not be exactly the same, however, as no current would flow. They have to differ in terms of their ion charge or oxidation stage. In the charged condition one tank contains doubly charged positive vanadium ions

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There is only one way out of this dilemma. When the wind is blowing and the sun is shining energy storage systems must be able to stockpile the energy needed to bridge periods of inadequate supply. Many concepts have been developed but they all have disadvantages: Pumped-storage power plants in the mountains only operate efficiently at high level of energy generation, exceeding 50 megawatt-hours, and they also spoil the appearance of the landscape.

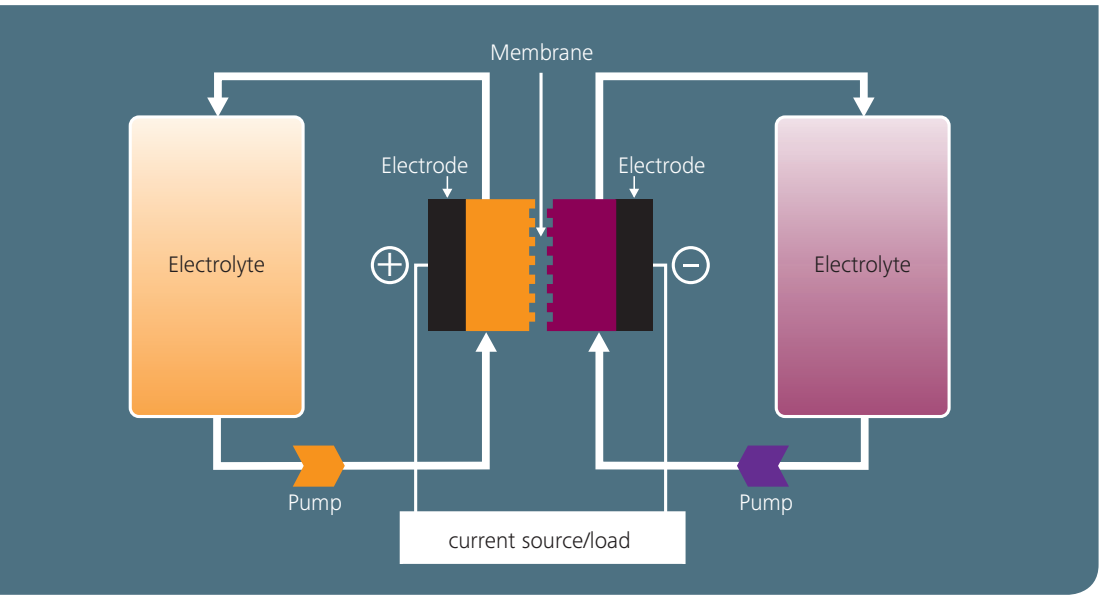
Great hope is invested in compressed-air storage systems but these have not yet been technically perfected and are only viable at even higher levels of output. Conventional batteries on the other hand are too small to store the energy from entire wind farms or large photovoltaic facilities delivering several megawatts of output. The Fraunhofer Institute for Chemical Technology ICT in Pfinztal near Karlsruhe intends to plug this gap with redox-flow batteries. The principle behind them has been known for a long time. Two liquid electrolytes containing metal ions flow through electrodes made of porous graphite fleece, separated by a membrane which is proton-permeable. During this exchange of charge a current flows over the electrodes which can be utilized. At first this seems like a description of a fuel cell – but there is a key difference. “The fuel produced by a fuel cell is consumed, whereas the redox-flow process is reversible,” explains Jens Tübke, Head of the Department for Applied Electrochemistry at the ICT. This means that if any surplus energy is generated – for instance during a strong wind – the electricity charges up the ions in the electrolyte, but when energy is needed the chemical reaction is reversed, as often as required.

The two technologies share a common feature in that like the fuel cell, the cell in which the electricity is generated in a redox-flow battery is separated from the energy storage system. The energy generated by a fuel cell comes from natural gas or other fuels, while in the redox-flow battery it comes from two tanks containing liquid electrolytes. Two pumps move the electrolyte evenly through the cell and back into the tanks. The advantage of such a system is that it is scalable. Larger tanks contain more energy, i.e. more kilowatt-hours, and permit longer buffer times. More cells – combined as stacks and modules – produce higher output, which is available within milliseconds. The two requirements of long-time buffering and high output can be combined as required. During darkness a redox-flow battery is suitable as a buffer for photovoltaic electricity, but can also provide high outputs quickly, e.g. when the grid needs balancing energy to stabilize the network. Wind power plants come somewhere in the middle – they need energy reserves for periods of a few minutes up to several hours.

Correct choice of electrolyte

The electrochemists are spoilt for choice as far as the electrolyte is concerned. Various material combinations are possible, such as iron-chromium or vanadium-bromine, in each case with sulfate as the ion partner. The ICT chemists, however, see the greatest potential in a combination of vanadium and vanadium, dissolved in water and sulfuric acid. Because both electrolytes contain the same materials they do not contaminate the cells and the tanks if the electrolytes become mixed.

The electrolytes must not be exactly the same, however, as no current would flow. They have to differ in terms of their ion charge or oxidation stage. In the charged condition one tank contains doubly charged positive vanadium ions



Schematic of a redox-flow cell: The energy storage units operate in conjunction with an electrolyte tank for each of the two electrodes. © *Fraunhofer ICT*

A pool of expertise

For three years the chemists at the Fraunhofer Institute for Chemical Technology have been working on the redox-flow concept in cooperation with colleagues from the Fraunhofer Institute for Solar Energy Systems ISE in Freiburg and the Fraunhofer Institute for Environmental, Safety and Energy Technology UMSICHT in Oberhausen. The Fraunhofer Applications Center for Systems Technology AST in Ilmenau is dealing with the question as to how the stored energy can be supplied as efficiently as possible to the grid. The Fraunhofer Institute for Systems and Innovation Research ISI in Karlsruhe is examining what resources are needed and developing business models.

which as they discharge are oxidized to form trebly charged ions i.e. they release an electron. The other tank initially contains quintuply charged positive vanadium ions which with the surplus electron from the first tank are reduced to quadruply charged ions. Chemists describe this as a redox reaction, which gives its name to the process. At some stage the discharging ions are consumed and the battery needs to be charged. For this purpose, current is applied and the electrolyte is pumped once more through the cells. The electrolytes are not consumed in this cycle, the battery can withstand at least 10,000 charge-discharge cycles. The use of vanadium ions would also have a pleasing side-effect as vanadium is a waste product of oil refining and titanium production.

Although the chemical principle has been known for a long time, the technology has not yet achieved a breakthrough. The Canadian manufacturer VRB, which was already marketing commercial redox-flow storage systems, has been sold and its future is uncertain. An Austrian company offers small systems for garage installation to buffer the energy generated by photovoltaic systems on the roof. Even though commercial systems have already been marketed, Tübke still sees considerable need for research work. His aim is to make the battery simpler and more robust, while at the same time being cheaper thanks to the use of improved materials for the membrane and electrodes. At present it would cost about 600 euros per kilowatt to make a redox-flow storage system, that equates with about 60 euros per kilowatt-hour.

Storing wind energy

That in itself would be an economic proposition in certain circumstances, for instance in regions where surplus wind power is generated. In Mecklenburg-West Pomerania, for example, the power suppliers sometimes have to turn off the wind turbines because the grid cannot handle the load, on other days there is no wind and the operator generates no revenue – both situations have a negative impact on profitability. The competition on the wind power market will exacerbate this and exert pressure on the wind farm operators to buffer energy so that it can be sold at the right moment. For the future Tübke's team aims to reduce costs by a factor of five. If they succeed in doing so, storage systems would be attractive for completely new business models. The producers of renewable energy would not only be able to use their capacity much more efficiently, they would also be able to make reserve output available. This would be particularly beneficial because it balances out short fluctuations in supply and attracts the highest prices on the market.
The aim in the near future is to build a demo battery with a modest output of just a few kilowatts. Concepts for larger systems have already been drawn up. The research engineers at Fraunhofer have designed a redox-flow battery with a capacity of two megawatts, which is yet to be built. It will comprise eight modules each made up of seven stacks containing 100 cells, connected in such a way that they deliver a voltage of close on 2000V and a current of around 1000A. Each of the eight modules would be about eight meters long and 1.5 meters wide. A building measuring 35 by 17 meters would be big enough to accommodate the modules and two electrolyte tanks each with a capacity of 300 cubic meters.

A storage system like this would be interesting for manufacturers and operators of wind power plants as well as for power suppliers and electricity traders. The concept could also represent an economic proposition for manufacturing plants already using solar panel systems and wishing to become even more energy-independent , or for meeting the energy needs of remote consumers, e.g. on islands. Jens Tübke predicts that over the next five years larger demo systems will be built which will be quickly followed by commercial redox-flow batteries, because their advantages are simply convincing. He is already thinking ahead to stage after the next and anticipates that the focus will move on to the development of redox-flow batteries as a feasible technology for electric cars. ■

Energy-saving light sources

The incandescent light bulb will soon be banished from our lives, replaced by more efficient, innovative light sources based on LED technology and luminous plastics. Experts discussed how they can help to save energy and protect the environment at a Fraunhofer forum on "green photonics".

Text: Evdoxia Tsakiridou

Light has a multitude of uses – in interior design, as an industrial tool, or as a life-giving force. The first tentative experiments to create light using electric energy date back to as early as 1800. In 1879, Thomas Alva Edison succeeded in improving the design of the carbon-filament lamp he had invented – the precursor of the incandescent light bulb – to provide 40 hours and subsequently 1000 hours of light. Even today, 130 years later, most of our indoor lighting is provided by incandescent lamps. But the omnipresent light bulb has one major drawback: it only converts between five and ten percent of the energy input into light – the rest is emitted in the form of heat. It is therefore not surprising that we meanwhile have to generate over 2600 terawatt-hours TWh of electricity to meet global demand for street and indoor lighting. That's 19 percent of worldwide electricity consumption.

"With more efficient systems, we would be able to save half of the energy currently used for lighting," said Andreas Tünnermann at the Fraunhofer "green photonics" forum. The director of the Fraunhofer Institute for Applied Optics and Precision Engineering in Jena added that this would lead to a significant reduction in CO_2 emissions, in the order of 600 megatons. This is the reason why incandescent light bulbs will soon be a thing of the past. Australia and New Zealand have been the first to ban them from stores, and Europe will be following their example by withdrawing them from sale in gradual stages. As of September 1, 2009, it will be impossible to buy traditional 100-watt light bulbs. Consumers will have to turn to other alternatives, such as energy-saving fluorescent lamps or LED arrays. The latter are based on tiny semiconductor circuits that generate light when an electrical voltage is applied. It is only recently that the pinhead-sized light-emitting diodes have emerged from their previously inconspicuous existence as standby indicators on TVs and hi-fi systems, emergency floor lighting in aircraft, or back-lighting for signage, car dashboards and cell phones. Until now, their output has been too weak for other applications.

In the meantime, researchers have found a way to increase LED efficiency and light intensity. For example, by using thin-film technology combined with special packaging techniques and optics, Klaus Streubel, Stefan Illek (both from OSRAM Opto Semiconductors) and Andreas Bräuer of the IOF have developed a means of producing LEDs of greater light intensity than before. Such developments have paved the way to high-efficiency LEDs and large-area LED lights. Novel packaging methods allow circuits generating different colors to be combined in a single, high-performance LED lamp with a color mixing system to produce light of any color including white. The semiconductor components consume about 80 percent less power than incandescent light bulbs and have a lifetime of 50,000 hours, which is 50 times longer. Their light efficiency currently stands at 50 lumens per watt: this is almost as good as today's energy-saving lamps, which typically emit 50 to 60 lumens per watt, and far better than conventional light bulbs with only 12 lumens per watt. "In a couple of years, we will have LED lamps generating 100 lumens per watt," promises Dr. Stefan Illek, a design engineer at OSRAM Opto Semiconductors in Regensburg. The improved light efficiency means that the electronically controllable devices can be used in other applications besides domestic lighting. They are already in use as back-lighting in LCD TVs, and there are working demonstrators of LEDs serving as miniature projectors in cell phones and as head-up displays integrated in car windshields.

"If city and district councils converted all street lighting to LEDs, they could reduce their energy

Fraunhofer is researching innovative light sources such as LEDs and OLEDs, which are capable of reducing energy requirements by up to 80 percent. © *Bernd Müller*

bill by between 25 and 30 percent," estimates Andreas Tünnermann. As an added bonus, the longer life of the semiconductor lamps means that they don't have to be replaced so frequently. And point-source LEDs could be used to illuminate streets and squares more efficiently. These LEDs are not the only candidate waiting to supplant the good old incandescent light bulb. Researchers are already developing the next generation of light sources based on organic light-emitting diodes, or OLEDs. These devices consist of a film of self-luminous plastic material measuring less than 500 nanometers in thickness. That's half of a thousandth of a millimeter or about one hundred times thinner than the diameter of a human hair. The thin plastic film contains chains of organic molecules, along which the electric charge carriers, i.e. electrons and holes, hop when a voltage is applied. At certain points along this path, the electrons and holes can recombine as in a conventional LED. The energy released by this process is radiated in the form of light. The color of the emitted light depends on the structure of the OLED molecules – and the variety available today allows practically any color to be generated. OLEDs render colors very accurately and consistently, and are efficient light converters. The main advantage of the surface light source is that it is thin, flat, transparent and flexible. At present, OLEDs are mainly used in displays for MP3 players, PDAs, cameras and cell phones. Once their design has been perfected, it will be possible to use them in ultra-thin, roll-up displays and other similar applications including transparent light walls, luminous wallpaper, luminous ceramic tiles, and self-adhesive films. Other suitable areas of application for the new light sources include direction signs, road signs, billboards, or the creation of special lighting effects in items of clothing, jewelry and furniture.

Another aspect of green photonics is the use of light to generate electricity. The global output of photovoltaic installations has risen steeply over recent years. The photovoltaic panels installed in Germany alone produced 1.5 gigawatts of electricity in 2008. The solar industry has seen its sales increase at a rate of 40 percent per year. At present the market is dominated by solar cells based on pure silicon. But thin-film solar cells will one day take their place, according to Tünnermann. They have the advantage of requiring fewer natural resources and less energy to produce.

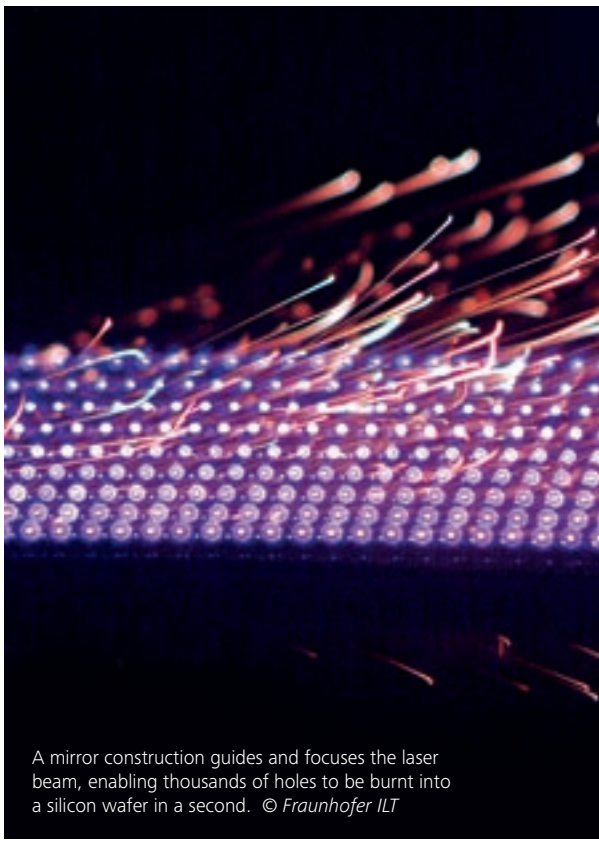
In the manufacturing industry, lasers have become an indispensable tool in the production of automobiles, ships, cell phones, solar cells, computer chips, medical devices, and clocks and watches. Dr. Kurt Mann of Trumpf Laser in Schramberg spoke about the material-friendly production methods made possible through the use of energy-efficient lasers, citing the example of diode lasers. "The diode laser is both the most compact and the most efficient type of laser available. Nearly 40 percent of the input energy arrives at the surface of the component being machined," he explained. Thanks to intensive development efforts, the diode laser is now robust enough for the industrial environment, where it is destined to find many more applications.

Green photonics is an important enabling technology with considerable potential for improving the CO_2 balance. ■

Laser fitness for solar cells

Solar energy has a bright future. It is renewable, available in unlimited quantities and produces no environmentally hazardous gases. Its only drawback right now is the price. But thanks to new production technologies, even that may be about to change.

Text: Monika Weiner



A mirror construction guides and focuses the laser beam, enabling thousands of holes to be burnt into a silicon wafer in a second. © *Fraunhofer ILT*

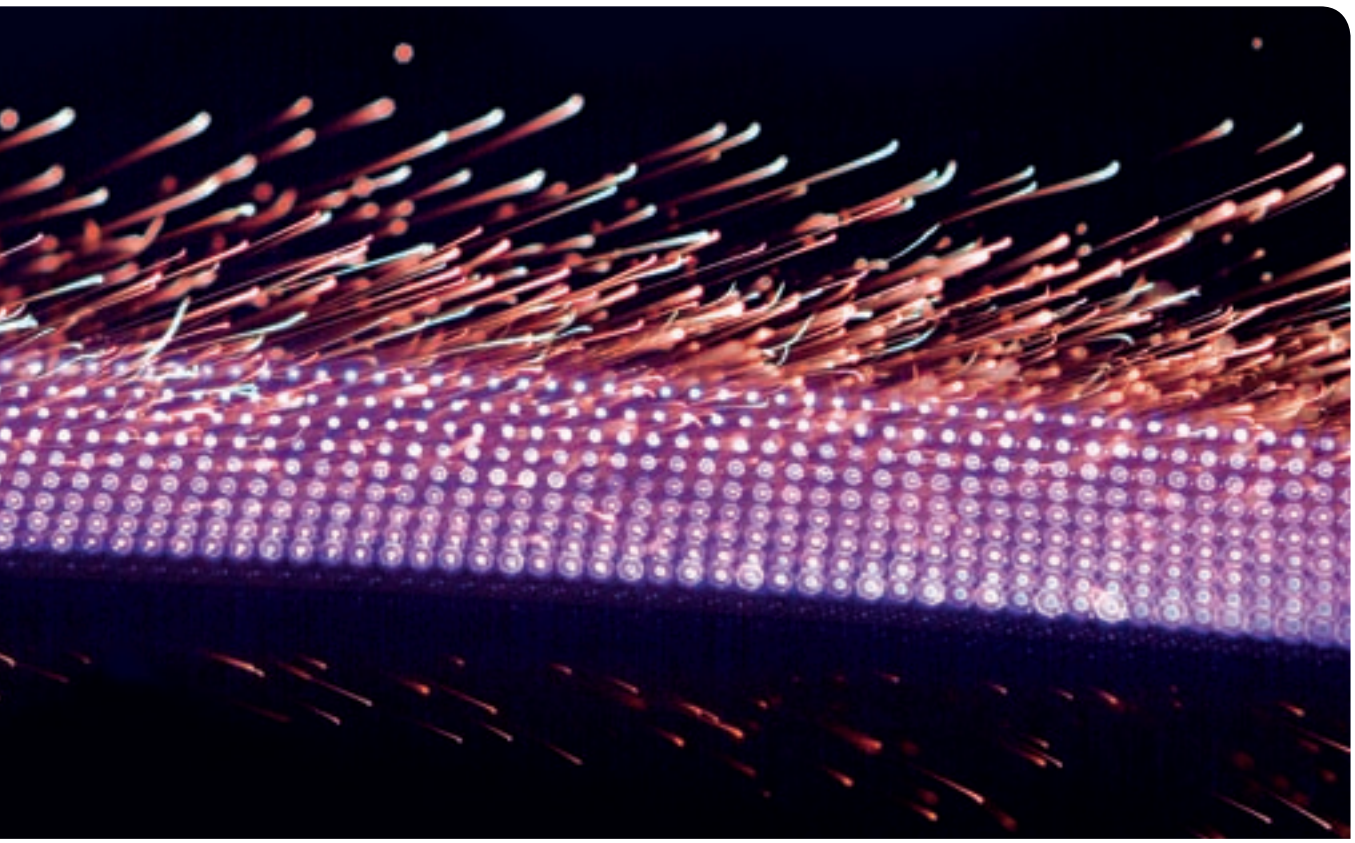
Cell phones, computers, MP3 players, kitchen stoves and irons all have one thing in common: they need electricity. In the future, we will also see increasing numbers of electric cars on our roads. If the most recent forecast by the World Energy Council is to be believed, global demand for electricity is set to double over the next 40 years. At the same time, the price of petroleum and natural gas is rising as both resources become increasingly scarce. Andreas Grohe from the Fraunhofer Institute for Solar Energy Systems ISE in Freiburg says: "Rising energy prices are making alternative energy sources – which have traditionally been considered too expensive – more attractive. Solar energy, for example, which never used to be competitive, will soon account for a significant share of our energy supply – and will no longer need to be subsidized." The physicist anticipates that grid parity will be achieved in a few years; in other words, that solar energy will cost the same and enjoy the same supply grid opportunities as conventionally generated domestic power.

Of course, this won't just happen of its own accord, and Grohe is quick to recognize this fact. "Solar energy must come down in price," he says. To make sure it does, he is collaborating with researchers at the Fraunhofer Institute for Laser Technology ILT in Aachen to develop technologies that will allow quicker, better and cheaper solar cell production in the future. "Lasers are fast, accurate and contactless, which makes them an ideal tool for manufacturing fragile solar cells," explains Dr. Arnold Gillner, head of the Microtechnology department at the ILT. He has been working with the solar engineers in Freiburg for the past three years. The interdisciplinary team is optimizing production techniques for solar cells and modules and developing new design types and variants.

In this process, developing new laser technologies and devising new concepts for harnessing solar energy naturally go hand in hand. Just recently, the researchers in Aachen succeeded in significantly speeding up their existing laser drilling process: "We've built a mirror construction that focuses the laser beam on the desired point without the light source having to be moved – that saves a lot of time," says Gillner. The test facility can already produce 3,000 holes a second, but that's just the beginning. "We're currently experimenting with different laser sources and optics," he says. "Our aim is to increase performance to 10,000 or even 20,000 holes per second."

Researchers at the ISE are following these developments with great interest because the holes open up new design possibilities for them. They will allow the electrical contacts currently located on the front of the cell, where they absorb light as a dark grid, to be moved to the back. "This will increase the energy yield," says Grohe. "The aim is to achieve 20 percent efficiency with industrially produced emitter wrap-through cells – that's a third more than the output of conventional silicon cells." To date, emitter wrap-through (EWT) cells have always been made of ultra-pure silicon, in which incidental light particles produce negative electrons and positive holes that then migrate to the electrodes. The Fraunhofer scientist adds: "Perhaps one day EWT technology will allow us to manufacture solar cells from unpurified metallurgical-grade silicon which, although it has poorer electrical properties, is cheaper."

However, drilling holes in silicon cells is only one of many laser applications connected with solar



cell production. The high-energy light beams can also be used to insulate the edges of solar cells or to create point contacts on the back of silicon cells – the ISE researchers have patented this process. And in the EU project SOLASYS (Next Generation Solar Cell and Module Laser Processing System), an international research team is currently developing new technologies that will optimize future production. The ILT in Aachen is coordinating the 6-million-euro project. "We're working on new methods to improve the cost-effectiveness of semiconductor doping, silicon drilling and surface structuring, and also module soldering," explains project coordinator Gillner.

The goal is to compete with traditional power generation

"Selective laser soldering", for example, can improve the rejection rate and quality of contacting and thus reduce manufacturing costs. To date, the electrodes have always been mechanically pressed onto the cells and then soldered. But as Gillner acknowledges, "silicon cells often break during this process – breakage is a primary cost factor in production." By contrast, with "selective laser soldering", the contacts are pressed onto the cells using compressed air and then soldered with the laser. The mechanical stress is reduced to almost zero and the temperature can be precisely regulated – the result is optimal contacts and very few rejects. Laser technology is also helping to improve thin-film solar cell production. The extremely thin film packages made of semiconducting oxide, amorphous silicon and metal that are deposited onto glass panels still only have a market share of between five and eight percent. Gillner admits: "This figure could be higher, because thin-film solar cells can be used anywhere non-transparent glass panels can be mounted – for example on house facades or noise protection walls. But their efficiency ratings are comparatively low, at five to eight percent." It is precisely this that the laser experts are now seeking to change. To date, manufacturers have always used mechanical processes or solid-state lasers operating in the nanosecond range to structure the active layers on the glass panels. In order to produce electrical connections between the semiconductor and the metal, grooves only a few micrometers wide must be created. To do this, the ILT engineers use a 400-watt ultra-short pulse laser that completes the process ten times faster than conventional diode-pumped solid-state lasers. "The ultra-short pulse laser is an ideal tool for ablating thin layers. It is highly accurate, does not heat the material and, operating with a pulse frequency of 80 MHz, takes less than two minutes to process a 2-by-3 meter glass panel," says Gillner. "The technology is very new, though, and we still need to develop high-performance scanning systems and optics that are specially adapted for the process. But it will bring down production costs in the medium term."

Andreas Grohe, too, is convinced that researchers are still just scratching the surface when it comes to the possibilities afforded by laser technology. "By working closely with our colleagues in the ILT, we are continuously discovering new fields of application, for example in the manufacture of conventional silicon and thin-film cells. And actually applying the technology leads to the development of new design types and variants." He believes this technical evolution will soon result in the researchers achieving their primary goal, that of harnessing solar energy at a price that can compete with traditional forms of power generation. ■

Factory planning made easy

Complex computer games can nowadays be played by inexperienced PC users - all they need to do is pick up the Wii remote controller and start playing. Now, researchers want to use new human-computer interfaces like those used for factory planning.

Text: Andreas Beuthner

The input devices designed for games consoles can be used intuitively. © *Nintendo/ddp*

Modern factories run with the precision of well-oiled clockwork – without any time lag and always just-in-time. To achieve this feat the machines must be arranged in the optimum layout and workflows coordinated accordingly – not an easy task for factory planners. Computer-aided tools can assist in this by creating models of factory structures and enabling true-to-life process cycles to be visualized, even before the equipment goes into operation in the factory hall.

Until now, however, users needed a great deal of experience and knowledge in handling the many complex planning software functions to achieve practicable results quickly. "It's usually only specialists who manage to do this," recognizes Mark Dürr from the Fraunhofer Institute for Manufacturing Engineering and Automation IPA in Stuttgart. To simplify things, IPA researchers developed the "i-plant" planning desk several years ago. It enables work teams to create a complete model of a factory hall layout,

50 years of Fraunhofer IPA

How can work processes be automated or rationalized? How can production workflows be designed to be more economical and more environmentally-friendly? The Fraunhofer Institute for Manufacturing Engineering and Automation IPA in Stuttgart has been developing solutions for these and other problems in the areas of production and automation for 50 years. The IPA was founded in 1959 and incorporated into the Fraunhofer-Gesellschaft in 1971. The institute's work helps companies to improve their competitiveness and thereby preserve jobs. The focal points of the IPA are corporate organization, surface technology and automation. The institute is renowned in particular for its developments in the field of robotics. Today 200 scientists work at the IPA. Its annual budget is 30 million euros, and 55 percent of its revenues come from industrial projects.

using digital objects representing machinery and equipment, and view it as a computer projection on a screen.

The i-plant has one drawback, however: it only has a limited capacity to perform genuine three-dimensional planning. While it is possible to add more degrees of freedom to the desk's planning application, for instance room height, this requires a complicated data entry procedure and makes the application more difficult to use. "If, on the other hand, we want to integrate knowledge and current information from production directly in the planning process, we need a simpler and more intuitive interface between human and computer," emphasizes Dürr. The Fraunhofer scientists are therefore working on a new research project which aims to combine the i-plant team-based factory planning system with the new input devices for computer games. The remote controllers designed for games consoles can be used intuitively and are packed with sophisticated control and navigation logic. The Nintendo Wii games console, for example, has no need of a keyboard or mouse for entering commands. Instead, video gamers interact with the virtual game world via a handheld remote controller. The Wii processor registers the player's hand movements and automatically converts them into computer instructions, enabling even absolute beginners without PC experience to play virtual tennis or golf with hardly any problems.

Intuitive control for the planning desk

It is this deceptively simple control device that the Fraunhofer researchers want to incorporate in their factory planning system. In the future, it will be possible to use the handy remote controller to operate even the most complex planning programs. The main advantage of the new planning system is that the intuitive user interface enables all employees from machine operator to managing director, but also architects and logisticians, to contribute their ideas.

The factory is admittedly not a meeting place for fun-seeking video game fans. Factory planning is a serious activity that aims to design an error-free, reliable production sequence based on the space available, machine cycle times and throughput targets. The IPA experts have the task of merging the simple and effective remote controllers with the modeling elements of the IPA planning table.

At the same time, the i-plant will be completely revised and developed further. The games industry only plays a minor role in the project as a supplier of high-performance, low-cost hardware which is within the budget of smaller firms.

First, the production specialists at the IPA intend to draw up specifications for the future version of the i-plant system, based on remote controllers. Clear specifications for an integrated database are particularly important, as these ensure seamless use of 3-D data throughout all planning areas. The researchers want to define the degrees of freedom for movements on the three spatial axes: "That means we must store the logic of the remote controller for each planning function," says IPA researcher Dürr. The next step on the agenda is a working prototype in which the interfaces between the input device and the planning table have been implemented.

"We are forging new paths for digital factory planning based on the 3-D functionality of the expanded input interface and the wireless connection to the extensive i-plant planning functions," Dürr is certain. Easier handling of high-tech tools in the planning sector is a huge advantage for many industrial companies, including smaller ones. Shorter development and planning times and closer interlocking of the planned cycles with actual production stages increase in-house productivity and competitive strength. ■

Remote controllers will soon make it easier to use the planning table. © *Fraunhofer IPA*

Extended service life for industrial machines

For subway trains, power stations or machines to work safely and reliably, they need to be maintained regularly. But when is the right time to do this? Well thought-out maintenance processes and procedures can save companies a great deal of money.

Text: Marion Horn

A metro train pulls into Berlin's Alexanderplatz station, its wheels clattering and squealing loudly. It judders along the rails, the passengers inside barely able to hold a conversation; even the people waiting on the platform can feel the vibrations. All the noise and jolting is caused by the fact there's at least one wheel which isn't perfectly round on one of the carriages. In order to ensure that the train runs more quietly, its wheels need to be checked regularly. How is this done? First, monitoring stations installed in the tunnels screen wheelsets for wheel flats, cracks and other changes, then experts evaluate the data collected and send any defective carriages to the workshop for manual inspection and repair. All in all a laborious process.

Scientists and commercial enterprises in Berlin-Brandenburg have recently joined forces in a drive to improve the maintenance and repair of trains, aircraft, power stations and machinery. They are currently developing resource-conserving and energy-efficient processes and technologies for the maintenance of capital-intensive machines and systems. The Berlin Transport Authority (Berliner Verkehrsbetriebe BVG) is one of the partners now working with the new Fraunhofer Innovation Cluster "Maintenance, Repair and Overhaul MRO in Energy and Transportation". The authority's CEO, Andreas Sturmowski, would like to minimize the downtime of trains. As he said at the launch of the cooperative venture: "It's undoubtedly the case that we're sometimes too quick or too slow to replace worn wheel parts. We want to learn how to judge this better and optimize the situation – that's really where our main interest lies and where we're seeking long-term solutions." Indeed, it would be ideal if the sensor data could be used to make predictions, so that action could be taken before failures occur.

Identifying defects in good time

Professor Eckart Uhlmann, director of the Fraunhofer Institute for Production Systems and Design Technology IPK in Berlin, explains: "Maintenance and repair are extremely important aspects when it comes to plant and machinery and other industrial products that involve a high capital investment. It is not simply a question of keeping a power station, for example, up and running safely and performing the necessary repairs. Maintenance activities also provide an opportunity for upgrading components to bring the system up to date with the latest industrial standards." Given that very little

To ensure that even older metro trains run smoothly, they undergo regular maintenance and modernization. © *Jochen Zick/Keystone*

Fraunhofer Innovation Cluster MRO in Energy and Transportation

Research partners

– Fraunhofer Institute for Production Systems and Design Technology IPK
– Fraunhofer Institute for Reliability and Microintegration IZM
– Institute of Land und Sea Transportation Systems, TU Berlin
– Aerospace Institute, TU Berlin
– Institute of Machine Tools and Factory Management, TU Berlin
– Federal Institute for Materials Research and Testing
– Brandenburg University of Technology Cottbus

Partners in industry

– Airbus Deutschland
– Alstom Power Service
– Amovis
– Berliner Stadtreinigungsbetriebe/BSR
– Berliner Verkehrsbetriebe/BVG
– DB Mobility Fernverkehr
– Fuss EMV
– Havelländische Eisenbahn
– Hegenscheidt-MFD
– Heidelberger Druckmaschinen
– MAN-Turbo
– MTU Maintenance
– Rolls-Royce Deutschland
– Siemens Energy Sector

scientific work has yet been done on these processes and technologies, the IPK and the Fraunhofer Institute for Reliability and Microintegration IZM have joined forces with five further research institutions and 14 commercial enterprises to launch the new innovation cluster. The cluster's total funding requirement of 14.3 million euros for the first three years will be split three ways between the Fraunhofer-Gesellschaft, the Länder of Berlin and Brandenburg, and the participating industrial companies.

www.innovationscluster-mro.de

Regular maintenance and targeted repair of damaged assemblies help to significantly prolong the service life of cost-intensive transportation assets, power generation plants and production facilities. This has particular relevance in the current economic climate, given that the decline in new investments means that existing machinery and facilities are required to remain in operation for longer – with safety and reliability remaining paramount all the while.

These days, services represent an increasingly important aspect of a company's business portfolio. Speaking at the inauguration of the innovation Cluster, Dr. Norbert Arndt, Director Engineering at Rolls-Royce Deutschland, reported: "Services meanwhile account for 52 percent of revenues in the Rolls-Royce Group." In civil aviation, one of Rolls-Royce's main operating areas, innovative service arrangements are now in great demand and manufacturers generally sell their products with an integrated service package. As a result, responsibility for maintenance and repair is being transferred to an increasing extent from the customer to the manufacturer, with airlines paying a fixed amount per flight hour.

Wear and tear, contamination, corrosion, vandalism and technical advancements are just some of the many reasons why there is a need for joint research and development work on energy-efficient and resource-conserving MRO processes and technologies. "The cluster initiative addresses an important technological and scientific challenge," says Dr. Mark Krieg, who manages the innovation Cluster's central office. "The initiative focuses primarily on the four fields of innovation that have emerged from industry requirements: Condition Assessment and Diagnosis, MRO Planning and Digital Assistance, Cleaning and Repair Technologies. Taking these as their starting point, cluster partners are working together on concrete projects to develop technologies to optimize MRO processes and then introducing them onto the market." Industry and science are thus amalgamating their competencies to ensure they remain effective in the marketplace. New cluster members are always welcome.

During the launch event, Andreas Fischer-Ludwig, site manger of the gas turbine plant in Berlin (Gasturbinenwerk Berlin) belonging to Siemens AG, said: "We can already look back over ten years of successful cooperation with the IPK. We now want to build on this as a partner in the innovation Cluster and jointly develop innovations within this network of research institutions and other machinery and tool manufacturers." ■

A new class of robots for the workshop

Until now, the use of robots has mainly been the privilege of large industrial companies. A new design approach aims to make these steel helpers accessible to small and medium-sized enterprises and skilled craftsmen in manufacturing.

Text: Klaus Jacob

The new welding robot is easy to operate mainly due to its intuitive instruction, even by non-experts.
© *Fraunhofer IPA*

"We manufacture with robots", is displayed in proud letters on Treffler company trucks. This long-established family business in the heart of Bavaria can trace its origins back to the sixteenth century. The ancestors of today's owners of the modern metalworking shop with almost 100 employees were farriers and nail-makers. Now a welding robot is being used. "Nobody else does that," says Paul Treffler junior, the present manager of the company. The advantages are obvious – "The Czechs and Poles are no longer feared competitors, as the robots work three to four times quicker than a welder. And the quality is amazing!" Tiredness and bad days are unknown concepts to robots – they weld with consistently high quality.

The Bavarian company owes this innovative advance to a EU project that is now in its final stages after running for four years under the lead management of the Stuttgart-based Fraunhofer Institute for Manufacturing Engineering and Automation IPA. The Fraunhofer Institute for Silicon Technology ISIT in Itzehoe and the Fraunhofer Institute for Systems and Innovation Research ISI in Karlsruhe have been collaborating on the project, which has the goal of enabling small and medium-sized enterprises (SMEs) to have access to a new class of robots – its name is "SMErobot". Up to now, the main beneficiaries of the efficiency-boosting technology have been large industrial concerns. The automobile sector alone snaps up more than half of all new robots – equipment weighing several tons, and taking weeks to be installed and programmed.

Small companies have very different requirements from big industry when it comes to plant and machinery. As they only produce in comparatively small quantities, they need flexible robots which can be retooled easily and quickly. The metal robotic assistants also need to be small and easily maneuverable and able to fit into an existing environment – and they must be affordable. Not an easy task. In the end, the SMErobot project found itself creating a completely new generation of robots. The project covers research and development assignments across the complete spectrum of typical robot technologies – actuators, sensors, control systems, operator terminals, and interfaces to link the robot to CAD and production data. The researchers have also developed methods and tools to enable non-expert users to plan robot deployment simply and reliably, and calculate the optimum cost parameters. All the big names in the business are taking part: the five largest European robot manufacturers, leading research institutes and universities, and a number of IT companies and consulting firms. The target group of SMEs in a variety of sectors is also represented, so that their requests and requirements can be directly taken into account.

Four pilot users were selected as typical representatives of the over 250,000 manufacturing companies of this size in Europe, each with different needs in terms of robot applications. In addition to the Bavarian metalworking company, Treffler, where robots are used for welding, there is a joinery (drilling, milling and coating), a foundry (fettling and "cleaning" of cast parts) and a forge (loading and unloading of machines).

The robots are easy to program

The researchers' most important task was to simplify the programming of the robot to such an extent that even a novice user could do it. The result can be seen in the IPA laboratory – a compact welding robot, noticeable for its two handles. An operator can use these handles to "show" the rotary arm what it has to do. Instead of writing complicated programs, the arm can simply be guided along the designated motion sequences, and an integrated sensor will simultaneously measure the welding groove. The robot even understands simple spoken commands. To avoid misunderstandings, it is context-sensitive – if the robot expects, for instance, an instruction about speed, it ignores other commands or demands confirmation. The developers have also given thought to the noise problem encountered in many factory workshops. Their solution is to enter the commands via a throat microphone.

There are other alternative means of instructing the robots. Commands can be generated from CAD data, as is becoming more and more common in the steel industry. If this type of digital data is not available, a freehand sketch with a digital stylus, incorporating a mini-camera, is also sufficient. Or the component can be quickly scanned in 3-D using a DLR handheld scanner. Easily comprehensible graphics will always show what the robot has understood, no matter how it is briefed, before it gets started. This not only makes it easier to operate, but also increases safety. If humans and machines are working together it must be ensured that the robot doesn't accidentally touch or – even worse – injure a human being. To prevent this, the steel workmates are fitted with sensors – for instance, laser scanners or cameras, which measure the distance between a person and the robot. The closer a worker moves to the metal skin of the robot, the slower it works, until finally it stops. The Fraunhofer Institute for Silicon Technology ISIT in Itzehoe has reached another milestone towards a safe and inexpensive robot. It has developed a force-torque-sensor which is relatively simple to produce and endows the robot with the necessary sensitivity. Integrated in the manipulator arm, this sensor can detect an impact with an unexpected obstacle – and effect an emergency halt. It also helps with the intuitive programming of the robot, by measuring the force with which the robot arm is guided while it is being briefed.

It is now up to the manufacturers to decide whether they will adopt the new ideas to produce a marketable workshop robot, and what sort of robot it will be. What is certain is that the "newcomer" will have "plug and produce" interfaces, similar to the "plug and play" standard for PCs. These will enable the robot to immediately recognize new components – whether they are grippers, sensors or operator terminals – and set to work without manual reconfiguration. The new robots are also significantly smaller and lighter than their industrial-scale cousins. The Augsburg manufacturer Kuka has developed a lightweight construction robot weighing only twelve kilograms.

But the decisive question is how expensive the new robot generation will be, and whether small companies will have the means to buy it. IPA expert Martin Hägele, is confident that the new helpmates will be affordable. "As a rule of thumb, in industry the robot itself only represents a quarter of the system costs," he emphasizes. Other expenses relate to feeding and separating technology, safety installations, programming and many more. Most of them do not apply to the little brother.

Entrepreneur Paul Treffler would be more than happy to accommodate a reasonably priced small robot. He can well imagine recruiting more smart helpers to work in his metalworking shop alongside their prototype. He is convinced that: "The day will come when all metalworkers will have their own robots." ■

Fraunhofer visual

Researchers from the Fraunhofer Institute for Electron Beam and Plasma Technology FEP have used recently developed vacuum technology to successfully restore the mirrors of the Jewel Room in the Green Vault in Dresden to almost original condition.

Still growing from strength to strength

The Fraunhofer-Gesellschaft performed better than ever in 2008, increasing its total business volume to a record €1.4 billion. At the same time it has been able to create and fill 1400 new posts, bringing the number of people working for the research organization to 15,000.

Text: Birgit Niesing

"The Fraunhofer-Gesellschaft looks back to a successful business year, despite the less-than-favorable general market conditions provoked by the global financial and economic crisis," says Professor Hans-Jörg Bullinger, President of the Fraunhofer-Gesellschaft, summing up the 2008 results. "Fraunhofer has continued to grow and has substantially increased its revenues from all sources." The total business volume increased by six percent to €1.4 billion, a new record level.

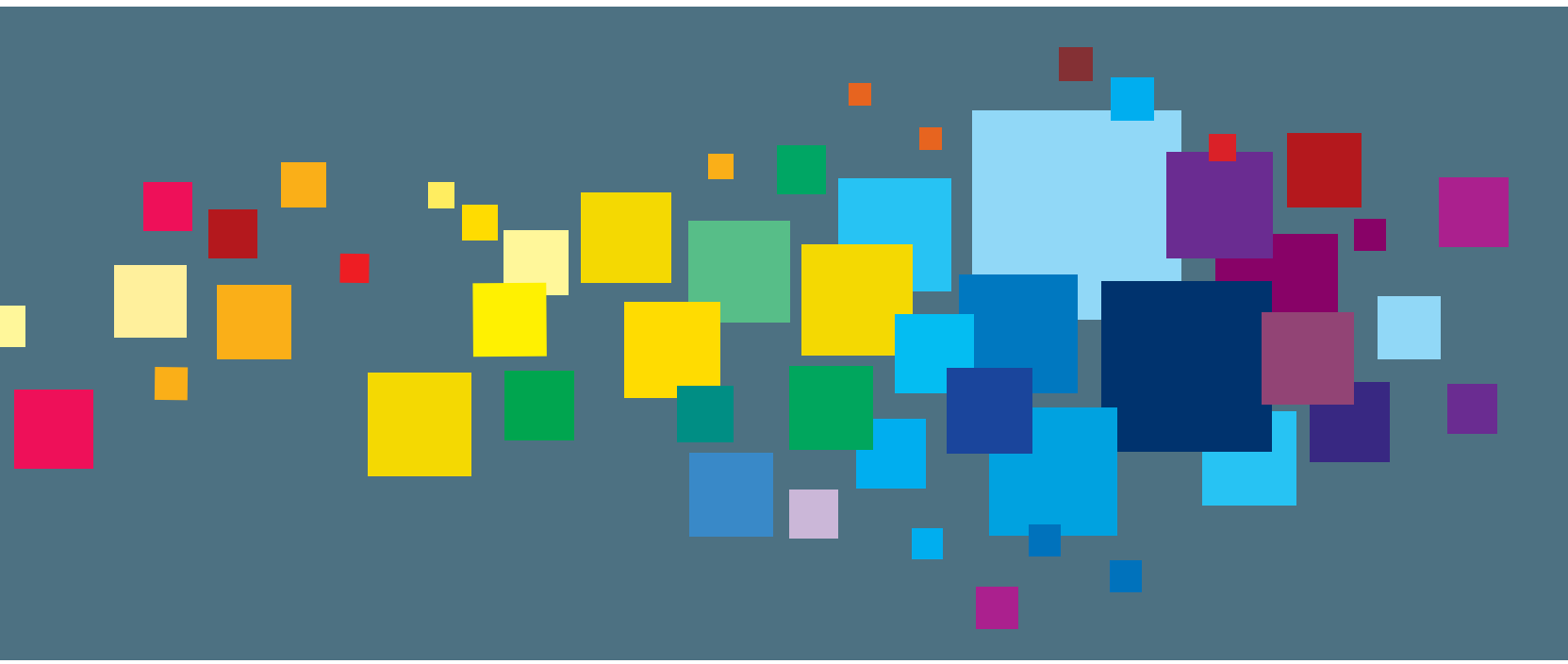
"Total business volume comprises actual expenditure on contract research, defense research, and major infrastructure capital expenditure," explains Dr. Alfred Gossner, Senior Vice President Finance and Controlling. Expenditure in the contract research sector, which represents the main part of the organization's research and development activities, increased by eleven percent to €1.29 billion. Expenditure in the defense research sector, at €38 million, was marginally lower than in the previous year. Major infrastructure capital expenditure was lower than in 2007, and amounted to €72 million.

Significant increase in industrial revenue

Fraunhofer finances its contract research activities through a combination of project revenue and government grants (base funding). Total revenue from project work for industrial and public projects totaled €859 million. The proportion of expenditure covered by third-party funding thus came to 68.6 percent. "Despite the weakening economy, the Fraunhofer-Gesellschaft was able to generate revenues of €369 million through direct contracts with industry," reports Gossner. This represents an increase of 13 percent compared with 2007. A further €83 million was generated in the form of license fees, bringing Fraunhofer's total industrial revenue to €452 million. Public-sector project revenue from the federal and Länder governments amounted to €248 million, which corresponds to 20 percent of the total business volume. Non-specific government grants (base funding) amounted to €432 million.

Fraunhofer's international activities also prospered in 2008, generating revenues of €147 million from contract research projects with partners outside the domestic market. "We surpassed the previous year's already strong performance by a further 18 percent, with satisfying growth rates in all relevant markets," reports Gossner. "The best results were obtained in Asia, where revenues increased by a substantial 45 percent." Overall, international customers accounted for 17 percent of total project revenue. "This sustained positive development is the result of the Fraunhofer-Gesellschaft's successful internationalization strategy," explains the chief financial officer.

Despite the global financial and economic crisis, the Fraunhofer-Gesellschaft expects to see continued growth in 2009 and 2010. This optimistic outlook is based on the fact that companies have a tendency to increase their research and development spending in times of economic recession. "Nevertheless, we have noticed a significant change in the terms of the contracts we are awarded. Customers no longer want to commit themselves to development projects with a technology roadmap extending to 2030. They want to see tangible results within one or a maximum of two years," says Bullinger.



"A growing number of research projects necessarily requires more people to do the work," emphasizes Professor Marion Schick, Senior Vice President Human Resources. To meet this need, 1400 new employees were hired in 2008, bringing the total number of employees at the end of the year to over 15,000. "To deal with the steep rise in the volume of research work, Fraunhofer intends to continue its recruitment drive in 2009 and create an additional 600 new jobs," says Schick.

Excellent research requires excellent human resources

Excellent research can only be produced with excellently qualified and motivated scientists. Fraunhofer has developed a variety of appropriate talent management tools. The Attract program aims to recruit and develop outstanding scientists with innovative ideas. In 2009 up to 40 new research groups were financed. The Vintage Class is a program to prepare and develop suitable candidates for succession to the post of institute director.

The early involvement of talented students is a key element in the Fraunhofer-Gesellschaft's long-term strategy of identifying prospective staff. Close cooperation with universities provides an ideal framework. The Talent School targets young people with technical flair. "Through this initiative we also support the activities of the MINT Pact launched by the German federal ministry of education and research (BMBF), which aims to encourage more girls to take a serious interest in the fields of mathematics, IT, natural sciences and technology – MINT for short," explains Schick. She adds: "Assuring equal opportunities for men and women forms an essential element of our human resources policy. In 2008, the proportion of women among the research staff rose to 19 percent. This figure is significantly higher than the percentage of female university graduates in the disciplines relevant to the Fraunhofer-Gesellschaft."

Popular employer

Students in Germany rate Fraunhofer as one of the most attractive employers. Its popularity is affirmed by the results of a survey published in the business magazine Wirtschaftwoche in May 2009. According to the Universum German Student Survey, Fraunhofer ranks second after auto-maker Porsche in the general classification, followed by Audi, BMW and Google. Fraunhofer also rates highly as an employer among the top quartile of each student year. Fraunhofer was ranked second by natural scientists, 4th by students of IT, and 7th by engineering students.

Know-how and innovations are set to become decisive competitive factors over the next decades. Patents are a useful way of protecting industrial and intellectual property, i.e. knowledge and inventions, while at the same time permitting their commercial exploitation. The Fraunhofer-Gesellschaft is one of the most prolific patent applicants in Germany. In 2008 alone, Fraunhofer employees submitted patent applications for 680 new inventions. Of these, an unprecedented 500 were filed with the German Patent and Trade Mark Office. The number of active patent clusters increased to over 5000. To ensure that its know-how and intellectual property rights are consistently utilized and exploited, Fraunhofer has

implemented a system of results-oriented intellectual property (IP) management.

Patent protection is a worthwhile investment: In 2008, the Fraunhofer-Gesellschaft generated €83 million in license-fee revenue from its portfolio of intellectual property rights. A major part of this revenue is attributable to the organization's outstanding success in the field of audio encoding. "To achieve similarly successful results in the future, we need to support a long-term program of pre-competitive research in selected fields of technology, with the aim of building up comprehensive patent clusters. The Fraunhofer Future Foundation was set up with this specific purpose in mind," says Professor Ulrich Buller, Senior Vice President Research Planning.

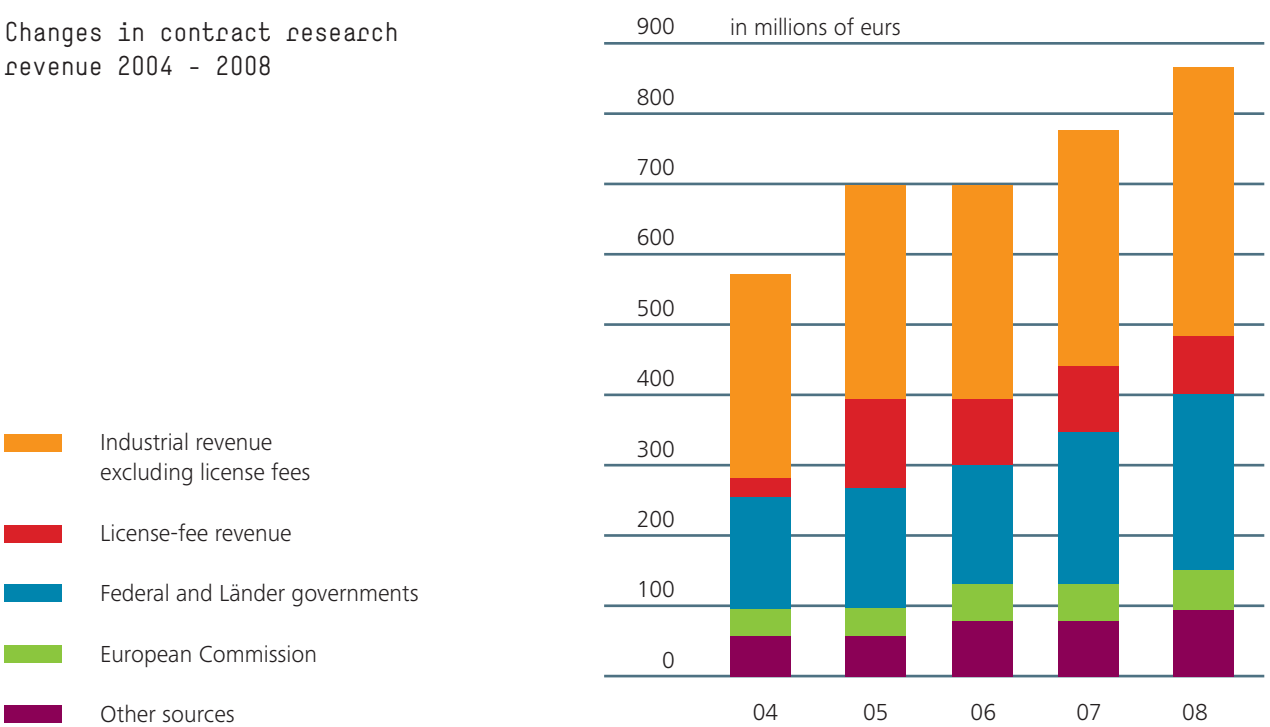
Strategic development and outlook

In 2008, Fraunhofer defined the key elements of its roadmap to the future. An intensive process of dialog culminated in a list of twelve so-called "frontline themes" that from now on will represent the main focus of Fraunhofer's innovation strategy – areas of research of major significance to the economy. "In the course of our analysis, we also identified areas of research likely to have a profound impact on society and industrial development but which the Fraunhofer-Gesellschaft is insufficiently equipped to fully exploit at present," reports Professor Bullinger. This gave rise to an initiative to augment the organization's research capacity in the fields of energy and healthcare by creating new institutes and merging existing institutes. In 2008, the Fraunhofer Institute for Wind Energy and Energy System Technology IWES was founded in Bremerhaven. The new institute combines the resources of the Institute for Solar Energy Supply Technology (ISET) in Kassel, which specializes in supplying energy from renewable sources, with those of the existing Fraunhofer Center for Wind Energy and Marine Technology CWMT in Bremerhaven.

A further example of the Fraunhofer-Gesellschaft's systematic portfolio management policy is the integration of the Bremen-based research center MeVis Research GmbH. This move gives Fraunhofer more specialist knowledge in the field of medical visualization and diagnostic systems. Plans for 2009 include the integration of the institutes of the Forschungsgesellschaft für Angewandte Naturwissenschaften e.V. FGAN – a Research Establishment for Applied Science. This will further enhance the Fraunhofer-Gesellschaft's expertise in the fields of defense-related and civil security research.

"The Fraunhofer-Gesellschaft intends to focus its human and technological resources on building up expertise in specific growth areas that will strengthen Germany's capacity for innovation and thereby its technological leadership, an especially important task in times of crisis," emphasizes Bullinger. ■

Changes in contract research revenue 2004 - 2008



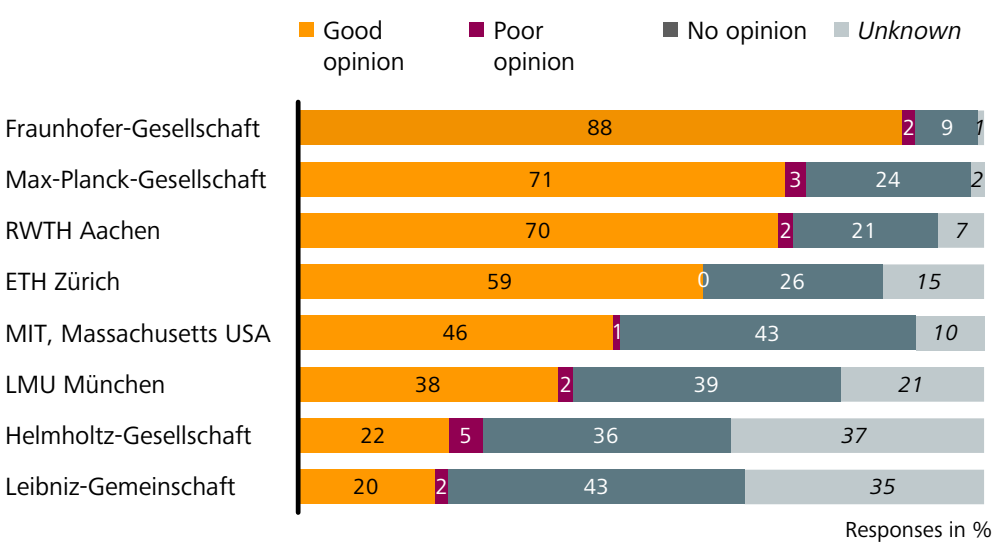
Favored technology partner

Even in times of crisis, companies are willing to invest in research and development – much to the benefit of the Fraunhofer institutes. Such are the findings of a survey carried out by the Allensbach opinion research center on behalf of the Fraunhofer-Gesellschaft.

Text: Monika Weiner

Research is in demand. Despite the fact that the financial crisis has hit the German economy hard, with savings being the order of the day in many areas, almost half of all companies want to invest more money in the development of new products over the next two years. Indeed, this figure rises to 53 percent among companies classing themselves as research-intensive. The Institute for Demoscopy in Allensbach conducted a survey of 309 managing directors, senior executives, company owners and heads of department in small, medium and large enterprises, and the results are encouraging for the Fraunhofer-Gesellschaft, Europe's largest applied research institution: 58 percent of respondents would like to further intensify their cooperation with external partners when it comes to developing innovative products. Again, the figure is even higher within the research-intensive sectors, increasing to 81 percent.

So how satisfied are companies with the r esearch options that are available in Germany in general, and those offered by the Fraunhofer-Gesellschaft in particular? According to what criteria do industry decision-makers award contracts? And at the end of the day, do they get what they want? The opinion researchers asked all these questions. 71 percent of those surveyed believe there is currently an adequate choice of external service providers who will take over research and development activities. The Fraunhofer-Gesellschaft is by far and away the most popular partner in this regard, with 88 percent of respondents having a good opinion of the organization. The Max Planck Society ranks second with 71 percent, followed by RWTH Aachen University in third place (70 percent) and then the Swiss Federal Institute of Technology Zurich (59 percent).



The Fraunhofer-Gesellschaft's image was rated particularly highly by the respondents: 93 percent said the organization has a good reputation, while 91 percent associate the name with high quality, and 88 percent with innovative developments. 87 percent have confidence in Fraunhofer and 86 percent believe the organization enhances Germany's ability to compete internationally. The upshot is that Fraunhofer ranks as the top research institution. Three quarters (75 percent) of those surveyed reported that Fraunhofer is important for their company. And once again, this figure rises among those companies classing themselves as research-intensive – to 83 percent.

Entrepreneurs value professional expertise

So what exactly do industry representatives value about Fraunhofer? The Institute for Demoscopy in Allensbach put this question to commercial enterprises that are currently cooperating with one or more Fraunhofer Institutes or have done so in the past. When it comes to cooperation with Fraunhofer Institutes, the all-important criterion is clearly professional expertise (90 percent agreement). Second comes the organization's experience in cooperating with companies (59 percent agreement), followed closely by personal contacts (58 percent).

Almost all companies were satisfied with their cooperation: 14 percent assessed it as "very good", 75 percent as "good". Similarly, almost all would at least consider further cooperation (97 percent). A quarter (25 percent) of respondents already have new projects planned. ■

Happy Anniversary! Fraunhofer USA at 15

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15 years ago, Germany's Fraunhofer-Gesellschaft, Europe's largest institution for applied research, established a new subsidiary. Today, the institute boasts six research centers in the United States. Through their close, joint collaboration, Fraunhofer and renowned American universities are designing and developing practical solutions for industry, both within Europe and abroad.

Text: Monika Weiner

Hindsight is always easier than foresight. Following the establishment of Fraunhofer USA 15 years ago, the history of Fraunhofer's US-based subsidiary could not be closer to the all-American success story: Today it boasts six research centers in the USA that collectively generated 30 million dollars in revenues last year alone. The centers collaborate with numerous American research institutions, elite universities among them like MIT and Johns Hopkins University. Also during this period, Fraunhofer USA blossomed into an institution with almost 200 employees. Together with their partners from industry, they jointly engineer new production techniques, medications and software designs. And just like their Fraunhofer Institute counterparts in Germany, these centers stand at the gateway between university-based research and commercial practices. No doubt whatsoever: The Fraunhofer model once again proved its value – this time in the USA.

Of course, there was no way of predicting such success back in 1994. Instead, courage and confidence were needed in order to export a German research model, as the former head of Fraunhofer and its founding director, Dr. Dirk Meits Polter, recalls: "Back then, Fraunhofer was an exclusively German institution. The internationalization of applied research was already well underway. Ultimately we realized that if we wanted our customers to take us seriously on a long-term basis, Fraunhofer would also have to prove its capabilities internationally. In this respect, the USA was an extremely appealing location, because research and economics evolve there at a highly dynamic pace. Several of our institutes were willing to face the challenges of this market." Following the official founding of Fraunhofer USA as a subsidiary, a number of institutes took the opportunity and leapt to the other side of the pond. Research centers were established. And thus began a history of transatlantic research collaboration that continues to blossom, and demonstrate its value today.

Powerful Software Analysis Tool: Brainchild of Cooperation

Defective software can become a costly matter " While testing NASA communications software, we determined that the transmission of image data from Mercury to the Control Center on Earth would need a third more time than expected, because data was unnecessarily re-transmitted under certain circumstances. Had this problem not been detected, then the costs of transmissions would have skyrocketed by thousands of dollars," states Prof. Rance Cleaveland, Director of the Fraunhofer Center for Experimental Software Engineering CESE. Error detection became possible through SAVE, the acronym for Software Architecture Visualization and Evaluation. SAVE was developed by a German-American research team: researchers at Fraunhofer USA are working together with experts from Johns Hopkins University Applied Physics Laboratory, as well as with colleagues at the German parent entity, the Fraunhofer Institute for Experimental Software Engineering IESE. "SAVE also displays the software structure of complex programs in an easy-to-read way. That's important when you want to systematically analyze programs and track errors that could lead to unexpected and undesirable conditions," says Cleaveland. CESE and IESE meanwhile submitted a joint application to patent the new analysis method of SAVE.

Diamonds: Transatlantic collaboration ensure Success

The advantages of this software are already delivering profitable benefits to NASA, to the U.S.-based Food and Drug Administration FDA which analyzes the reliability of medical technology and to the industry partners of the German institute.

Since time immemorial, the diamond has been the symbol for fidelity and stability. The gem also plays a critical role in the long-standing collaboration between Fraunhofer researchers in Germany and in the USA. Admittedly, in this case the use of diamonds pertains less to symbolism, and more to practical matters. Diamonds are a coveted and precious commodity; therefore, scientists and engineers for years now have been seeking methods to produce them affordably. Prof. Jes Asmussen's research group at Michigan State University has been developing diamond technology since the 1980ies. The group developed plasma machines and processes to efficiently make diamonds from methane

History at a glance

In September of 1994, Fraunhofer USA began operations when two Fraunhofer Institutes in Aachen opened research centers in the U.S. :

The University of Michigan together with the Fraunhofer Institute for Laser Technology ILT created the Fraunhofer Center for Laser Technology in Plymouth, Michigan.

Boston University partnered with the Fraunhofer Institute for Production Technology IPT in Aachen and created the Fraunhofer Center for Manufacturing Innovation. The original objective was tool and die making but over the years the Center's research has evolved into providing innovative manufacturing solutions in areas such as pharmaceuticals, medical instrumentation, and optoelectronics.

Also in 1994, the Fraunhofer Institute for Material and Beam Technology opened the Center for Surface and Laser Processing CSLP, today's Center for Coatings and Laser Applications CCL. The Center is located at Michigan State University, and is one of the world's leading applied research labs developing synthetic diamond technology.

Five years later the Fraunhofer Institute for Experimental Software Engineering created the Center for Experimental Software Engineering CESE at the University of Maryland. Some of their major projects have been with NASA's space shuttle missions.

The Fraunhofer Fraunhofer Institute for Molecular Biology and Applied Ecology IME, along with support from the State of Delaware started the Fraunhofer Center for

and hydrogen gases using chemical vapour deposition. The success of the group caught the attention of the engineers at the Fraunhofer Center for Coatings and Laser Applications. Subsequently, both institutions joined together as teams and continued to advance this method.

"It was often the technical details that determined success or failure," Thomas Schuelke of CCL attests. "During the synthesis process, the pressure and temperature conditions have to be set and adjusted with absolute precision. We studied these parameters and then started to automate the manufacturing process.

Ultimately, a new kind of production machine that meets industry standards emerged. It can finish diamond monocrystals for the jewellery business and for the electronics industry." This machine technology has become commercially available since then: industry partner Lamda Technologies builds and distributes the diamond production machines in the US and world markets. "Our work indicates that the Fraunhofer model – the research at the interface between basic principles and industrial applications – has again proven its value in the USA," concludes Schuelke.

Together with his work group – which includes a growing membership of German graduate students who come to the USA for six months to familiarize themselves with the country, people and work ethic – Schuelke is working assiduously on the next generation of machines and processes for diamond harvesting on a mass scale. They would like to enable industry to simultaneously produce several diamonds of more than one cubic centimeter in size. "We have to consider several technical details at this stage. We need to increase operating pressures and modify the synthesis process accordingly," explains the team leader. "The atmospheric pressure plasma technology also holds much promise. Here's where our colleagues' experience at the German parent institute comes into play and it is extremely useful to us. We are in constant contact with the Fraunhofer Institute for Material and Beam Technology IWS in Dresden."

Lab on a Chip: Multi-discipline à la Fraunhofer

From time to time, transatlantic networks also unlock completely new interdisciplinary research approaches. So, for instance, mechanical engineers, molecular biologists and biophysicists are collectively developing a "lab-on-a-chip". The team includes researchers from the Center for Manufacturing Innovation CMI in Boston, scientists at Boston University, clinicians from Beth Israel Deaconess Medical Center and Harvard Medical School, engineers from the Fraunhofer Institute for Manufacturing Engineering IPT and experts from the Fraunhofer Institute for Molecular Biology and Applied Ecology IME in Aachen.

At the core of the mini-lab, a desktop instrument, is a chip that can isolate and analyze DNA and RNA from blood samples. "Lab-on-a-chip technology is a quantum leap in device development. Until now, scientists had to use a fully equipped laboratory to prepare and test genetic samples

Molecular Biotechnology CMB in 2001.

CMB develops technologies to produce vaccines in greenhouses, using host plants and engineered plant viruses.

The Fraunhofer Office for Digital Media Technologies opened in San Jose, California, in 2007. The goal is to promote the audio-coding technologies of the Fraunhofer Institute for Integrated Circuits IIS, where mp3 was invented.

The Fraunhofer Center for Sustainable Energy was opened in Boston in 2008. The Center is located near the Massachusetts Institute for Technology campus. Just like its parent Institute, the Fraunhofer Institute for Solar Energy, the Center specializes in solar energy and building energy efficiency.

using PCR-technology – Polymerase Chain Reaction," explains Dr. Alexis Sauer Budge of CMI. "Now, everything fits on a small chip, no larger than a credit card."

Based on expert opinions, lab-on-a-chip technology will revolutionize the practice of medicine in the very near future. Previously, physicians and patients had to wait hours, sometimes even days, for the results from the clinical laboratories. The mini-labs allow for immediate, onsite administration of the tests – so medical professionals can dispense with waiting for the results from the laboratory. Indeed, tests in a mini-lab are still considered expensive – chips manufactured with conventional silicon technology have pricing on their side. "Our process is considerably cheaper, because our chips were produced in plastic," explains Dr. Alexis Sauer-Budge. Colleagues from IPT, the German parent institute in Aachen, have produced the chips by injection molding. "Now we can manufacture chips in the single dollar range. That's a significant improvement." Now that the prototype is finished several US- and Europe-based corporations have already signaled their interest in the technology. The potential uses for lab-on-a-chip technology are manifold: Besides testing hereditary substances, they are also suitable for analyzing bacterial and viral infections with immunoassays. Together with their German colleagues, the American researchers are currently working on new tests – such as the test to diagnose bacterial meningitis. Medications of the future, "Made by Fraunhofer". "New technologies, such as the plant-based production of pharmaceuticals, are likely to have a lasting influence on bio-manufacturing and pharmaceutical development in the future", states Dr. Vidadi Yusibov, the Director of the Fraunhofer Center for Molecular Biology in Delaware. Several years ago, CMB received a grant from the Bill and Melinda Gates foundation to develop an affordable and effective subunit vaccine against avian influenza viruses. Using plants to produce the antigens that are needed for the production of the vaccination the researchers now have selected pre-clinical candidates and are planning to initiate a clinical development program to further develop these candidates. "There has been an increasing interest in our technology and its capabilities within the scientific community, not only in the US but abroad as well," says Yusibov. The CMB and Fraunhofer Institute for Molecular Biology and Applied Ecology IME in Germany are planning to combine their efforts to facilitate and promote the validation of this highly valuable technology.

Learning from Success

With its representative offices and subsidiary companies, the Fraunhofer-Gesellschaft is represented on all continents "However, this all started with Fraunhofer USA," concludes Dr. Polter, former head of Fraunhofer. "There, we learned what it means to run a business in a foreign country: you don't automatically understand a culture – not by a long shot – just because you can speak the language; by no means is German perfectionism in demand everywhere; other procedures of project and time management exist than those you are familiar with; you have to adapt yourself to different conditions if you want to be successful. But even that can make matters terribly exciting." ■

Masdar City: eco-city of the desert

The City of the Future is burgeoning right on the city limits of Abu Dhabi: Masdar City should provide housing and jobs for 50,000 people. But here's the real highlight: This paragon of an eco-city gets its power exclusively from renewable energies. Fraunhofer researchers are participating in the development of new technologies for this project.

Text: Monika Weiner

A city in the desert that offers all the amenities of modern everyday living – yet unlike the metropolis of today, this city protects the environment from the impact of carbon dioxide emissions, waste and sewage. An idea that is the perfect fantasy. And yet, such a dream can become a reality, as currently demonstrated by Abu Dhabi, a small emirate on the Persian Gulf that owes its wealth to a bounty of bubbling crude oil reserves. On the periphery of the capital in direct proximity to the airport, groundbreaking ceremonies were recently held for the construction of a truly incomparable project for the future: Masdar City. It will be powered solely by renewable energies, thus emitting no carbon dioxide whatsoever. Solar and windmill power plants will supply the energy needs of its 50,000 residents – for washing and ironing, for air conditioning their homes and for operating their factories. Even the desalination and waste water processing plants are designed to run on renewable energies. Beyond that, city plans call for full waste recycling and an alternative, car-free transportation grid with pedestrian and bicycle paths, as well as a fleet of electric vehicles for individual transportation, driven underneath the city. An auspicious project proving that climate protection is feasible. Project sponsors in Abu Dhabi are also using the project to demonstrate that the tiny emirate is prepared for life after the Petroleum Age. The Eco-City of the Desert will become a beacon, serving as a model for future urban designs. As Dr. Sultan Al Jaber, Chief Executive Officer of the Masdar Project, explains, "We want to accelerate the development of innovative sustainable technologies and make them available on a global basis."

Masdar City: a mass experiment in sustainable urban development

Masdar City is not only an immensely ambitious project, it is also a one-of-a-kind mass experiment. Never before has a CO2-neutral city literally been raised from the desert sands. Its realization demands interdisciplinary solutions from scientists and engineers alike: urban development concepts must be developed and the technical systems for energy production and water supply, traffic and logistics must be processed and evaluated. Solar collector systems and energy-efficient building technologies are just as much in demand as electromobility and the latest methods applied to potable and sewage water processing technologies.

„The issues facing Masdar City are a challenge for applied research, because they are all key future technologies: energy supply without carbon dioxide, car-free transportation concepts, waste reduction and water recycling," Dr. Hans-Jörg Bullinger, President of the Fraunhofer Gesellschaft, reiterates.

Researchers worldwide are participating in the design and realization of Masdar City – among them, the renowned US-based Massachusetts Institute of Technology MIT and the Tokyo Institute of Technology. Fraunhofer Institutes are also contributing their expertise. „Masdar City is a prestige project, and we are delighted that we can be a part of it. We need ambitious projects like this one, so that we can push ahead with the inevitable transition of our energy supply to renewable energies," explains Dr. Eicke Weber. Not too long ago, the Director of the Fraunhofer Institute for Solar Energy Systems ISE in Freiburg signed off on a Memorandum of Understanding that provides documentary evidence of Fraunhofer's and Masdar's commitment and intention to collaborate. And Dieter Fuchs, Head of the Fraunhofer Representative Office in Dubai, explains. „There is not a single, more exciting project for a green city of this caliber anywhere in the world."

Participating in the structuring of a project group are the Fraunhofer Institute for Building Physics IBP and the Fraunhofer Institute for Industrial Engineering IAO in Stuttgart, in addition to the ISE in Freiburg. „The group is tasked with acquiring projects and preparing for the establishment of a center. We also intend to examine the possibility of eventually founding a joint institute for sustainable urban development," Weber reveals. „The project group will cooperate with the Masdar Institute of Science and Technology, which is currently in development with the support of MIT. It can only be to our

Look at the futur: A bird's eye view of the Masdar City. © *DLR/Abu Dhabi Future Energy Company*

"The link between applied research and sustainability is one of the strengths of our institutes. Thus it stands to reason that Fraunhofer knowhow be brought to Masdar City, a truly unique ecological project for the future." Hans-Jörg Bullinger, President of the Fraunhofer-Gesellschaft

benefit that we are already cooperating with MIT and have outstanding contacts available."

Research simplifies planning

Even now, Fraunhofer researchers are involved in several projects. For example, on a testing site in the deserts of Abu Dhabi, a team from the ISE is investigating which solar cooling systems are best suited for building climate control under the given local conditions. „We are evaluating various systems," explains Dr. Hans-Martin Hennig, who manages thermal systems and building engineering at ISE. „The test systems all contain solar collectors and thermal-driven cooling systems supplied by solar heat, which are used for indoor central heating and cooling. However, the systems differ from each other due to an array of technical details, such as power and reliability. The goal of our study is to ascertain which system is best suited to each of the various applications – residential, commercial and hotel."

How do you design and build houses that consume a minimum in energy, but simultaneously create a maximum in comfort? Scientists from ISE are currently identifying the appropriate climate for inside the houses that are planned for development on a site that is six square kilometers, near the Abu Dhabi airport. No matter that the buildings do not even exist yet: thanks to specialized software, researchers can calculate the flow of energy in the buildings even as early as during the planning phase. The specialists from IBP are able to simulate the indoor temperatures that should prevail inside the finished homes and office spaces. Using their software programs, they can calculate the temperature and moisture distribution inside the buildings, even under the most extreme climate conditions: both values are of decisive importance to comfort and health. For anyone whose curiosity is already piqued, and who wishes to see how the City of the Future will look, a 3-D virtual tour through Masdar City is now available in real time, thanks to virtual reality software developed at IAO. „An ideal tool for planners and visitors," says Dr. Wilhelm Bauer, Deputy Director of the IAO.

„The experiences that we gather in Abu Dhabi are immensely important to applied research," Weber notes. „Renewable energies and sustainable urban development are mega-issues. The events happening in Masdar City now will resound throughout the world." In fact, the International Renewable Energy Agency IRENA, founded in 2009, has approved a resolution to establish its headquarters in Abu Dhabi. ■

Air pollution, water contamination and the disposal of refuse and wastewater are some of the most serious problems in São Paulo. © *Yann Arthus-Bertrand/Corbis*

Clean rivers are just the beginning

Clean, fresh drinking water is a precious commodity that can be as scarce in the tropics as in the desert. Brazil, for example, has plenty of rivers, but they are often polluted with fecal matter. Researchers from the Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB demonstrate in a model project how wastewater can be treated economically.

Text: Monika Weiner

The dimensions are overwhelming – with an area of eight million square kilometers Brazil is the fifth largest country in the world. 185 million people live here, with 20 million alone in the greater urban area of São Paulo, the largest city in Latin America. Everything is on a large scale in Brazil – the country, the population, the rivers, the poverty and the wealth. To feel at home here it's advisable not only to master Portuguese, but also to think in other dimensions.

"The latter is a challenge, particularly for Europeans," states Dr. Werner Sternad. The Fraunhofer scientist has been commuting back and forth between Stuttgart und São Paulo for nine years. He meanwhile speaks Portuguese and has become an expert on water supply and disposal in Latin America. "It's a hugely important topic in Brazil. Although the country is situated in the tropics and the longest river in the world, the Amazon, flows through it, clean drinking water in the large conurbations is rare," explains Sternad.

The reason for this is that these megacities require an enormous amount of drinking water, which existing sources can no longer cover. Local suppliers have to resort to river water, but it's polluted, as sewage treatment plants are rare, even if there is often a fully developed canal network for wastewater. Often, sewage flows untreated into the rivers. The river water must then pass through a technically complex cleaning process, before it can be fed into the mains – hence the urgent need for technical solutions which make it easier to access clean water.

Clean water pays off

These solutions are the area of expertise of the IGB researchers. Werner Sternad has developed an extensive water management system for the municipal administration in Americana, a "small city" with 200 000 inhabitants in the north east of São Paulo State. "Americana is situated in the river basin of the Piracicaba, Capivari and Jundiaí rivers, which also provide part of the water supply for the city of São Paulo. But the quality of the water is poor. Apart from being full of germs, it also contains an excess of nitrogen and phosphorus resulting from eutrophication, nutrients which encourage algae to proliferate," says the scientist.

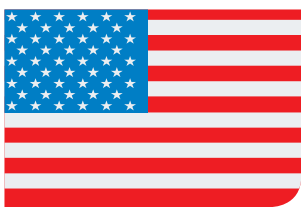
Sternad and his colleagues determined from computer models that appropriate wastewater treatment technology can stop pollution and eutrophication. But that's not the whole story: "The calculations also revealed that it's worth using innovative technologies. Increasing investment by 20 percent could raise the quality of the treated wastewater to European standards. That's more than the Brazilian law prescribes, but the excess expenditure can be written off in the long-term, since the units can be run without having to be modernized every few years, which would be necessary otherwise," explains Sternad.

Energy as a waste product

In a pilot plant the Fraunhofer researchers show that the technology really does work. Firstly, nitrification completely breaks down the urea, then subsequent denitrification and precipitation remove the nitrate and phosphorus from the system. A sophisticated measurement and control technique regulates the whole process fully automatically. "The pilot plant should now act as a model for modernizing the city's large sewage plant," reports Sternad.

Supplying clean water is undoubtedly the most important function of sewage treatment plants, but modern technology enables them to deliver even more: Americana's Carioba sewage plant will also be able to supply fuel and fertilizer. The fuel is extracted from the methane that develops in the digestion tank of the sewage plant, and once it is purified this biomethane has the same quality as natural gas. "We have calculated that there is enough gas to run the whole municipal vehicle fleet of Americana," explains Sternad. "The gas has a calorific value corresponding to 1500 liters of fuel per day. Until now it has simply been burnt in a flare."

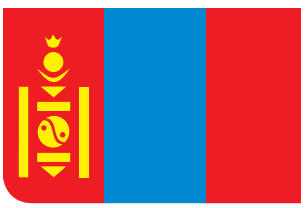
Sludge gas is not the only source of biogas, as it can also be obtained from kitchen waste – which until now has usually ended up on landfills in Brazil. Fraunhofer researchers have shown that there are viable alternatives for Americana, in the form of a small pilot plant which supplies 60 liters of biogas a day. "That's not a lot, but it shows that organic waste can definitely serve as a source of raw material," explains Sternad. "The process is creating great interest amongst the Brazilians, as the country has a fully developed natural gas filling station network and most newly registered vehicles are equipped with flex engines – these can also be run on gas, if they have an additional gas tank." Werner Sternad is convinced that the Brazilians' interest in using biogas will continue to grow in the next few years. "More energy is already needed for the increasing number of air-conditioning units alone. But the technology for extracting and purifying biomethane is there, it just needs to be used and adapted to Brazilian conditions – to an electricity supply, which is not always stable, to a different supply voltage and network frequency, to tropical climatic conditions. In short – to another dimension". ■



Anyone out there?

Researchers at the SETI Institute (Search for Extraterrestrial Intelligence) in California are using highly sensitive radio antennas to eavesdrop on the skies. They are searching for signs of extraterrestrial life – perhaps even of extraterrestrial intelligence – in cosmic radio signals. This astronomical project, in the truest sense of the word, is based on the idea that technologically advanced civilizations would most probably use radio waves for communication. Radio signals have to be modulated in order to transmit information. These modulations can be detected over great distances, so SETI researchers are trying to detect them in the cosmic background noise.

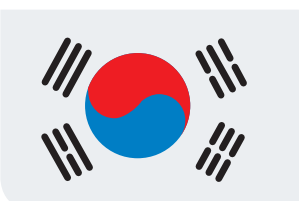
Radio waves from space are weak, however, and sophisticated equipment is needed to amplify the signals before they can be decoded. Experts from the SETI Institute have been looking for the best amplifiers in the world for the new Allen Telescope Array (ATA). In the end they chose technology from the Fraunhofer Institute for Applied Solid State Physics IAF in Freiburg. The amplifier chip is only 2 x 1.5 millimeters in size and can amplify signals almost noiselessly by a factor of 100.



Water management

Water is scarce in many parts of the globe. Researchers from the Fraunhofer Applications Center for Systems Technology AST have developed an idea for protecting drinking water in Mongolia. "Mongolia has a continental climate and is therefore very dry. Only in summer does it rain occasionally. That makes it difficult to supply the population with water – particularly in crowded urban areas," recognizes project manager Dr. Buren Scharaw. "The situation is made worse by antiquated industrial plants and mines, and the lack of sewage plants. In many places the water pumped from wells is polluted."

In the Mongolia project model, called "MoMo" for short, Scharaw and his colleagues show how these problems can be solved. Special calculation software for drinking water networks reveals where shortages are occurring and suggests how they can be avoided. Used in combination with software for process optimization of sewage plants, the researchers were able to calculate how wastewater treatment can be optimized under difficult climatic conditions.



Solar cell research

Seoul, the megacity, is investing in alternative energies and by 2020 renewable sources should cover ten percent of its energy requirement. The Koreans are focusing primarily on solar technology, with scientists at Konkuk university researching new technologies such as dye solar cells and organic solar cells. Researchers in Korea will also be working closely with Fraunhofer researchers in the years ahead. A Memorandum of Understanding between the Fraunhofer Institute for Solar Energy Systems ISE in Freiburg and Konkuk university was signed recently.

Researching together

Central Europe is densely populated, has few fossil fuel resources, but requires huge quantities of water and energy to meet the population's daily needs, and for transport and industry. The United Arab Emirates, on the other hand, is traditionally sparsely populated, has little water, but is rich in oil and gas wells. There could hardly be a greater contrast between two future research partners. But it is said that opposites attract, „and in research they can even be mutually enriching," said Dr. Dieter Fuchs, General Manager, Fraunhofer Representative Office Middle East, at the signing of a memorandum of understanding between the Emirates Institute for Advanced Science and Technology and Fraunhofer in Dubai.

The state-owned institution wishes to work together with Fraunhofer's experts, for instance in joint research projects on the use of alternative energy sources, sustainable water supplies and water-treatment plants, and the development and implementation of environmentally friendly processes, for example, in intelligent construction.

Help AIDS patients

The university clinic in Gondar, Ethiopia, cares for more than five million people. Many HIV patients suffer concurrently from infections with different pathogens, including malaria, tuberculosis and leishmaniasis. Until now, there has been little research into these co-infections which make treatment difficult. The Virus-Host Interaction Laboratory at the Fraunhofer Institute for Cell Therapy and Immunology IZI in Leipzig is investigating the interactions between the different pathogens, under the leadership of Dr. Jörg Baumann and Dr. Sabine Breun. Together with colleagues at Gondar university, and joined by Prof. Dr. Dieter Reissig from Leipzig university, the Fraunhofer research scientists are examining how co-infections may influence a course of therapy. The German company PARTEC has now honored the German-Ethiopian network with the Second World AIDS Day Award.

Technology for elderly

Technology can make life much easier – even in old age. Researchers from five European countries are jointly developing intelligent ICT-systems designed to help the elderly and the sick, and people needing care, to cope better with their everyday lives. In the EU project EMERGE – the acronym stands for Emergency Monitoring Prevention – scientists are currently working on a new assistance solution for care patients. Its purpose is to recognize potential emergency incidents – for example helplessness or severe behavior deviations – and alert emergency medical services in time. The necessary sensors are totally ambient and installed unobtrusively, discretely integrated in furniture, beds or carpets.

The technology was early-tested in a field trial in Greece in 2009 – scientists from the Fraunhofer Institute for Experimental Software Engineering IESE in Kaiserslautern equipped an O'Nestor home care center in Athens with the requisite devices and sensors. In the meanwhile researchers have used the long-term data recorded there to improve the early detection and prevention of emergency incidents. Further field trials in Kaiserslautern, Germany are currently running.

Patient in Europe

More and more Europeans are regularly crossing borders, either to travel to work, to see clients or go on holiday. "Increasing mobility is presenting health care with new challenges," explains Dr. Jörg Caumanns of the Fraunhofer Institute for Software and Systems Engineering ISST in Berlin. "In an emergency, medical information such as patient data or prescriptions must be available throughout Europe." In the epSOS EU project – 'Smart Open Services for European Patients' – Caumanns and his international team are developing an infrastructure for eHealth information that will support the exchange of important medical data. The demands on this system are extremely high as it must not only offer reliable data protection but also reliable protection against disruptions.

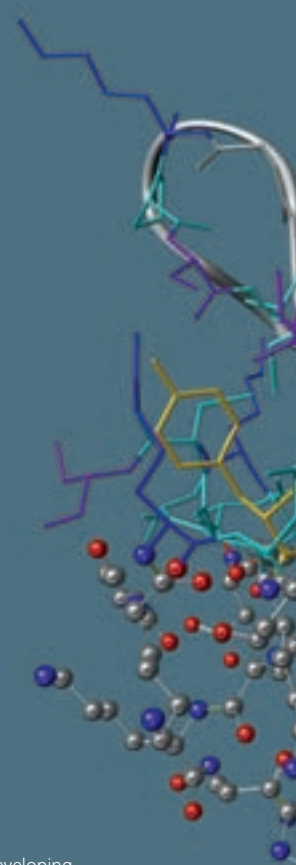
Gentle energy

Eco-power is in. The number of wind turbines and solar cells in Western Europe is increasing constantly. But what are the prospects for regenerative energies in Eastern Europe? A workshop organized recently in Budapest by the Fraunhofer Center for Central and Eastern Europe, Leipzig, debated this question. Eastern Europeans are indeed extremely interested in pursuing the subject, and Hungarian researchers want to work closely with Fraunhofer institutes in future. An interdisciplinary team in Romania is currently identifying potentials for generating and using energies from renewable sources. It will also examine to what extent the necessary systems can be manufactured on site. The Fraunhofer Institutes for Interfacial Engineering and Biotechnology IGB in Stuttgart, for Solar Energy Systems ISE in Freiburg, for Information and Data Processing IITB and for Systems and Innovation Research ISI in Karlsruhe are working together under the leadership of the Fraunhofer Institute for Manufacturing Engineering and Automation IPA in Stuttgart.

Fraunhofer in Austria

Fraunhofer has a new subsidiary: Fraunhofer Austria Research GmbH. The non-profit company's two business units coordinate the work of Fraunhofer Research Groups based at the Universities of Technology in Vienna and Graz respectively, developing practical solutions for customers in industry.

Text: Monika Weiner



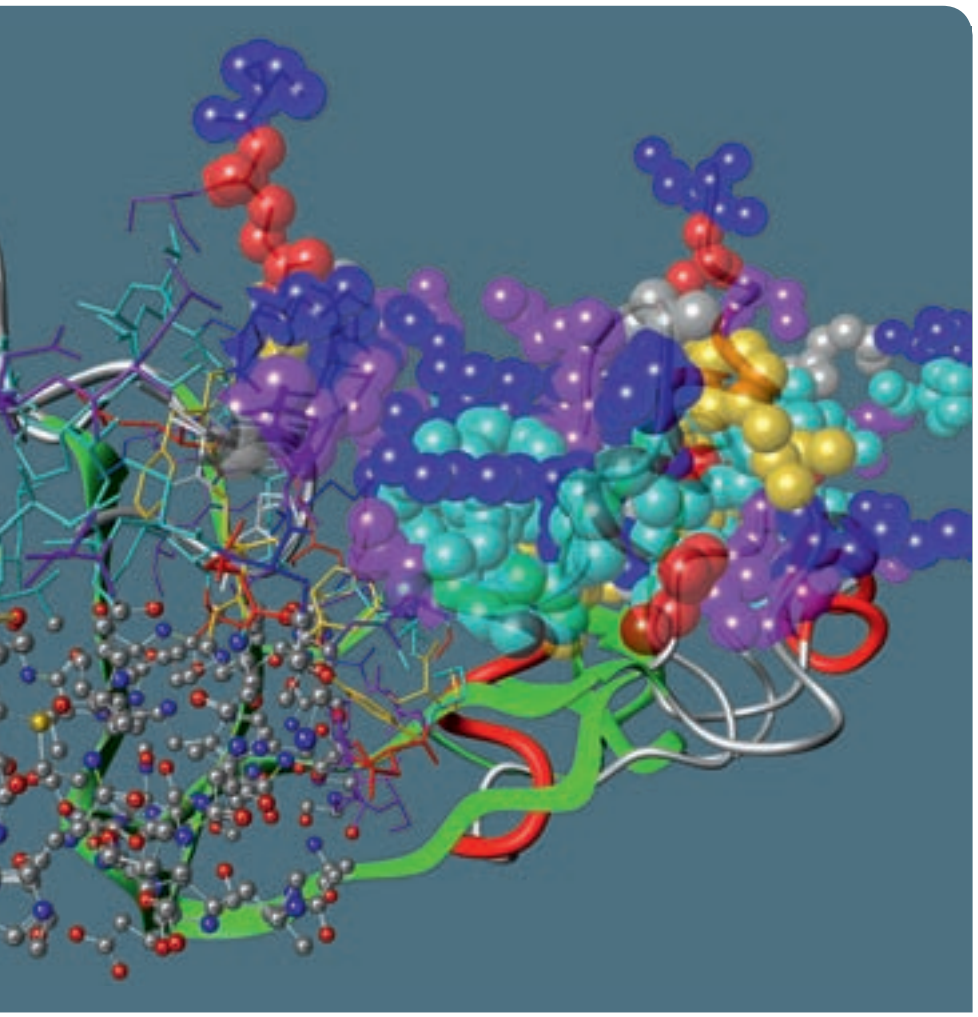
Fraunhofer researchers in Graz are developing BioBrowser software for visualizing molecules.
© *Fraunhofer Austria*

"Research cuts across all frontiers – and that applies to contract research too," declared Professor Hans-Jörg Bullinger, President of the Fraunhofer-Gesellschaft, at the official opening of Fraunhofer Austria Research GmbH in Vienna. "A substantial market for research and development services has developed in Europe in recent years. Those who want to profit from this market must be prepared to face international competition, establish contacts, and act on technological trends and market developments." The institutes of the Fraunhofer-Gesellschaft were quick to recognize this: in 2008 they generated revenues totaling 52 million euros from contract research in the European Economic Area, including almost seven million euros in Austria alone. This makes Austria the Fraunhofer-Gesellschaft's most important partner in Europe. "The creation of Fraunhofer Austria Research GmbH is our response to Austria's growing demand for technology transfer," adds Fraunhofer senior vice president Professor Ulrich Buller. "It is the ideal opportunity for us to profitably apply the experience we have gathered during the six decades that we have already spent transforming new technical developments into real-world products."

"Founding Fraunhofer Austria Research GmbH is an important step towards more intensive collaboration with Austria," emphasizes Professor Wilfried Sihn, the managing director of the new company, who is assisted by Professor Dieter Fellner. The company's two business units coordinate the activities of Fraunhofer Research Groups based at the Universities of Technology in Vienna and Graz respectively, developing practical solutions for customers in industry. By the end of 2009, 17 employees will be working at Fraunhofer Austria.

The Fraunhofer Project Group for Visual Computing in Graz works in close association with the Institute for Computer Graphics and Vision (ICG) at the University of Technology, which is one of the leading European centers of excellence in this field. "Here we are developing innovative ideas that are just waiting for the killer application," says Fellner, the native Austrian who leads the project group in Graz in addition to his post as director of the Fraunhofer Institute for Computer Graphics Research IGD in Darmstadt. One example of the way in which innovative ideas can find applications in industry is the high-resolution computer graphics software for the visualization of surfaces, developed by the research team in Graz.

"Curved surfaces are commonly represented by a network of triangles. At first glance the surfaces appear to be smooth, but areas of roughness are



revealed when the resolution is increased. Such inaccuracies can have serious consequences when every detail counts – as in the case of design drawings. The new algorithms we have developed now allow surfaces to be visualized accurately for the first time, without workarounds," explains Dr. Eva Eggeling, manager of the Visual Computing business unit at Fraunhofer Austria Research GmbH in Graz. Working with her team, she has adapted the algorithms to the requirements of industrial customers. The technique is meanwhile being used by partners in the automotive industry to design fenders and wheel rims.

Molecular biologists are also benefiting from the cooperation between Graz University of Technology and Fraunhofer. New visualization software enables three-dimensional images to be created of complex folded proteins consisting of thousands of amino acids. The images can be rotated and zoomed, and it is even possible to see the bonds between individual molecules. "The quantity of data generated when investigating the structure of molecules is so enormous that it is difficult to master. Our tool converts these data into easily assimilated images," says Eggeling.

The Fraunhofer Project Group for Production Management and Logistics has made its home in the Austrian capital of Vienna – a strategically important location according to Professor Wilfried Sihn, chairman of the Institute for Management Sciences at the University of Technology in Vienna and managing director of Fraunhofer Austria. "Vienna has always been a meeting point between eastern and western Europe, and as such is the ideal support base for technology transfer activities focusing on eastern European countries."

The Fraunhofer Project Group in Vienna specializes in optimizing production and logistics networks for specific products or companies, taking into account both environmental and economic factors. "Our aim is to develop customized, end-to-end solutions that will enable our customers to optimize their value creation networks on a sustainable basis," relates Daniel Palm, head of the business unit for production and logistics management.

Research focuses on visual computing and production

"Optimal production depends on many variables. Product-related factors, such as the size and weight of components, are important. But the distance to the customer market also has to be taken into account. Other crucial factors include the production volume, the level of automation, the local labor market and infrastructure, and the required quality standards. Further aspects that need to be considered are government support and/or restrictions, and the cost and environmental impact of transporting the goods to the customer," says Palm. After blindly following the crowd and moving production to low-wage countries, many companies have discovered in retrospect that this does not necessarily produce the desired results. "By taking a holistic approach, we are able to optimize the production parameters. And it often turns out that manufacturing in Austria or Germany is the best option," relates Palm.

Not long ago, the Fraunhofer researchers joined forces with experts at Vienna University of Technology to study the impact of the financial crisis on the automotive industry in eastern Europe. They came to the astonishing conclusion that suppliers and manufacturers in eastern Europe are likely to weather the crisis better than companies in the West. "The eastern plants have a number of advantages," explains Palm: "They have lower production costs, often new efficient factories, and they manufacture small cars, which are much in demand these days because more and more buyers are opting for fuel-efficient models, for both ecological and economic reasons. This puts pressure on plants in western Europe to rethink their strategy, which in turn changes the parameters of the game again." This example not only illustrates the complex interrelationships involved but also demonstrates that even a crisis can hold opportunities for astute players in the manufacturing sector. ■

German-French research camaraderie

Combining shared goals: Fraunhofer researchers and their colleagues from France-based Carnot institutes have already developed numerous industry-viable products.

Text: Monika Weiner

France enjoys immense popularity among the Germans – not just among vacation travelers, but among business professionals as well. The neighbor on the opposite bank of the Rhine is the Federal Republic of Germany's most important export trade partner. "Businesses that operate abroad also expect relevant foreign experience from the research partners that they consult," explains Fraunhofer president Hans-Jörg Bullinger. "As an organization for applied research, we have to know the political and economic conditions in the countries that are important to our clients – and in this case, France gets top priority."

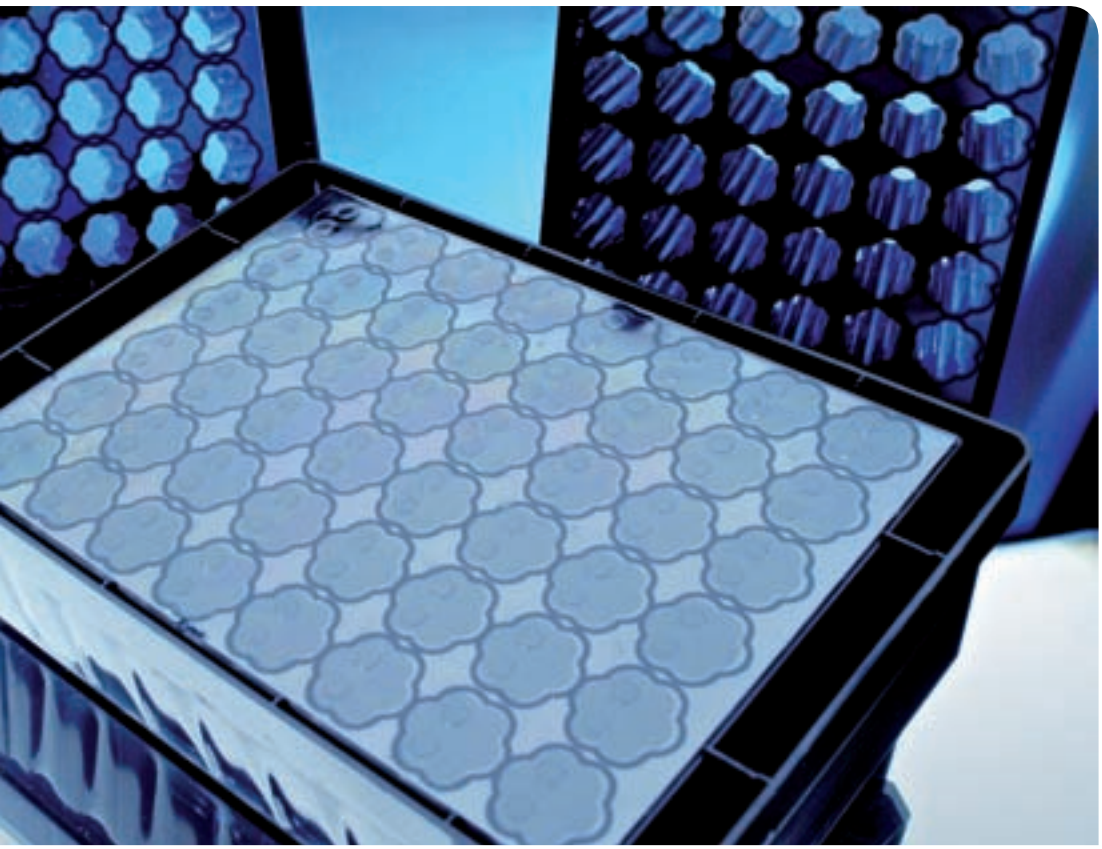
Over time, 33 research institutes have come to make up today's Carnot network. All are publicly financed and all have committed to organizing research partnerships with businesses thereby promoting technology transfer. The parallels with the German Fraunhofer model are no coincidence: Fraunhofer served as the inspiration for the expansion of the network and for the restructuring of the institutes. "The stage was set by the reorientation of the French research landscape," explains Volker Tippmann of Fraunhofer Research Planning, who witnessed this phase while serving as a delegate of the Fraunhofer-Gesellschaft. "With the founding of the Agence National de la Recherche ANR in 2005, a centralized research funding agency materialized that supports applications-oriented research. Since 2006, the ANR decorates institutes which are successfully collaborating with partners from business and industry with the Carnot label." The Carnot institutes cover a broad technological and scientific spectrum, including micro- and nanotechnologies, materials research, environmental engineering, life sciences, geosciences and building physics.

Joint research projects

The cooperation between the Carnot institutes and Fraunhofer was supported by German and French sponsors. In 2007, twelve jointly-funded Fraunhofer/Carnot projects crossed the starting line. Solid results have already been achieved since then: Researchers from the Fraunhofer Institute for Experimental Software Engineering IESE in Kaiserslautern, together with colleagues from the Institut Carnot Laboratoire d'Analyse et d'Architecture des Systèmes LAAS in Toulouse tested the safety of software systems used in automotive engineering. At the Fraunhofer Institute for Manufacturing Engineering and Automation IPA in Stuttgart, a device was developed in joint collaboration with the Institut Carnot Laboratoire d'Intégration des Systèmes et des Technologies CEA-LIST that allows the suturing of delicate blood vessel tissues in minimally invasive surgery. In addition, experts from the Fraunhofer Institute for Laser Technology ILT and colleagues from the Institut Carnot MINES studied the mechanical properties of fiber composite materials that are spliced together using lasers.

Encouraged by these results, in February 2008 the ministers of research of the two countries signed a bilateral economic development program to expand the cooperation between Fraunhofer and Carnot institutes at the 3rd German-French Research Forum in Paris. Initially, three annual tender procedures are scheduled,

Fraunhofer brings its experts and expertise, for example, in laser beam welding of plastics, to this German-French collaboration.
© *Fraunhofer ILT*



with a total funding endowment of ten million euros per year. At the start of 2009, almost eighty German-French teams applied for the first round of bids. Eleven projects were ultimately selected by a committee of experts. These projects were presented on October 27th at the official start of the Fraunhofer-Carnot Program in Paris.

Systems for cost-effective analysis of blood samples

Among other objectives, plans call for the development of a cost-effective microanalysis system for healthcare. Researchers from the Fraunhofer Institute for Reliability and Microintegration IZM in Berlin, in conjunction with their colleagues from the Fraunhofer Institute for Cell Therapy and Immunology IZI in Leipzig and the France-based Institut Carnot FEMTO Innovation are aiming to advance the development of lab-on-a-chip technology. They expect to make swift and cost-effective analysis of blood samples possible directly in the doctor's office in the future, dispensing with the heretofore inevitable, circuitous route through a major laboratory. At the same time, experts from the Fraunhofer Institute for Physical Measurement Techniques IPM in Freiburg and the Institut Carnot IEMN continue to make progress on antennas for terahertz radiation. This technology is increasingly being used for security controls, because it makes explosives and drugs visible, and has no health-related side effects on human beings. Another joint project, between the Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB in Stuttgart and the Institut Carnot CIRIMAT, holds promise for the cultivation of osseous (bone) tissue using innovative biomaterials. Such materials could be used in surgery, for instance, when new bone material must be grown in accident victims.

"The cooperation between Fraunhofer and Carnot is a win-win situation," concludes Tippmann. "Thanks to their close collaboration, these groups of researchers are not only getting to know the business and economic situation of their respective partner countries, they are furthermore developing products that can be marketed in both nations." ■

The cooperation projects

ICT Technology
DeepCity3D – Integrated 3D visualization for urban surface and underground data; **project partners:** Fraunhofer Institute for Computer Graphics Research IGD and BRGM Bureau de Recherches Géologiques et Minières

RT-DESCRIBE – Iterative Design Process for Self-Describing Real Time Embedded Software Components; **project partners:** Fraunhofer Research Institution for Systems of Communications Technology ESK and CEA LIST (Lab of applied research on software-intensive technologies)

TOTEM – Theory and Tools for Distributed Authoring of Mobile Mixed Reality Games; **project partners:** Fraunhofer Institute for Applied Information Technology FIT and TELECOM EURECOM

APUS – Auspicious high-Performant Ultrafast laser System; **project partners:** Fraunhofer Institute for Applied Optics and Precision Engineering IOF and ESP Energy and propulsion system

Health
3µP – Multi-Reaction, Multi-Sample Microfluidic Platform; **project partners:** Fraunhofer Institute for Reliability and Microintegration IZM, Fraunhofer Institute for Cell Therapy and Immunology IZI and FEMTO-Innovation

Bio-capabilities – Investigation of new anti-bacterial biomaterials based on biomimetic calcium phosphates to prevent bone infections – Comparative critical study in view of industrial developments; **project partners:** Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB and CIRIMAT Centre Interuniversitaire de Recherche et d'Ingénierie des Matériaux

Transportation
DEVICE – Downsized hybrid Diesel Engine for Very low fuel consumption and CO2 Emission; **project partners:** Fraunhofer Institute for Structural Durability and System Reliability LBF and IFP-Moteurs Institut Français du Pétrole-Moteurs and Volkswagen AG

DEVICE-SOFT – Deductive Verification for Industrial Critical Embedded Software; **project partners:** Fraunhofer Institute for Computer Architecture and Software Technology FIRST and CEA LIST

Energy
SolarBond – Development of multi-junctions high efficiency solar cells on reclaimable substrates; **project partners:** Fraunhofer Institute for Solar Energy Systems ISE and CEA LETI Laboratory for Electronics and Information Technology

Environment
VERTIGAN – Vertical-cavity emitters based-on GaN for optical fiber sensors; **project partners**: Fraunhofer Institute for Applied Solid State Physics IAF und C3S Centrale-Supélec Sciences des Systèmes

Security
ARTEMIS – Antennas aRrays for Terahertz Material Identification and Security applications; **project partners:** Fraunhofer Institute for Physical Measurement Techniques IPM and IEMN Institute of Electronics, Microelectronics and Nanotechnology

Digital archiving

To date, our entire cinematic heritage has been recorded on film and stored on huge reels. But now that both cinema and TV are starting to go digital, we need to find new methods of archiving too.

Text: Birgit Niesing

In future, films will be archived digitally. © *Fraunhofer IIS*

It was only a year ago that experts in Buenos Aires discovered reels of film containing forgotten scenes from Fritz Lang's classic silent movie Metropolis. Eighty years on from its first showing, we can now pretty much piece together the full-length original version of this famous science fiction movie, which is roughly 25 minutes longer than the shortened German and American cut.

Even today, most movie footage still tends to be shot on 35-millimeter film and archived on huge reels. The problem with this system is that film buffs, historians and TV editors have only very limited access to the treasures archived in this way. Given how expensive and time-consuming they are to make, access copies have only been produced for a very small number of films. And finding a specific reel or reels of film isn't always a straightforward task either. The content of the reels is usually only noted on a single accompanying document, and if that piece of paper is missing or the writing has faded, it can be very difficult to find the desired piece of film.

Digitization makes archiving easier

Dr. Siegfried Fößel of the Fraunhofer Institute for Integrated Circuits IIS in Erlangen says: "It's worthwhile trying to digitize films so that better use can be made of existing archived material. Of course, in the future, increasing numbers of motion pictures will also be recorded digitally, and that's another reason for going over to digital archiving."

So how can films be digitally archived? Researchers from the IIS and European film archives worked together to answer this question within the EU project "EDCINE" (Enhanced Digital CINEma). Fößel explains the scientists' approach: "Digitization of film material and the production of digital motion pictures both give rise to enormous amounts of data, easily running to several terabytes. To facilitate the handling of such quantities of data while simultaneously developing the best possible long-term archiving solutions and ensuring easy access, the proposed architecture involves a two-tier model."

To start with, the uncompressed data, i.e. the data as it stands at the end of the post-production process, is compressed and stored using a lossless process. This means the images retain their very high resolution, depth of color and dynamic. This "master archive package" is comparable to the original film in conventional film archives and is stored on magnetic tapes or other digital data carriers. It can then be used at a later date, for example in digital restoration of films. But will the stored data still be usable in fifty years' time? Fößel acknowledges this concern: "For long-term archiving, well-documented established and open standards will have to be used. That's the only way we can ensure that future generations will still be able to read and interpret archived digital material."

EDCINE

Sixteen partners worked on the EU project "EDCINE" (Enhanced Digital CINEma), which focused on the following three areas of interest:

– technologies for streaming to digital movie theaters
– technologies for immersive audiovisual experiences in digital movie theaters
– concepts and data formats for digital film archives

The project ran for three years and ended in June 2009.

The contributors to the "digital film archive" sub-project are:
– Fraunhofer IIS, Germany
– Cinémathèque Royale de Belgique
– MOG Solutions, Portugal

As part of this project, the scientists not only developed a concept and software tools, but also a demonstrator for film archiving. The partners additionally offered technical tutorials on archiving, running ten workshops throughout Europe.

However, the average archive user is unlikely to be in a position to handle the enormous amounts of data in the master archive package – hence an "intermediate access package" is produced using an automatic conversion process. This format, too, contains all the film images as individual frames, but scaled down to a pre-determined maximum resolution and color depth and converted into a standard color space for the purpose of archiving. The images are compressed using a lossy process, in order to reduce the amount of data.

Users can search online for films

Fößel says: "Metadata – information that describes the characteristics of the film – can be extracted from the intermediate access package using either a manual or an automated process, and stored in a database." For example, a user can search online for films by a particular director and even watch a short preview. Once they find the film they're looking for, they can order the complete film or extracts thereof in the most appropriate format for their purpose – e.g. "digital cinema package" (DCP) for a digital cinema screening, H.264 data for use in a home cinema, or MPEG-2 data for TV broadcasting or further processing.

An automatic conversion process produces a "dissemination package" for distribution of the material and prepares the data for download or streaming. In this way, the same database can serve movie theaters, television broadcasters and private users. Digital archiving has another tremendous advantage, too: the master data can be used to make as many high-quality access copies as desired without damaging the original material – this is not the case with film.

www.edcine.org

Those interested in digital film archiving have already been given the opportunity to see for themselves how the process works. In conjunction with the Cinémathèque Royale de Belgique and MOG Solutions, researchers from the IIS recently ran a number of practical demonstration workshops on how to use digital technologies in film archiving in various European cities. ■

Automated Tissue Engineering on Demand

There is an increasing demand for skin. Manufacturers of pharmaceuticals, chemicals, cosmetics and medical engineering products need it in order to test the compatibility of their products with human skin. Fraunhofer researchers intend to manufacture artificial skin in a fully automated process.

Text: Monika Weiner

Skin from a factory – this has long been the dream of pharmacologists, chemists and doctors. Research has an urgent need for large quantities of 'skin models', which can be used to determine if products such as creams and soaps, cleaning agents, medicines and adhesive bandages are compatible with skin, or if they instead will lead to irritation or allergic reactions for the consumer. Such test results are seen as more meaningful than those from animal experiments, and can even make such experiments largely superfluous.

But artificial skin is rare. "The production is complex and involves a great deal of manual work. At this time, even the market's established international companies cannot produce more than 2,000 tiny skinpieces a month. With annual requirements of more than 6.5 million units in the EU area alone, however, the industrial demand far exceeds all currently available production capacities," reports Jörg Saxler. Together with Prof. Heike Mertsching, he is coordinating the "Automated Tissue Engineering on Demand" project within the Fraunhofer-Gesellschaft.

Tissue engineering is still in its infancy. "Until now, the offer was limited predominantly to single-layer skin models that consist of a single cell type," explains Mertsching, who heads the Cell Systems Department at the Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB. "Thanks to developments at our institute, the project team has access to a patent-protected skin model that consists of two layers with different cell types. This gives us an almost perfect copy of human skin, and one that provides more information than any system currently available on the market."

An interdisciplinary team of Fraunhofer researchers is currently developing the first fully automated production system for two-layer skin models. "Our engineers and biologists are the only ones who have succeeded in fully automating the entire process chain for manufacturing two-layer skin models," explains Saxler from the Fraunhofer Institute for Production Technology IPT, where he is responsible for technology management and heads the "Life Science Engineering" business unit. In a multi-stage process, first small pieces of skin are sterilized. Then they are cut into small pieces, modified with specific enzymes, and isolated into two cell fractions, which are then propagated separately on cell culture surfaces. The next step in the process combines the two cell types into a two-layer model, with collagen added to the cells that are to form the flexible lower layer, or dermis. This gives the tissue natural elasticity. In a humid incubator kept at body temperature, it takes the cell fractions less than three weeks to grow together and form a finished skin model with a diameter of roughly one centimeter. The technique has already proven its use in practice, but until now it has been too expensive and complicated for mass production. Mertsching explains, "The production is associated with a great deal of manual work, and this reduces the method's efficiency."

The project team, in which engineers, scientists and technicians from four Fraunhofer institutes are cooperating, is currently working at full speed to automate the work steps. The researchers at the IGB and the Fraunhofer Institute for Cell Therapy and Immunology IZI are handling the development of the biological fundamentals and validation of the machine and its sub-modules. Experts from the Fraunhofer Institute for Manufacturing and Automation IPA and the Fraunhofer Institute for Production Technology IPT are taking care of prototype development, automation and integration of the machine into a complete functional system. "At the beginning, our greatest challenge was to overcome existing barriers, because each discipline had its own very different approach," Saxler remembers. "Meanwhile, the four institutes are working together very smoothly – everyone knows that progress is impossible without input from the others." After working together for one year, the project team has already initiated eight patent procedures.

A computer model of the overall system, along with the three fundamental sub-modules shows, how the system will work:. The first module prepares the tissue samples and isolates the two cell types; the second proliferates them. The finished skin models are built up and cultivated in the third, and then packed by a robot.

The researchers still have a lot of meticulous work ahead before the machine will be finished. The difference between success and failure often depends on details, such as the quality of the skin pieces, processing times of enzymes, and liquid viscosities. Furthermore, the cell cultures must be monitored throughout the entire manufacturing process in order to

The system is intended for the fully automatic production of skin models ready for shipping.
© *Fraunhofer IGB*

provide optimal process control and to allow timely detection of any contamination with fungi or bacteria. The skin factory is expected to be finished in two years. "Our goal is a monthly production of 5,000 skin models with perfect quality, and a unit price under 34 euros. These are levels that are attractive for industry," Saxler continues.

With skin from the factory an old dream would come true

But chemical, cosmetic, pharmaceutical, and medical technology companies who have to test the reaction of skin to their products are not the only ones interested in Automated Tissue Engineering. In transplantation medicine, surgeons require healthy tissue in order to replace destroyed skin sections when burn injuries cover large portions of the body. The two-layer models that the new machine is intended to produce are not yet suitable for this purpose, however. "They don't have a blood supply, and are consequently rejected by the body after some time," Saxler explains.

But IGB researchers are already working on a full-skin model that will even include blood vessels. Once the research has been completed, fully automatic production of the transplants should also be possible. "We have designed the production system in such a way that it satisfies the high standards for good manufacturing practices (GMP) for the manufacture of products used in medicine," Mertsching explains. "And so they are also suitable for producing artificial skin for transplants." ■

Biomass to replace petroleum

Straw, wood, microalgae and a host of other renewable raw materials can be used in lieu of petroleum.

Text: Marion Horn

The new Chemical and Biotechnological Process Center CBP is being built in Leuna. © *MEV*

Plastics, varnishes, detergents, adhesives, cosmetics – numerous products manufactured by the chemical industry are currently made from petroleum. But today chemical companies around the world are striving to reduce their reliance on this expensive and scarce resource, and already many products are being manufactured from biomass. This requires highly sophisticated processes. "For example, many plant substances have to be chemically altered using enzymes before they can be processed further," explains Professor Thomas Hirth, director of the Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB in Stuttgart. "If they are to be used as a source of raw materials on an industrial scale, plant substances must be available at favorable prices and must be of a consistent quality. These new processes should also be looking to move away from human and/or animal foodstuffs."

The use of renewable raw materials on an industrial scale represents a considerable financial and technological challenge even for large commercial enterprises, and many small and medium-sized companies fail in their efforts despite initial success in developing attractive products in the laboratory. The new Chemical and Biotechnological Process Center (CBP) in Leuna aims to bridge the gap between the laboratory and industrial applications and will be available to all cooperation partners for research and development purposes. Scientists from the IGB and the Fraunhofer Institute for Chemical Technology ICT are working together with InfraLeuna GmbH, the company that operates the Leuna chemical site, to draw up the plans for the CBP. This highly versatile biorefinery concept will pave the way to new methods of processing biological raw materials that will ensure an on-demand supply of oils, fats, cellulose and starch or sugar-based feedstocks for transformation into products.

Of the currently budgeted capital investment of 50 million euros, the Land of Saxony-Anhalt has agreed to contribute 24.1 million, including start-up funding for the project group. Further funding will be derived from initial research projects, for which support is being provided by the German federal ministries of education and research BMBF, food, agriculture and consumer protection BMELV, and environment, nature conservation and nuclear safety BMU. The Fraunhofer-Gesellschaft intends to use 9.6 million euros of the base funding it receives from the BMBF to finance its involvement. So far, 23 industrial enterprises and 15 universities and research institutions have announced their intention to participate in the venture. ■

Electronics from the printer

Contact: Dr.-Ing. Michael Jank, michael.jank@iisb.fraunhofer.de

If we want to incorporate simple electronic functions in everyday products – for example, a yogurt pot that can monitor its own temperature – this additional functionality must not add much, if anything, to the total price. Researchers at the Fraunhofer Institute for Integrated Systems and Device Technology IISB in Erlangen are currently looking into novel materials and the associated processes for printing low-cost electronic applications.

The scientists have set up a process line in which electron devices made of inorganic materials can be printed using nanoparticles – with an ink jet similar to that found in any office printer.

The institute is working on the production of nanoparticles and inks, optimizing the printing process and developing devices and applications.

The wetting behavior is crucial for control of printed images. Silver nanoparticle ink jetted onto non-treated plastic substrate (left) and surface optimized silicon dioxide (right).
© Fraunhofer IISB

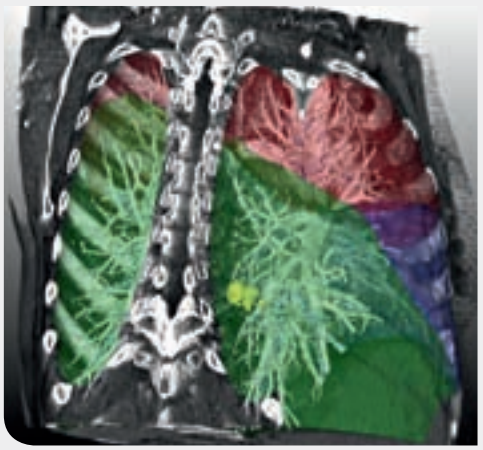
Growing demand for raw materials

Contact: Gerhard Angerer, gerhard.angerer@isi.fraunhofer.de

The majority of today's emerging technologies depend on the availability of specific raw materials. Chromium, for example, is needed to produce stainless steel, silver to produce printed RFID tags, germanium to produce lenses for infrared optics. On behalf of the German federal ministry of economics and technology (BMWi), scientists at the Fraunhofer Institute for Systems and Innovation Research ISI and the Institute for Futures Studies and Technology Assessment IZT have analyzed what quantities of different raw materials will be required in 2030 and which future technologies are likely to be worst hit by potential supply shortages.

The researchers initially assessed the state-of-the-art, market readiness, raw material requirements and recycling potential of almost 100 future technologies. Of these, they then selected 32 individual technologies from six high-tech and cutting-edge sectors which are particularly reliant on raw material supplies for a more in-depth assessment of likely industrial applications and raw material requirements. Their study provides companies in both the manufacturing and processing sectors with raw market data that will enable them to improve their understanding of the interplay between technological progress and the availability of raw materials and to take this into account when planning operations. One thing the study did reveal is that gallium, neodymium, indium, germanium, scandium, platinum, tantalum and silver are the raw materials of prime importance to future technological developments.

Download the study at
www.isi.fraunhofer.de/n/departm.htm



Medical imaging facilitates the pre-operative planning of lung surgery. *© Fraunhofer MEVIS*

Risk minimization

Contact: Dr. Guido Prause, guido.prause@mevis.fraunhofer.de

Researchers at the Fraunhofer Institute for Medical Image Computing MEVIS in Bremen are working on systems and software tools to help surgeons plan lung surgery procedures more accurately. To do so, they have drawn on their many years' experience in the computer-assisted planning of liver surgery.

The future systems will use radiological images to assess the probable outcome and potential risks of planned surgical procedures for individual patients and will also support surgeons in the operating theater. The new methodes will undergo further development and testing in leading lung surgery institutions. 14 partners are involved in the project, including the University Hospitals of Freiburg, Greifswald and Lübeck, as well as a number of other hospitals and clinics in Germany.

Tracking hidden plagiarism

Only geeks never cheated in school. Almost every student takes a peek over his neighbor's shoulder, often only to find that their solution did not look very promising either. But with the Internet and an almost unlimited access to information, plagiarism has become easy – whole passages from documents can be copied and claimed as one's own. Plagiatims has become a serious problem, not only in schools, but also in academia.

Text: Britta Danger

How to detect plagiarism is still an unresolved question. But Cristian Grozea from the Fraunhofer Institute FIRST in Berlin has found an approach that leads to results of unprecedented precision. His method has just won first prize in the inaugural International Competition on Plagiarism Detection. Searching for similarities in 14.000 documents he found 65 percent of all plagiarism incidences with a precision of 75 percent.

"I already had quite some experience with plagiarism detection," says Grozea, who took part in the competition parallel to his regular projects at the Fraunhofer. "When I was teaching at the University of Bucharest, I developed a program to detect if my students were copying their exercises in web-programming from each other." Nineteen exercises was apparently too much work for some of them to complete. To verify his suspicion Grozea had to get creative. "There were about 600 projects, too many to compare by hand for similarities. So I designed a program to check automatically." By compressing the programs the students wrote, and reducing the data to easily comparable numeric values, Grozea successfully unmasked a couple of his students.

But not everyone is able to do this, and commercially available tools are not yet good enough. To address this issue, the Bauhaus University of Weimar and the Universidad Politécnica de Valencia organized the competition. "There were no consolidated findings about the approaches on plagiarism detection," says Martin Potthast, co-organizer of the competition. To challenge researchers from all over the world, they prepared 28,000 documents – extractions from all sorts of books, ranging from novels such as One Thousand and One Nights to economic reports.

A competition shows who has got the answer

Some 14.000 documents in English, German and Spanish served as originals, while the other 14.000 were transformed into examples of plagiarism. Easier cases to detect involved the complete integration of whole passages several pages in length, while more difficult examples modeled obfuscation attempts with subtle transformations, like replacing words with synonyms and antonyms. To give the researchers a chance to adapt their methods to the challenge, half of the documents were used for a test run where the similarities between the documents were known. In the second run, the competitors had to detect the plagiarism by themselves.

Data compression shows the way

To find similarities with high accuracy, Grozea, who holds a PhD in theoretical computer science, chose to compare the 7000 source documents to all 7000 suspicious ones individually, resulting in 49 million document pairs. This was a difficult task as his time was limited due to his simultaneous work on other projects, and his computer resources were scarce. Grozea chose to benefit from his experience with his students at the university and to again compress the data. To get hold of these masses of information he applied so-called kernel methods for pre-filtering. He fragmented the pairs into short pieces, named N-grams, of 16 characters each. These lists of N-grams enable the computation

Hard times for plagiarism: New methodes show the theft of ideas. © *dieKLEINERT.de / Nils Fliegner*

of similarities to be detected. What sounds simple in theory is quite a challenge in reality. "To compress all those files up to book length would be enormously time consuming. One second for each pair would have meant three years of computer work," says Grozea.

Luckily, the actual project Grozea is working on at the Fraunhofer helped to find a solution and accelerate the speed. It is named REMIND and applies machine learning to network intrusion detection – the attack of computers by malware or viruses. "If you want to examine the network traffic you need very fast systems, especially if you are operating this intrusion detection system at the gateway of some company. When you are receiving abnormal traffic for a couple of minutes it may well be that you are already controlled by some malware that is sending spam from your computer." explains Grozea, speaking about the challenge of protecting computers against menaces from the Internet.

To react fast to these attacks, Grozea worked on real time capabilities that detect attacks as soon as they appear. By engineering software and utilizing a higher number of central processing units, he reached an acceleration of more than thirty times faster than the original processing speed. "When I considered my options to tackle the plagiarism challenge I was already aware of a very fast code – my code." says Grozea. That allowed for another advantage – the search could be done on one single computer in only twelve hours.

Once the suspicious passages were identified, the second phase of the computing began. "I did not yet know which paragraph corresponds to which paragraph." To be accurate and efficient at the same time, Grozea chose only the fifty most promising suspicious documents on which to proceed further, resulting in 350,000 document pairs to compare instead of 50 Million. "I needed something really fast again," says Grozea.

He developed a so-called heuristic method that recognizes passages that are often repeated, localizes the copied passages, and identifies the type of plagiarism. To make the results more readily accessible for further handling, Grozea visualized the results with a method he called Encoplot. With one look it is visible how many instances of plagiarism can be found. One dot corresponds to a match. One single match is not critical – it just means that 16 characters in the two documents are the same.

The truth shows behind lines and clowds

A real plagiarism incident looks like a diagonal line. "This cluster here shows an almost verbatim copy," says Grozea, and points at one of his examples. "It is really long and clear." He then shows a fuzzy assembly of dots. "With a lot of permutations it looks like a cloud. If you delete or change words, the diagonal is interrupted." From the position in the diagram it is also clear where in the documents the similarities between original and suspicious document are located.

This could be a valuable feature in the future, because in the end it should not be left to a computer to decide if a certain passage is a legitimate quotation of another text, or a theft of ideas. ■

History in 3-D

Once the 3D-COFORM collaborative project is completed, museum visitors will benefit from a vast three-dimensional digital archive documenting works of art and other exhibits from museums all over the world.

Text: Tim Schröder

Even Michelangelo's "David" has been scanned in three dimensions for tomorrow's digital museums. © *Corbis*

3-D computer graphics are meanwhile an indispensable tool for automobile designers, allowing them to create a realistic virtual model of the car on the computer long before it takes it shape in sheet metal. Such virtual models can be rotated and viewed from any angle, and even diffract sunlight in a deceptively authentic way on the finished surface. But while 3-D has long been routine in such applications – it's a complete newcomer in museums. The European 3D-COFORM project will change that perspective as it spends the next few years developing tools to digitize mankind's museum heritage. Vases, ancient spears or even whole temples will be documented in three dimensions. In the same way that designers nowadays view prototypes on the screen from all angles, museum visitors will one day be able to rotate Roman amphorae on the screen.

And that's just the beginning. The basic idea of 3D-COFORM is to create a global virtual collection that makes it easier for scientists to search in archives for comparable forgotten objects or works originating from the same artists or peoples. What makes the project so innovative is the intelligence behind the virtual collection: it will be able to find the digitized and saved objects itself and create links between them. With just a few search terms researchers will be able to find what they are looking for. Asked to "Show me Greek vases with at least two arched handles, dating from the sixth century B.C ", the database will show a whole batch of exhibits from collections all over the world.

Seeing that printed catalogs with simple photos, or even just written descriptions of objects, are the norm at present, there's still a long way to go. Only a few collections are available as two-dimensional images on the Internet. And although 3-D scanners have already been on the market for years – making it possible to scan paintings or statues and generate corresponding 3-D images – there are hardly any on the World Wide Web. Yet there are enormous advantages to seeing things in 3-D. In contrast to a photo, a 3-D data set contains all the spatial information necessary to view an object from all angles. It also provides valuable data for art restorers, such as information about the texture of the surface, the finish of a painting or the condition of a pigment. Of course, there are already impressive 3-D animations of art objects today, such as the portrayal of the statue of David by Michelangelo. "We are, however, a long way off from linking up three-dimensional data of different objects in a meaningful way," says André Stork, head of department at the Fraunhofer Institute for Computer Graphics Research IGD in Darmstadt and partner in the 3D-COFORM consortium. Despite the first-class 3-D scanner, technical hurdles still remain.

As a graphics expert, Stork, together with his colleagues, is responsible primarily for generating 3-D models and preparing them for the digital archive. "A 3-D scan is in the end nothing more than a cloud of measuring points. It's only possible to create a genuine likeness of the object by subsequently applying an appropriate rendering process," says Stork. Researchers develop algorithms, or sets of calculation rules, which construe the actual object from the measured data. They must be capable of determining whether a corner is truly angled at 90 degrees and whether an apparently flat surface is genuinely flat or slightly concave. "The human eye can detect such things immediately, but a computer can only do so after explicit training," explains the scientist. The task of documenting millions of objects calls for software that can detect the structure of each object quickly and reliably. This depends primarily on identifying certain structures correctly, such as the arms of statues or columns in a building. Experts use the term "segmentation" to denote this type of graphic categorization.

Algorithms recognize recurring patterns on vases

The algorithms must also be capable of recognizing specific details of interest to historians, such as recurring patterns on vases, which enable them to be authenticated as the work of specific artists or manufactories. 3-D images will make the work easier for researchers in the future. Segmentation and annotation functions provide the three-dimensional data set with a huge amount of information, such as the length and width of a column or the curvature of the neck of a jug. It's precisely these details which will form the basis of future Internet research. Tomorrow's museum search engine will no longer be restricted to written descriptions alone. It will be able to trace an object based on characteristics contained in the 3-D data set. The researchers in Darmstadt are also investigating what this graphic 3-D fingerprint looks like on the Internet and how it can be selected with search engines. They are also working on browser design.

Searching and finding is one thing. Realistic and detailed depiction is also a prerequisite of virtual presentation. The image of a temple is much more authentic if it also includes the play of shadows on its columns. And the curved surface of a brass object appears lifeless if it does not reflect its surroundings. Stork and his colleagues are using all the tricks of the computer graphics trade to breathe life into the virtual copies of the unique historical artifacts. They utilize a combination of different techniques to simulate light effects. Ray tracing, for instance, faithfully reproduces the reflections visible on mirrored surfaces by calculating the exact source of each pixel in the reflected image. Other techniques are used to reproduce the dark shadows cast by intense sunlight. To perfect the result still further, the shadows become less distinct if an object is illuminated by several light sources at the same time. "We can even go as far as to show a virtual object in the same light conditions in which it was seen at the original excavation site ", says Stork. This is hardly necessary for every object; the minimum required is true-to-life presentation. Precise 3-D graphics will enable art restorers, for example, to document the condition of an object more accurately, such as whether the painted wooden frame is still intact, or whether there are cracks in the varnish used to seal the painting. All this information is available in the 3-D image.

Many questions still need to be answered. Not only those concerning the graphics, but also what form the data will take when it is made available to the users. Millions of objects must be scanned for online display – an enormous task. The members of the 3D-COFORM consortium, led by the University of Brighton in England, have already started to develop initial concepts for digitization centers, which will be tasked with scanning in the exhibits from exhibitions and museums worldwide. But support is also at hand in the form of another EU project, Europeana, in which an initial step towards digitization has been made by preparing all exhibits from European exhibitions and museums for two-dimensional reproduction on the Internet. Stork sees this as a kind of test run for the 3D-COFORM archive of the future. ■

Projectmanager Dr. Abrantes (left) and Prof. Elias (right) show 'The Mover' to Minister Gago. © *Fraunhofer*

Opening in Porto

The Fraunhofer Portugal Research Center for Assistive Information and Communication Solutions (AICOS) was officially presented to the public on September 29. AICOS Director Professor Dirk Elias welcomed the Portuguese Minister of Science, Technology and Higher Education José Mariano Gago, German Ministry of Education and Research State Secretary Professor Frieder Meyer-Krahmer, the President of the Portuguese Science and Technology Foundation and high-ranking representatives of Portuguese industry, government and research along with around 100 other guests.

At the event, AICOS presented latest research developments connected with Ambient Assisted Living, including the Mover project. Mover makes use of a cellphone with an integrated acceleration measurement device. It calculates the activity of its user and compares the data via the Internet with that of other participants to determine their level of activity, which is classified as 'Sleeper', 'Sitter' or 'Hyper'. Participants thus receive feedback on whether they are moving around enough. Mover also incorporates a fall detection system. If after a fall no further movement is registered, two addressees are notified by SMS or email. The system has been submitted as an entry in Google's Android Developer Challenge II competition.

Extracting water from desert air. © *Logos*

Drinking Water from Air Humidity

Even desert air contains considerable amounts of water. In the Negev desert, for example, the annual average relative air humidity is 64 percent – in every cubic meter of air there are 11.5 milliliters of water. Research scientists at the Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB in Stuttgart have found a way of converting this air humidity into drinkable water, working together with their colleagues from the company Logos Innovationen. A hydroscopic saline solution absorbs water contained in humid air. The diluted brine is then drawn by vacuum into another tank a few meters off the ground. Energy from solar collectors heats up the brine, until the evaporated non-saline water is condensed and runs down through a completely filled tube. The gravity of this water column continuously produces the vacuum., while the brine is again ready to absorb air humidity.

Fraunhofer logistics experts go stateside

Logistics knows no bounds. Researchers at the Fraunhofer Institute for Material Flow and Logistics IML in Dortmund have decided to intensify their collaboration with the Material Handling Institute of America MHIA in Atlanta, Georgia. The two research establishments signed a memorandum of understanding to this effect during a visit by North Rhine-Westphalia's research and technology minister, Professor Andreas Pinkwart. Dortmund University of Technology, which is closely linked to the IML, also gained a new cooperation partner – the Georgia Institute of Technology. "These agreements reinforce and emphasize the exceedingly successful cooperation between our scientific institutions in the field of logistics, where we rank among the top establishments worldwide and are highly respected by the international research community," commented Professor Michael ten Hompel. And IML director Professor Uwe Clausen added: "We will continue to intensify existing cooperations – for instance, in the optimization of transport logistics and air traffic management."

Technology Guide

Our everyday lives are dictated by technical developments, and we will be increasingly moulded and changed by them. We can only actively help to shape the future if we know what awaits us. So how can we maintain a clear overview? The "Technology Guide: Principles – Applications – Trends" can provide sound assistance. It contains over a hundred articles written by experts from small and large companies, research establishments, universities, associations and authorities who give clear descriptions of all the main fields of technology.

The Technology Guide comprehensibly explains current and future technology and is illustrated with numerous photographs, drawings and diagrams. It is aimed at everyone in society, politics, industry or research who is interested in technology – not just specialists, but anyone curious to find out where we are headed. The Technology Guide covers a wide range of topics, from information and communication technology, materials, mobility and transport, to energy, resources, nature and the environment.

Just like tourists navigating their way through a foreign city with guidebooks in their hands, interested readers can familiarize themselves with the technological fields presented in the book. Professor Hans-Jörg Bullinger, President of the Fraunhofer-Gesellschaft and publisher of the extensive compendium, stresses that "presenting an overview makes it easier to discuss the material, not just for laymen but also for researchers from different disciplines."

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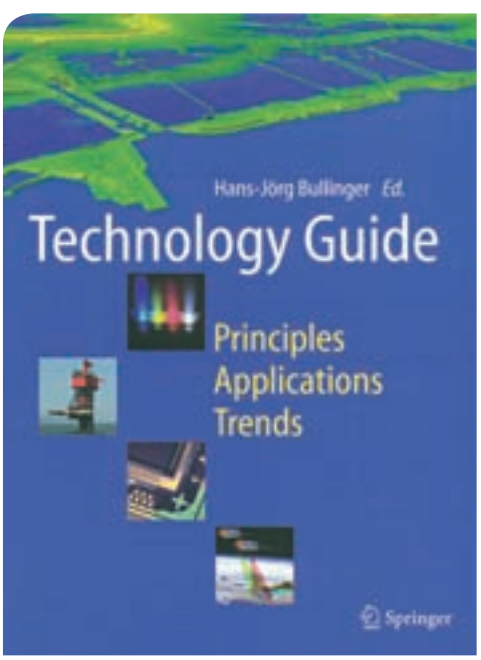

A new guidebook to technology is now published by Fraunhofer-President Prof. Hans-Jörg Bullinger.

Editorial notes

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