

RESEARCH NEWS

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1 Repelling the drop on top

It would make life a lot easier if the surfaces of window panes, corrosion coatings or microfluidic systems in medical labs could keep themselves free of water and other liquids. A new simulation program can now work out just how such surfaces have to look for a variety of applications.

2 Artificial muscle as shock absorber

Engineers are working on intelligent materials that can diminish vibrations and extract power from the environment. These electro-active elastomers could dampen annoying vibrations in a car, for example, or supply wireless power to sensors in otherwise inaccessible places.

3 Compact and flexible thermal storage

Biogas plants, combined heat and power plants don't just generate electricity, they also produce heat. However, unlike the electricity they yield, the heat generally dissipates unused. A new technology is set to change this: It will allow the heat to be stored loss-free in the smallest of spaces for lengthy periods of time, for use as and when required.

4 Naturally adhesive

Until now most adhesives have been manufactured from petroleum-based materials. However, they can also be obtained from renewable raw materials – for example from proteins, natural rubber, starch, or cellulose. Fraunhofer researchers are working on new formulas for industrial applications.

5 Virtual plant planning, retrofitting and maintenance

Process plants have useful lives of thirty to fifty years, during which time they are routinely retrofitted. Virtual reality software simplifies and helps keep track of retrofit planning and testing. Fraunhofer researchers and BASF SE are jointly developing VR solutions for the plant life cycle.

6 Browsing without the hurdles

The majority of websites have major shortcomings. Unclean programming frequently causes excessive load times. Companies are only gradually recognizing the advantages of a barrier-free Internet. Fraunhofer researchers are crafting tools that can be used to monitor compliance with web standards.

The Fraunhofer-Gesellschaft is the leading organization for applied research in Europe. Its research activities are conducted by 60 Fraunhofer Institutes at over 40 different locations throughout Germany. The Fraunhofer-Gesellschaft employs a staff of around 20,000, who work with an annual research budget totaling 1,8 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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1 Repelling the drop on top

It's raining cats and dogs and even the short run out to the car leaves your vision obscured by rain on your spectacles. There might soon be no need to reach for a cloth to wipe them off. If the surface of the lens resembled that of a lotus leaf, the drops would all fall off by themselves. The practicality of such self-cleaning surfaces is not limited to eyewear. Corrosion coatings would put up a better fight against rust without the tiny puddles of water that tend to collect on top of them.

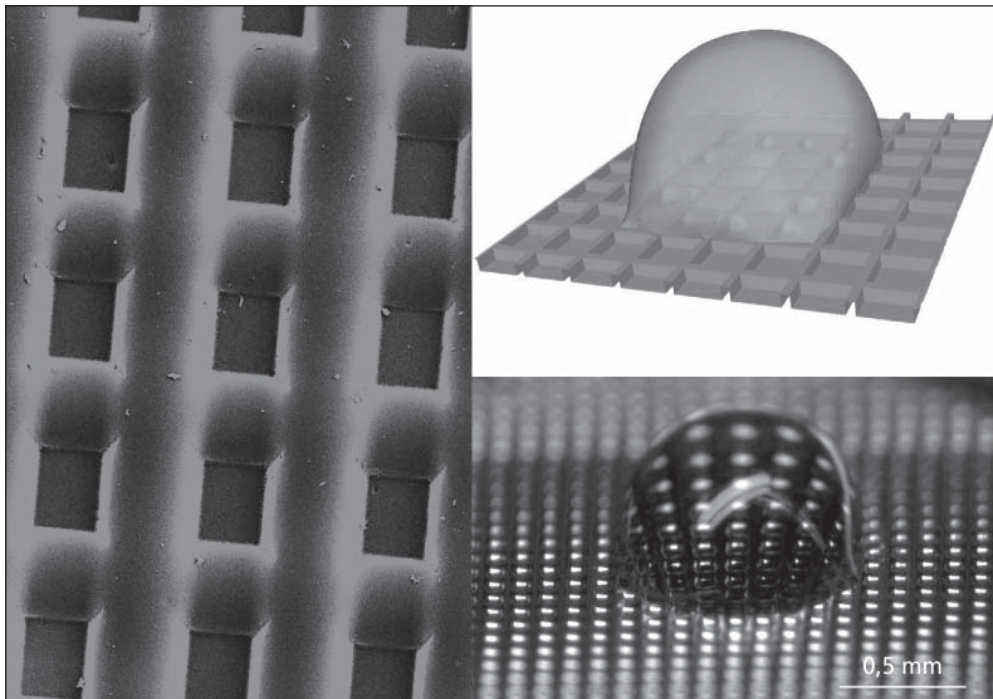
But exactly what characterizes surfaces that do the best job of cleaning themselves? Researchers at the Fraunhofer Institute for Mechanics of Materials IWM in Freiburg have now developed simulation software that provides the answers. "Our simulation shows how various liquids behave on different surfaces, no matter if these are flat, curved or structured," explains Dr. Adham Hashibon, project manager at the IWM. The program simulates the form the liquid droplets take on the surface, indicating whether the liquid distributes itself over the surface, or contracts to form droplets in order to minimize contact with the surface. The program is also able to calculate the flow behavior in terms of how liquids move across different surfaces, whereby the determinant factors at different scales of measurement are integrated, from atomic interactions to the impact of microscopic surface structure.

The software analyzes what goes on within a given droplet – how the individual water molecules interact with each other, how a droplet is attracted by the surface and how it resists the air. Researchers refer to a three-phase contact link between liquid, surface and air. "How liquid behaves on a surface is influenced by a great deal of parameters, including the surface characteristics of the material as well as its structure, but also by substances dissolved in the liquid. We have taken all this into account to different degrees of detail within the simulation so that we are able to clearly reproduce our experimental findings," says Hashibon.

Improving microfluidic systems

The simulation is also useful in medical examinations. When doctors have to analyze tissue cells or parts of DNA, they often use microfluidic systems such as constant-flow cuvettes. Liquid containing dissolved substances is analyzed as it flows through tiny channels and minute chambers, and it is essential that no liquid whatsoever remains after the procedure has been completed. Any residual drops would then mix with a new sample and distort findings. The simulation will now be used to help optimize such microfluidic systems and to design surfaces so that as little liquid as possible gets left behind. "Our goal was to better understand and control the wetting behavior of liquids on structured surfaces," says Hashibon. But that's not all. This tool can also be used to implement a kind of traffic management system within the microfluidic system. When a channel splits into two, giving each fork a different surface structure makes it

possible to separate the various components of the liquid, sending DNA molecules one way while other components are led along the alternative route. This technique can be used to heighten the concentration of certain molecules and is especially important, for instance, in raising the detection sensitivity of analysis techniques.



Left: Micrometer-scale structured polystyrene surfaces for use with micro-fluids. **Right:** Static wetting of this type of surface with water – simulation and experiment. (© Fraunhofer IWM) | Picture in color and printing quality: www.fraunhofer.de/press

2 Artificial muscle as shock absorber

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It is not very fun to ride a bicycle on a street plastered with cobblestones. At least the bike has a saddle seat filled with silicone. That lessens the shocks and bumps, and counteracts some of the annoying vibrations. In a professional's eyes, the material in the saddle is an "elastomer" – a material that is yielding and malleable, like a rubber band. Engineers at the Fraunhofer Institute for Structural Durability and System Reliability LBF in Darmstadt are now working on the next generation: They are designing components made of elastomers that actively respond to unwanted vibrations, and dampen them more effectively than ever before.

Elastomers have been used in engineering for decades, such as shock absorbers in mechanical engineering or in the bearings for vehicle engines. Until now, they have had a purely passive effect on vibrations or impact collisions. It would be more effective if the elastomers were to respond proactively and counteract vibrations. In the same way a tennis player slows down the ball on a drop shot by pulling back on her racket, an active elastomer draws out the energy from the vibration in a targeted manner by swinging in precise push-pull mode. Theoretically, this would make the vibration dissipate completely.

Elastomers vibrate under alternating current

There are already materials that are good for this purpose. "They are called 'electroactive elastomers'," explains LBF scientist William Kaal. "They are elastic substances that change their form when exposed to an electrical field." The trick: apply an alternating current, and the material starts to vibrate. If there are smart electronics controlling the elastomers, making them vibrate precisely in push-pull mode, then unwanted vibrations in equipment or an engine will dissipate for the most part. To demonstrate that the principle works, the Darmstadt-based researchers created a model. Smaller than a pack of cigarettes, it is comprised of 40 thin elastomer electrode layers. The experts call it a "stack actuator." "The challenge was the design of the electrodes with which we apply the electric field to the elastomer layers," as Kaal's colleague Jan Hansmann clarifies. Usually, electrodes are made out of metal. However, metals are relatively rigid, which impedes the deformation of the elastomer. Fraunhofer experts deliver an elegant solution to the problem: "We put microscopic-sized holes in the electrodes," says Hansmann. "If an electric voltage deforms the elastomer, then the elastomer can disperse into these holes." The result is an actuator that can rise or fall a few tenths of a centimeter upon command – several times a second, in fact. To demonstrate these capabilities, William Kaal attaches a small mechanical oscillator to the device. When he turns it on, the oscillator begins shaking powerfully – the actuator has hit its resonance frequency perfectly. On the other hand, the instrument can actively absorb vibrations: If the oscillator is tapped by hand, it quickly settles down when the actuator vibrates in push-pull mode.

The LBF engineers believe one potential application for their stack actuator can be found in vehicle construction. “An engine’s vibrations can be really disruptive,” says William Kaal. “The vibrations are channeled through the chassis into the car’s interior, where the passengers start to feel them.” Of course, engines are installed meticulously, and yet: “Active elastomers may help further reduce vibrations in the car,” Kaal asserts.

When vibrations turn into power

The function of the stack actuator can also be reversed: rather than produce vibrations, the device can also absorb vibrations from its surroundings to produce energy. The principle works, and researchers have proven it. As they placed an electromagnetic oscillator on their stack actuator, it converted the vibrations into power. “That would be of interest, for example, if you wanted to monitor inaccessible sites where there are vibrations but no power connections,” Jan Hansmann believes – as he cites an example: the temperature and vibration sensors that monitor bridges for their condition.

The stack actuator technology has been largely perfected: “The manufacturing process can be readily automated. That is important for industrial mass production,” thinks Kaal. Nevertheless, endurance tests still have to show what the long-term viability of the intelligent actuators is like. Ultimately, they must be able to withstand harsh environments of the kind found in the engine compartment of a car.



This image shows the lattice-shaped electrode in the foreground, and the elastomer in the background. (© Ursula Raapke) | Picture in color and printing quality: www.fraunhofer.de/press

3 Compact and flexible thermal storage

RESEARCH NEWS

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There's a growing trend towards generating electricity from biogas. But these systems would be considerably more effective if better use could be made of the heat that is produced in the process. Roughly half of the total energy content of the fuel is released as heat, which typically dissipates into the atmosphere unused. Large quantities of heat likewise escape from combined heat and power plants, not to mention many industrial installations. The root of the problem lies in the fact that the heat is not generally used at the time it is generated – and options for storing it are limited. Traditionally, water tanks have been used for this purpose, but they can only absorb a finite quantity of heat. And of course, the heat can only be stored for short periods of time, because although the water tanks are insulated, the water gradually loses its heat to the surrounding atmosphere.

Working together with industrial partners such as ZeoSys GmbH in Berlin, scientists from the Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB in Stuttgart are currently developing a new type of thermal storage system. This new system can store three to four times the amount of heat that water can, so it only requires storage containers around a quarter the size of water tanks. Moreover, it is able to store the heat loss-free over lengthy periods of time and can even operate at temperatures well in excess of 100 degrees Celsius. The new system contains zeolite pellets, from the Greek *zeō*, meaning 'boil' and *lithos*, meaning 'stone'. Normally this material is used as an ion exchanger, for example to soften water. Because zeolites are porous, they have a huge surface area: A single gram of these pellets boasts a surface area of up to 1000 square meters. When the material comes into contact with water vapor, it binds the steam within its pores by means of a physicochemical reaction, which generates heat. The water is in reverse removed from the material by the application of heat and the energy is stored, but not as a result of the material becoming palpably warm – as when water tanks are used. What is stored is the potential to adsorb water and in the process release heat; the term 'sorptive thermal storage' is frequently used to describe these systems. And provided the dried zeolite material is prevented from coming into contact with water, it can store the heat for an unlimited amount of time.

Mobile test facility with a storage volume of 750 liters

Although the basic principle has been widely understood for some time, it had never before been translated into a broad-based technical application for storage systems. "We took the principle and confirmed it was technically feasible," says Mike Blicher, group manager, heat and sorption systems in the IGB. Initially, the researchers used a 1.5- and then a 15-liter reactor to demonstrate that the process really does work. Blicher explains: "First we developed the process engineering, then we looked around to see how we could physically implement the thermal storage principle – i.e. how a

storage device has to be constructed, and at which locations heat exchangers, pumps and valves are needed." The institute's development partners were responsible for the material testing side of the project, investigating which of the various zeolites would be best suited for the purpose, how big the zeolite pellets needed to be, and whether or not the material would remain stable even after numerous storage cycles. They proved that heat could be stored and discharged many thousands of times without the system showing significant signs of wear and tear. The researchers subsequently up-scaled their operations to the current test facility, which has a storage volume of 750 liters and is mounted in a transportable container, along with all the additional equipment it requires. Its mobility allows the scientists to test the system in a variety of locations under realistic conditions.

The next stage of their work will be to reduce production costs, further optimize the system and adapt it for a variety of applications. Ultimately, the goal is to be able to store heat both in industrial installations and in small combined heat and power plants such as those used in larger residential buildings. To start with, priority will be given to industrial applications. "It would be ideal if we were able to devise a modular system that would allow us to construct each storage device to suit the individual requirement," says Blicher. The Fraunhofer researchers will be using a model system to demonstrate the principles of sorptive thermal storage at ACHEMA 2012 in Frankfurt from June 18 through 22 (Hall 9.2, Booth D64).



These zeolite pellets can bind steam within their pores, generating heat.

(© Fraunhofer IGB) | Picture in color and printing quality: www.fraunhofer.de/press

4 Naturally adhesive

Shoes, cars, airplanes, rotor blades for wind turbines, self-adhesive notes, plasters – this is just a sample of the many products featuring adhesives. More than 820,000 tons of adhesive were produced in Germany in 2010, according to the German Adhesives Association – Industrieverband Klebstoffe. To this day the majority of adhesives are manufactured from petroleum-based materials. Only gradually is the industry also offering adhesives made from renewable raw materials such as starch, cellulose, dextrans, and proteins. Pioneering products featuring these new adhesives include wallpaper pastes and glue sticks.

Adhesive based on polylactic acid

In two projects, researchers at the Fraunhofer Institute for Environmental, Safety and Energy Technology UMSICHT are working on further new adhesive formulas based on renewable raw materials. In cooperation with the Recklinghausen site of the Westfälische Hochschule, University of Applied Sciences, and the companies Jowat, Logo tape, and Novamelt, and with support from Germany's Federal Ministry of Food, Agriculture and Consumer Protection, researchers at UMSICHT in Oberhausen are developing a pressure-sensitive adhesive for industrial applications. Products using pressure-sensitive adhesives include adhesive bandages, self-adhesive labels, and adhesive tapes. They are subject to particularly demanding requirements: They have to remain permanently adhesive at room temperature. Gentle pressure should suffice for them to adhere to almost all substrates, and yet it must be possible to remove them without leaving behind any residue. To achieve this, the adhesive force must precisely match the respective use.

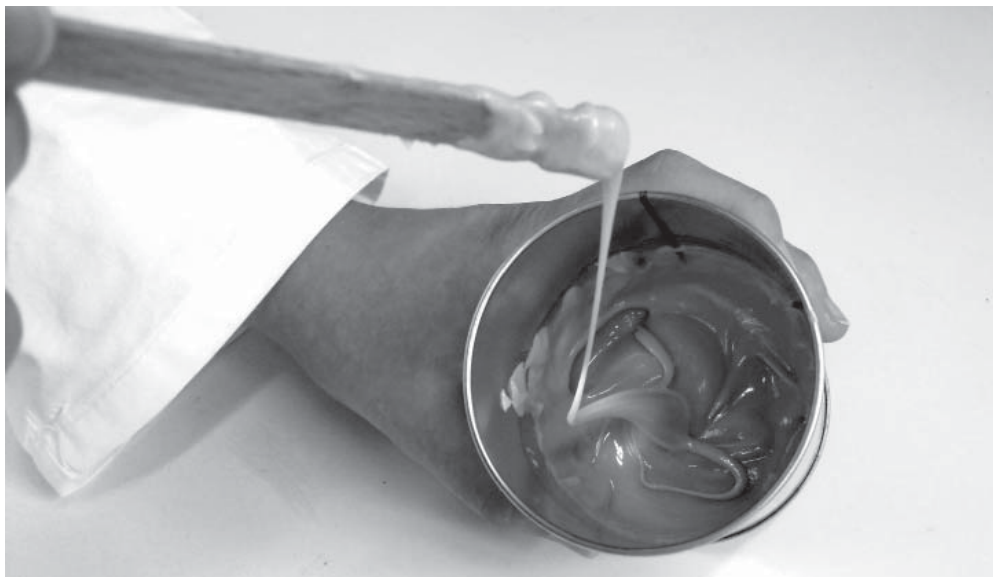
Pressure-sensitive adhesives are based on backbone polymers, which give the adhesives their inner strength (cohesion). The challenge for the UMSICHT researchers is to develop a backbone polymer from the raw material polylactic acid. What makes this biological material particularly attractive is its low production cost; since lactic acid is produced on an industrial scale, costs are in the region of prices for fossil-based backbone polymers. "However, the properties of polylactic acid are completely different from those of the polymers used to date, such as polyacrylates and styrene-based block copolymers," explains Dr. Stephan Kabasci, who heads the UMSICHT renewable resources business unit. This means that the researchers have to develop a completely new formula.

Packaging using compostable films

However, adhesives are also found in many types of packaging, for example where laminating films protect foodstuffs from dirt, moisture, and chemicals. This involves covering printed packaging and printed paper products on one or both sides with a transparent, shiny, matt, or embossed plastic film. In a collaborative project, UMSICHT

scientists are working with the companies Achilles Papierveredelung Bielefeld, Jowat, and Deckert Management Consultants to develop innovative adhesive systems that meet the exacting quality requirements of laminated products as well as being compostable. In pursuit of this objective, the researchers are focusing primarily on water-based dispersion adhesives, in which the adhesive components are dispersed very finely in water. They are applied to one side of the product and joined while wet.

Nature shows us another path to developing biological adhesives. The buoy barnacle (*Dosima fascicularis*) produces a special adhesive which it uses to attach itself tightly to flotsam. This super-adhesive is so strong that it is almost impossible to break down into its constituent parts using ordinary solvents. Another special property it has is its ability to cure under water. Researchers at the Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM in Bremen are now trying to find out which amino acid components make up the relevant proteins. "Once we've done that, the next step will be to recreate the adhesive proteins in the laboratory," says Dr. Ingo Grunwald, expert for biological adhesives at the IFAM. Such bioadhesives are primarily of interest for medical applications, for example to close incisions or to replace or support the pins and screws used to treat bone fractures.



This adhesive is based on the renewable raw material polylactic acid. (© Heike Holthausen, Westfälische Hochschule, Recklinghausen) | Picture in color and printing quality: www.fraunhofer.de/press

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5 Virtual plant planning, retrofitting and maintenance

RESEARCH NEWS

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With over 110 000 employees, BASF is the world's largest chemical company. At its headquarters in Ludwigshafen, the company runs over 160 production facilities, two steam crackers, two gas and steam turbine power plants and one sewage treatment plant. Virtual technologies are helping make information and data on every plant on the premises available digitally to planning engineers, process engineers, assembly coordinators, safety experts and asset managers. A virtual copy of a plant displays every possible view, whether in graphics or figures, in drawings or simulations. This expedites and improves the planning and implementation of new plants or additions and retrofits.

Design reviews are an integral part of the planning process – a virtual model for design reviews realistically reproduces every component with the information related to it. The spatial representation makes hidden components or components aligned behind one another easily viewable. "We reviewed the design of a process plant retrofit together with BASF experts," reports Sabine Szlyer, virtual reality specialist at the Fraunhofer Institute for Factory Operation and Automation IFF. "The space in the plant can be determined far more easily. What sounds so obvious is really a giant leap in perception."

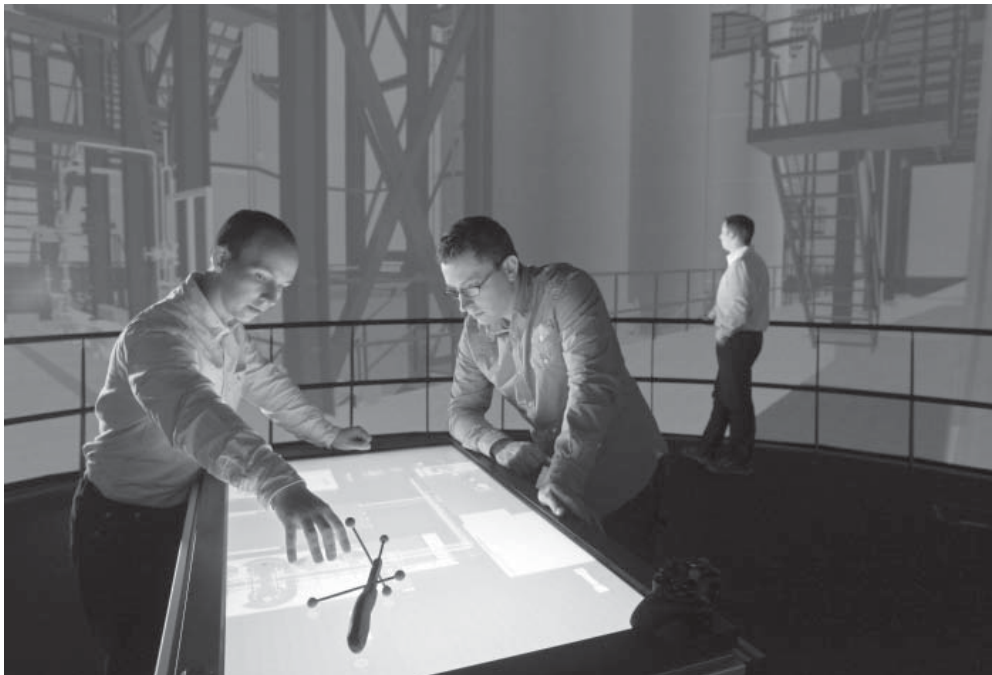
360 degree projection virtually identical to the original

The design was reviewed in the Elbe Dom of the Fraunhofer IFF's Virtual Development and Training Centre VDTC in Magdeburg. "After all, the six-meter high, 360 degree projection surface projects a level of a plant, which is virtually identical to the original. This gives viewers the sensation of standing directly in the plant," explains the researcher. The three-dimensional data from BASF's planning tools, including the meta data of the plant's individual components, were exported into the Fraunhofer IFF-researchers' special virtual reality software – the Virtual Development and Training-Platform. This enabled plant operators, plant planners and their colleagues, such as piping contractors, equipment and instrument engineers, steel building contractors or safety supervisors, to view details of the plant faithfully reproduced at full scale in the virtual model and clarify many questions such as whether all of the operating elements are easily accessible or all the safety valves are easily operated during an inspection "we are so impressed by the design review with virtual reality that we have set up two VR stations in Ludwigshafen. That enables our planning teams there to review designs of other plants any time," says Axel Franke, Senior Engineering Manager at BASF.

A retrofit plant performs differently than before and, in the worst case, incorrect operation could bring all plant operation to a complete standstill. Continuous safety training is therefore a top priority in chemical plant engineering. A virtual interactive learning environment is already being used for training in Ludwigshafen. Fraunhofer

experts designed a scenario for the retrofit of a nitric acid plant, which enabled the team of operators to inspect and get acquainted with the plant already before its commissioning. The Fraunhofer experts set up a mobile VR training station directly in the control room. The training module presents the complete 3-D model of the plant. All of the meta data such as serial numbers, temperatures, pressures and media as well as training materials can be viewed. Workers were able to familiarize themselves with its new operation, identify new access points and learn new safety regulations.

The experts from BASF and the Fraunhofer IFF concur that plant engineers will be unable to operate internationally in the future without virtual technologies. BASF is working on intensifying its use of virtual technologies in the future in order to maintain its leadership among chemical plant operators. The Fraunhofer IFF will continue providing conceptual support.



Design review on the planning model of BASF's factory in the Elbe Dom of the Fraunhofer IFF Virtual Development and Training Centre VDTc. The giant 360 degree projection facilitates in-depth discussion of all of the plant's details. (© Dirk Mahler) | Picture in color and printing quality: www.fraunhofer.de/press

6 Browsing without the hurdles

RESEARCH NEWS

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For companies in Germany, web accessibility has never been a compelling issue until now – this was also confirmed by a series of tests conducted in 2011 by the Fraunhofer Institute for Applied Information Technology FIT in Sankt Augustin. The scientists at the Web Compliance Center used their analysis tools to test the “web compliance” – or adherence to international web standards – among the Internet sites of German companies listed on the DAX. The outcome: 90 percent of the websites exhibited substantial flaws. For instance, important data could only be found after much effort, the websites took too long to load, or they were deficiently displayed on mobile devices. “‘Web compliance’ not only means optimizing websites so that they can be used by disabled and older persons,” explains Dr. Carlos Velasco of the Web Compliance Center at FIT. “Search engines such as Google also have considerable problems with faulty sites. This may make the sites impossible to find or prevent them from ranking high in search requests. That is why this issue actually deserves a high priority.”

Economic advantages through accessibility

An increasing number of companies have since realized that accessibility also comes with major economic advantages. Hewlett Packard Italia, Public-I Group and Polymedia, for example, are participating in the EU research project, “Inclusive Future-Internet Web Services (I2Web).” Coordinated by FIT, the project has a budget of EUR 2.7 million for a 2 and half years. The partners include the University of York (United Kingdom) and the University of Ljubljana (Slovenia), as well as the National Council for the Blind of Ireland and the Foundation for Assistive Technology (FAST). Participating companies offer Internet television, Video On Demand (VOD), online banking services and content management systems. These sites will soon be barrier-free.

Monitoring social networks for illegal activities

To enable site operators to monitor their sites efficiently, the FIT computer scientists had already developed the “imergo Web Compliance Suite” back in 2004. It is comprised of a series of tools that can be integrated into content management systems. They review websites for adherence to certain rules, and these not only cover accessibility: for instance, one could monitor a social network such as Facebook for certain word groups that point to illegal activities. A company could also verify if the corporate design standards were being met on all their pages. “Typically, several content editors take care of large websites,” says Velasco. “The suite tests whether the logo is located in the right spot on every page, for example.”

The EU project “I2Web” launched in 2010 is a kind of progression from the “imergo Web Compliance Suite.” The prototype contains, for instance, a development environment for an Expert Viewer. Not all accessibility guidelines can be checked automatically

by a software program. For instance, photographs on a website should have a suitable alternative text. While a test tool can detect whether a text exists, it cannot determine if it also “suitably” describes what can be seen in the image. So the Expert Viewer offers a list of all relevant image texts that editors can review for the correctness of content. One important part of the EU project is conformity with interfaces, such as when customers wish to use Video On Demand or Internet TV on their televisions. “I2Web” ensures that the websites work seamlessly on all devices (if possible), and can be operated with complete accessibility.

Given the rapid pace of the Internet’s evolution, the researchers at FIT will not soon run out of things to do: they will consistently have to adapt their tools to new browsers, the latest mobile devices and additional interfaces. But their work pays off: Open Text, a leading provider of content management systems, successfully markets the “imergo tools” as an additional option on its products.