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RESEARCH NEWS

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1 Infrared camera provides a better view

Infrared cameras see more than the naked eye and can make road traffic safer. Cameras for the long-wave infrared range, however, have the disadvantage that the sensor requires constant cooling, which adds to the cost and complexity of the device. Now a new type of detector has been developed which functions at room temperature.

2 Smart meters help to save money

How can domestic electricity customers be motivated to use energy more efficiently, let alone make more efficient use of renewable sources? One possibility is to install electronic meters to measure the electricity consumed. In the RESIDENS project, scientists are examining how to get the best out of smart meters by simplifying their use.

3 Health check for fish

Fish in fish farms are exposed to very high health risks. Owing to the cramped conditions, pathogens quickly spread. In future, wireless miniature sensors implanted under the skin of the fish will help to prevent diseases, by monitoring and diagnosing their health.

4 Nanopores make sterile filtration more reliable

Irregular pores, low flow rates: The plastic membrane filters used in sterile filtration do not always ensure that conditions are really sterile. Filter membranes of aluminum oxide are more reliable – the size of the nanopores can be determined with precision. Even the smallest viruses cannot pass through the membrane.

5 Robots get an artificial skin

Robots are breaking barriers: Long banished behind steel barriers, they are entering new fields of application such as the manufacturing, household and healthcare sectors. The requisite safety can be provided by a tactile sensor system, which can be integrated in a floor or applied directly to robots as an artificial skin.

6 Using the rays of the sun to convert sea- to drinking water

Many of the world's remote areas with water shortages also have three things in abundance: Sun, wind and sea. How renewable energies can be harnessed more effectively in the future to transform salty seawater and brackish water into drinking water is the subject of a current study issued by an EU initiative dubbed »ProDes«.

The Fraunhofer-Gesellschaft is the leading organization for applied research in Europe. Its research activities are conducted by 59 Fraunhofer Institutes at over 40 different locations throughout Germany. The Fraunhofer-Gesellschaft employs a staff of around 17,150, who work with an annual research budget totaling 1.6 billion euros. Roughly two thirds of this sum is generated through contract research on behalf of industry and publicly funded research projects. Branches in the USA and Asia serve to promote international cooperation.

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Infrared camera provides a better view

At night on an unlit country road: the bends in the road restrict the view ahead and, to make things worse, it is foggy. The car driver is exercising all due care and yet still does not see the deer on the road ahead until it is nearly too late. An emergency stop prevents a collision with the animal just in time. In such situations infrared cameras could provide a better level of safety. Objects at roughly body temperature are luminous in the infrared region at a wavelength of around ten micrometers. Detectors in the camera register this thermal radiation and locate the source of heat. This could enable drivers to see people or animals long before they come into vision through dipped headlights. Other road users would not be inconvenienced by the invisible infrared radiation.

The problem is that infrared cameras for the wavelength range above five micrometers like it cold – the sensor has to be constantly cooled down to about minus 193 degrees Celsius. Uncooled imagers for the long-wave infrared range do already exist today, but they are mainly used in the military sphere and are more or less unavailable on the European market. This is now set to change. Research scientists at the Fraunhofer Institute for Microelectronic Circuits and Systems IMS in Duisburg have succeeded in producing an imaging sensor for the long-wave infrared range that functions at room temperature. »We could be the first in Germany to offer this technology«, says Dr. Dirk Weiler, scientist at the IMS.

At the heart of the IRFPA (Infrared Focal Plane Array) sensor is a microbolometer – a temperature-sensitive detector that absorbs long-wave infrared light. To produce a two-dimensional image, several microbolometers are combined to form an array. If the microbolometer absorbs light from a heat source, its interior temperature rises and its electrical resistance changes. A readout chip then converts this resistance value directly into a digital signal. Previously this was not possible without a further intermediate step – normally the electrical pulse is first translated into an analog signal and then digitized using an analog/digital converter. »We use a very specific type of converter, a sigma-delta converter, in our imager. This has enabled us to produce a digital signal directly«, Weiler explains.

As complex and costly cooling is no longer required, further areas of application become feasible beyond the automotive sector. »Mobile devices in particular should benefit from the new development«, states Weiler confidently. The fact that the cooling mechanism is no longer needed not only saves weight. The battery power

available and therefore the operating time of the mobile device increase because no energy is needed for cooling. The potential uses of mobile infrared cameras include firefighting, where they could detect hidden hotspots or locate people in smoke-filled buildings.

Initial laboratory tests with the new sensor element were successful. The research scientists have already been able to produce a number of infrared images.

This photo was taken by an infrared camera equipped with a temperature-sensitive detector. The image shows the various temperature fields. (© Fraunhofer IMS)

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Smart meters help to save money

Who wouldn't like to know how much electricity they consumed yesterday or whether it is cheaper to turn the washing machine on in the afternoon or to wait until after ten o' clock at night? But the problem is that you only find out how much electricity you have used once a year with the annual statement. In most cases, it is impossible to determine whether the extra amount owed is due to higher electricity prices or higher consumption caused by the huge new flatscreen TV, the set-top box and daily surfing on the Internet. And many electricity customers have no idea at all how they can help to make more efficient use of energy from renewable sources by adapting their behavior.

In the project »RESIDENS: research project for more efficient energy usage by system orientated integration of end consumers« researchers are examining how electricity customers can be motivated to use energy from renewable sources more efficiently. The work is being conducted as a collaborative effort by researchers at Ilmenau University of Technology, the Fraunhofer Application Center for System Technology AST and the Fraunhofer Institute for Digital Media Technology IDMT in Ilmenau. But electricity customers can only use energy more efficiently if they know exactly how much power they are consuming at any time, and under what conditions they can save money by using green electricity. This is why the researchers are using electronic power meters, which measure how much electricity is consumed and transmit the recorded data at almost any predefined interval to the meter-reading company. »Smart meters make it possible to analyze the data in numerous different ways«, explains AST engineer Dr. Peter Bretschneider. For instance, you can display a reading of the instantaneous power consumption or the cost of a kilowatt-hour of electricity. And you can trace how much energy you have used over a certain period. The smart meter enables actual consumption to be determined on a monthly basis. The meter also displays the currently applicable tariff, enabling customers to select the appropriate time to do their laundry, by waiting until off-peak rates apply before starting the washing machine.

To simplify the use of the new digital meters for electricity customers, the researchers are also working on applications for a Web portal, where consumers will be able to see at a glance how much they paid for electricity last year, how much energy they have consumed today, and how the cost compares with the previous day's electricity consumption. An annual overview highlights the months in which the most electricity was consumed, and a daily overview pinpoints the hours of peak consumption.

The portal will also inform consumers of the most cost-effective times to use green electricity and calculate their carbon footprint on the basis of their present pattern of consumption. This might prompt electricity customers to switch more often to energy from renewable sources. »Smart metering is about more than just producing an intelligent readout of meter data. It encompasses the entire spectrum from tariffs, metering and communication technology to data administration and processing«, emphasizes Bretschneider.

The research project is divided into three parts. In the first phase, the objective is to assess the degree to which energy policy measures are accepted by consumers and evaluate the related behavior patterns. In the second phase, the experts will evaluate the acceptance of the electronic power meters. »This will include a detailed analysis of the strong and weak points identified in connection with the systematic integration of the smart meter, and of possible improvements from the end-user perspective«, reports Bretschneider. On the basis of the results from the first two studies, the researchers aim to develop a strategy to educate electricity customers in the use of smart meters and improve the implementation of energy-saving measures in general.

Smart meters store digital electricity consumption data that is transmitted at almost any predefined interval to the meter-reading company. (© Andreas Ingerl)

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Health check for fish

Aquaculture is the fastest growing sector of the food industry worldwide. According to statistics gathered by the World Food and Agriculture Organization FAO, the production of fish, mussels and other shellfish in aquaculture has increased by about nine per cent annually since 1990. The reasons for this are the overexploitation of natural fishing areas and the rise in fish consumption due to a growing world population. But intensive farming is detrimental to the health of the fish, who have to live in cramped conditions that often exceed the recommended population densities, where parasites and diseases can spread very quickly. To fight infections, extensive use is made of antibiotics, traces of which inevitably end up on consumers' plates. In the »FischFIT Monitoring« project, research scientists at the Fraunhofer Institute for Reliability and Microintegration IZM in Berlin have developed a tiny sensor system to combat this problem in advance. The system continuously monitors and diagnoses the health and behavior of farmed fish. The project partners are ELBAU Elektronik Berlin, the Leibniz Institute of Freshwater Ecology and Inland Fisheries Berlin and the Institute of Agricultural and Urban Ecological Projects at the Humboldt University of Berlin.

»Our FischFit Monitor is a microsensor system comprising five separate sensors with wireless data communication functions. Implanted under the skin of the fish, the sensors not only measure the skin resistance, blood pressure, heart and respiratory rate as well as the body temperature, but also their swimming behavior and movement activity. They therefore register how quickly a fish swims and whether it is moving hectically. On the basis of the measured data we can quickly identify any changes in behavior and draw conclusions about the health of the fish«, explains Dr. Volker Grosser, who leads the IZM research group. »The sensor systems available up to now have usually only measured the body temperature of the fish and the temperature of the water. Fish in aquaculture are often not even monitored at all.«

The microsensor system consisting of a material compatible to fish incorporates a special feature – its battery can be recharged wirelessly under water. The base station, which functions as a read/write device, transfers the measured data by Bluetooth or cable to the computer with the analysis software. The base station receives its power from the laptop. »The FischFit Monitor is only suitable for freshwater aquaculture, for use in ponds, rivers and tanks. Saltwater disrupts the radio link between the sensor and the reader unit. In fish farms, the reader unit is fastened to the edge of the tank. In rivers and ponds it is attached to the feeding stations. The FischFit Monitor functions even under extreme environmental conditions«, states Großer.

The present demonstrator is four centimeters long, two centimeters wide and eight millimeters high. The aim is to reduce these dimensions considerably. The device has already been implanted in carp and initial data transmission tests were successful. In future the research scientists intend to use the system in game fish aquaculture, for example for the production of sturgeon. The FischFit Monitor could also be adapted for use with mammals, in particular livestock such as cattle and pigs.

The microsensor system measures the skin resistance, body temperature, blood pressure, heart and respiratory rate of fish. (© Fraunhofer IZM)

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Nanopores make sterile filtration more reliable

The good ones are kept, the bad ones done away with – that, in a nutshell, is the principle behind sterile filtration: A filtration membrane frees liquids of unwanted particles and germs. Nothing larger than the filter's pores, only a few ten-thousandths of a millimeter in diameter, can pass through. Conventional membranes, usually made of plastic, come with limitations: Their pores are not evenly distributed and are occasionally too wide – and particles slip through after all. Conventional filtration membranes also have virtually no way of stopping viruses: Because most viruses are smaller than the pores, this technology offers no way to filter them out.

Now, researchers at the Fraunhofer Institute for Mechanics of Materials IWM in Halle, Germany, have created a new generation of filtration membranes: They developed ceramic membranes with a uniform pore structure and a very tight and even pore size distribution. »Compared to the ceramic membranes we have seen previously, they offer better mechanical stability and considerably higher flow rates. As a result, for the first time they are also able to replace polymer membranes«, notes Annika Thormann, project manager at IWM. These membranes guarantee much more reliable filtration results than polymer membranes do. Electron microscope images of the membranes prove: The pores are regularly aligned alongside one another like the honeycombs in a beehive, one identical to the next.

To produce such filtration membranes, what is required first is the right raw material: »We use highly pure aluminum that we mold to the desired shape using extrusion equipment and thermomechanical structuring«, Thormann explains. But just how can you create tiny pores on an aluminum plate with such precision? »A chemical reaction does the job«, Thormann says. The molded aluminum part is placed in an acid bath where anodic oxidation takes place. An oxide layer just a few microns thick forms on the surface during electrolysis. »Tiny pores form in the aluminum during oxidation,« Thormann explains. These nanopores are honeycomb-shaped, vertical to the surface, and are arrayed parallel to one another. »To set the pore size, we have to keep the voltage and the concentration of the acid stable«, Thormann notes. The thickness of the nanoporous layer – and hence the flow rate of the membrane itself – can be fine-tuned as well via the duration of the oxidation process. In the end, the only step remaining is to open up the pores. This step is accomplished with chemical etching to remove unneeded residual aluminum.

The result: High-precision filtration membranes with a high porosity level. »We can vary pore diameters between 15 and 450 nanometers«, says Thormann. At 15 nanometers, even the smallest viruses don't stand a chance of slipping through. The new filtration membranes are particularly beneficial to biotechnology. Aside from use of the filtration properties to produce sterile media the membranes can also facilitate tissue engineering – the cultivation of artificial tissue – thanks to their high porosity.

This mechanically stabilized nanoporous filter membrane exhibits a regular pore structure. At the same time, the pore size distribution is very tight and even. (© Fraunhofer IWM)

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Robots get an artificial skin

A mobile robot carefully transports a sample through a biotech lab where it is surrounded by the routine hustle and bustle. Lab technicians are conversing with one another and performing tests. One technician inadvertently runs into the robot, which stops moving immediately. An artificial skin covering the robot makes this possible. Consisting of conductive foam, textiles and an intelligent evaluation circuit, the sensor system detects points of contact and differentiates between gentle and strong contact. It registers people immediately. The shape and size of the sensor cells implemented in the skin can be varied depending on the application. They detect any contact. The higher the number of sensor cells, the more precisely a point of collision can be detected. A sensor controller processes the measured values and transmits them to the robot or, alternatively, a computer, a machine or production line.

Researchers at the Fraunhofer Institute for Factory Operation and Automation IFF in Magdeburg designed and patented this sensor system in 2008 for its assistant robot LiSA, which stocks incubators and measuring instruments in biotech labs with sample cups and relieves lab staff from such work. Since then the engineers have refined the sensor system for a wide array of applications such as industrial robots and flooring. Contact with humans or objects will be reliably detectable in the future, a basic prerequisite for the implementation of robots in human environments without protective barriers. »Our artificial skin can be adapted to any complex geometry, including curved or very flat. We use large-area floor sensors to define safety zones that people may not enter«, says Markus Fritzsche, researcher at the Fraunhofer IFF. »These areas can be changed dynamically.« The tactile skin now also functions as an input medium, for instance, to guide robots by translating contact into motion. »This requires little force. If I touch the robot, it attempts to evade the pressure. Thus, I can direct even a 200 kilogram robot in the desired direction«, says Fritzsche describing the system's advantages. Another of the artificial skin's distinctive features is the integrated damping elements that additionally diminish any collisions by cushioning impacts.

Diverse variants of the tactile sensor system now exist, the shell material ranging from breathable to waterproof. »This opens entirely new fields of application such as medical engineering or manufacturing«, says Fritzsche. »Pressure sensitive flooring is ideal for monitoring workspaces in factories or instantly registering fallen patients in a nursing home for instance. Robots and mobile equipment outfitted with the artificial skin register any collision and brake immediately. In addition, we can provide

robot grippers a sense of touch and thus detect whether they are actually gripping something.«

Numerous variants of the artificial skin have been prototyped. Fritzsche is convinced: »We'll encounter all sorts of forms of artificial skin in everyday life in the near future.«

Pressure sensitive flooring detects people and slows or stops the robot's movement. (© Fraunhofer)

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Using the rays of the sun to convert sea- to drinking water

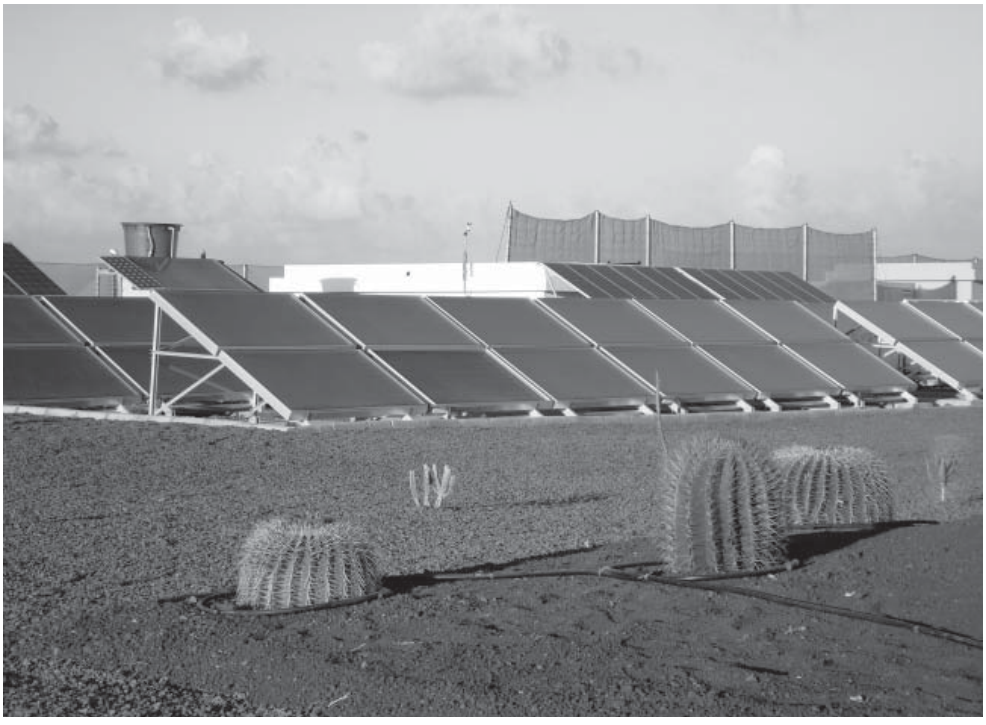
Worldwide, more and more people are obtaining their drinking water either from the sea or from increasingly salty inland sources. Analysts at Global Water Intelligence, an industry service, estimate that in 2008, desalination facilities around the world produced nearly 52 million cubic meters (12 billion gallons) of water each day – the equivalent of four or five times the daily production of water in Germany. This amount is expected to more than double by the year 2016. The bulk of this amount is attributable to the Arab countries around the Persian Gulf. Spain ranks fourth worldwide. Other European countries are increasingly turning to desalination as well, including France, Greece and Italy. The goal: To secure the water supply for islands, settlements or entire cities, to supply water to tourist resorts, or to irrigate farmland. While most of the large desalination plants are fueled by oil or gas, smaller and medium-sized plants can run partly or even entirely on renewable energies. »Often, the people in charge aren't even aware of the opportunities they have here. They also don't know how reliable and efficient solar-powered desalination plants, or wind-powered and perhaps some day tidal-energy-driven plants, work«, regrets Marcel Wieghaus of the Fraunhofer Institute for Solar Energy Systems ISE in Freiburg, Germany. The European »ProDes« initiative, of which ISE is a member, intends to change that. Its goal is to provide outreach while bringing all participants together to promote use of renewable energies for water desalination: »ProDes« stands for »Promotion of Renewable Energy for Water Production through Desalination«.

The initiative has established an array of processes for desalinating seawater and brackish water. Most major European desalination plants rely on reverse osmosis: High pressure and semipermeable membrane separate water from salt and unwanted organic constituents. Plants run on conventional energy forms can deliver up to around 400,000 cubic meters (91 million gallons) of drinking water each day. When it comes to desalination plants run on renewable energies, the spectrum ranges from simple solar distillation plants with a capacity of a few liters a day to wind-powered reverse-osmosis plants capable of desalinating up to nearly 2,000 cubic meters (half a million gallons).

Not every plant is suited to every location, however. The best technology for the task depends on the salinity of untreated water, the local infrastructure and the quantity of water required. »The more remote the location, the more worthwhile and profitable it is to use plant systems run on renewable energy and to set up a water treatment operation that is not dependent on an external energy supply«, Wieghaus observes.

Together with his team of researchers, he has installed solar-powered desalination plants on the Canary Islands of Gran Canaria and Tenerife.

A path-breaking overview of the renewable-energy technologies for desalination and the current state of technology is provided by the »ProDes-Roadmap«, a document drawn up under the direction of ISE. The document also identifies strategies for overcoming legal, financial and political obstacles. The study can be found at the ProDes website (www.prodes-project.org). The website also offers information about activities such as its workshops and the initiative's e-learning course. »ProDes« was launched in October 2008 as an »Intelligent Energy« project of the EU Commission.



Fraunhofer ISE intends to contribute to the development of solar-powered water desalination plants such as the one shown here, in Gran Canaria. (© Fraunhofer ISE)

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