New materials reduce CO_2 emissions

Well insulated and mobile : **combating climate change**

Nearly one-fifth of global greenhouse gas emissions are attributable to buildings, making it high time for an architectural revolution. Using new energy concepts and novel raw materials for energy-saving insulation, researchers at Bayer MaterialScience are now putting buildings on a diet, and in the future, foams with nano-pores will enhance the energy efficiency of insulation even more. The Bayer material specialists also aim to reduce CO_2 emissions from transportation and are working on lighter- weight materials for fuel-saving cars.

A power supply for buildings only from renewable sources? This vision is soon to become reality in the United Arab Emirates. In a place where air-conditioners, cooled swimming pools and SUVs are standard in many households, architects are planning a minor revolution: by 2015, on what is now just desert, they want to build Masdar City, a zero-carbon center of science and innovation for some 50,000 residents. The city is to consume only as much energy as it can generate from renewable sources, primarily solar energy. Experts agree the new town is putting its efforts in the right place, because according to the Intergovernmental Panel on Climate Change (IPCC), 18 percent of global carbon dioxide emissions is attributable to heating, air-conditioning and lighting in the residential and commercial building sectors.

For the global climate, however, Masdar City is no more than a drop in the bucket. Megacities like New Delhi consume enormous amounts of energy. But there, too, environmental awareness is on the rise. In Greater Noida, near New Delhi, Bayer MaterialScience is erecting an office building for 40 employees that will set new standards in India. Thanks to architecture adapted to the local climate, polyurethane rigid foam thermal insulation and polycarbonate glazing, the building's energy consumption is far below the average in India. The energy required can be supplied from renewable sources. According to calculations, the additional investment in materials and photovoltaics will pay off in less than ten years.

Software designs energy-efficient architecture

The EcoCommercial Building, or ECB for short, is part of the Bayer Climate Program and proof of how materials from the research laboratories of Bayer MaterialScience can cut energy consumption and emissions. But the Bayer researchers involved in the building project are thinking even further ahead. "The EcoCommercial Building is a novel approach to the planning and architectural design of energy-efficient buildings," says Dr. Saskia Rühmer, a member of the project team that developed the innovative EcoCommercial Building business model at Bayer MaterialScience.

The Bayer experts rely on simulation software that uses climate data to calculate an ideal building configuration, such as the size of the windows compared to the facade, or the ideal thickness of insulation in the floors, walls and roof. The new method has attracted the attention of numerous specialists in Germany's building industry. Investors, architects and developers have contacted Bayer MaterialScience wanting to know more about the new ECB energy-saving method: "We never expected so many inquiries," the innovation manager admits.

To show that the ECB concept functions in Germany as well, a new childcare facility with 60 places is currently being built for Bayer CropScience at its Monheim site. At a cost of €2.5 million, the building is a sound investment. Averaged over the year, it has zero effect on the climate thanks to the best thermal insulation and leading solar-thermal, geothermal and photovoltaic technologies. Before the facility has even opened its doors, it has already been awarded

An advanced building material: Peter Capellen (large photo) examines polycarbonate sheets in the laboratory. The high-tech plastic is lightweight, break-resistant and provides protection against heat. Transparent polycarbonate sheets are used as heat insulation in the EcoCommercial building (photo right) currently being constructed by Bayer in India.

It's in the mix

Professor Reinhard Strey is head of Cologne University's Institute of Physical Chemistry. *research* spoke to him about microemulsions and how they could revolutionize chemistry.

What's so unusual about microemulsions?

Conventional emulsions are comprised of droplets, such as oil, dispersed in a liquid, such as water. If you add a surfactant, it reduces interfacial tension and stabilizes the emulsion. However, the mixture is still milky in appearance and will eventually separate: the oil rises to the top. Not so with microemulsions. It's not only that the droplets are smaller; microemulsions are real mixtures formed without adding energy by stirring, and they are thermodynamically stable under certain conditions. As a result, microemulsions are transparent.

Microemulsions are the basis of nanofoams. How far along are you in their development?

According to our calculations, one cubic centimeter of a microemulsion contains a quintillion surfactant bubbles containing blowing gas, which would be equivalent to a pore size of about 50 nanometers in the foam. We are still searching for the right ingredients. Foaming is a race against time, because the polyurethane components react very quickly and the blowing gas droplets expand as pressure subsides. But I expect a breakthrough soon. Using microemulsions, we already have produced foams made of sugar with pore sizes of several micrometers. They even contain edible surfactants, and that would open up entirely new possibilities for the food industry.

Where else can microemulsions be used?

Although the application options are endless, they are limited at present because microemulsions are not part of the university curriculum and the field doesn't have enough specialists. Another promising application is water/diesel microemulsions as eco-friendly fuels, which would make it possible for diesel engines in ships, trains, trucks and even passenger cars to run clean without a particulate filter.

the 2009 Energy-Optimized Building Award by the German Federal Ministry of Economics and Technology.

With its ECB concept, Bayer MaterialScience views itself as a partner to the building industry and aims in the future to provide more consulting services for the optimum use of Bayer materials in buildings. For example, the company is collaborating with the Berlin Climate Federation and its roundtable discussion panel for the housing industry, which mainly addresses the subject of renovating the many old buildings in Germany's capital. These ageing structures are to be retrofitted with new energy technologies, such as high-performance insulation. The best alternative is polyurethane (PU) foam, because it demonstrates the best insulating effect. For example, to achieve the same performance as a layer of polyurethane thermal insulation ten centimeters thick, a mineral fiber layer would have to be 17 centimeters thick. Rigid polyurethane foam also boasts a good overall energy balance, because the insulation saves over 70 times more energy than it consumes over its life cycle, including production, transport and use. In this calculation, the life cycle is equal to the average useful life of a building: 50 years.

Polyurethane: a material for climate protection

Dr. Rolf Roers, Head of Application Development, Metal Panel, at Bayer MaterialScience in Europe, has long been convinced of polyurethane's perfect suitability for climate protection. His team develops rigid foam systems for components comprising steel outer layers and rigid foam cores. Metal composites of this kind, also referred to as sandwich elements, have seen increased use recently in the construction of walls and roofs in large industrial, refrigeration, warehouse and exhibition buildings, as well as in athletic facilities and schools. For these applications, the elements must not only be very strong, maintenance-free and cost-efficient in production, they must also meet tough demands on thermal insulation and fire protection. These two areas in particular are of growing importance for industrial structures. The current trend therefore is polyisocyanurate-modified rigid

Dr. Lutz Brassat checks the structure of a sheet made from the new high-performance insulating material PIR. The material boasts better thermal insulation properties, mechanical strength and fire behavior than polyurethane.

foam (PIR), because it meets the strict requirements of a new E.U. standard for fire behavior and associated smoke gases. PIR can now be used for those applications in which polyurethane products were previously not permitted for fire-safety reasons. "PIR displays better thermal insulation and mechanical properties. Also, its behavior in the event of fire is significantly better than polyurethane," says Dr. Lutz Brassat, Head of Applications Development for rigid polyurethane foam raw materials. In the new high-performance insulation, far more excess isocyanate is used, so that it can crosslink with itself. The thermal conductivity of the insulation is optimized by a smaller cell structure with reduced average pore size. Bayer experts say the market trend is moving from conventional polyurethane to PIR foams. They already dominate the U.S. market and will also take up the lead in Europe. "We have only just begun marketing the climate-related advantages of polyurethane and PIR sandwich elements, and our efforts undoubtedly will cause a significant jump in demand for these components over the next few years," says Roers, who believes that Bayer MaterialScience is well positioned in the European market with its latest product developments.

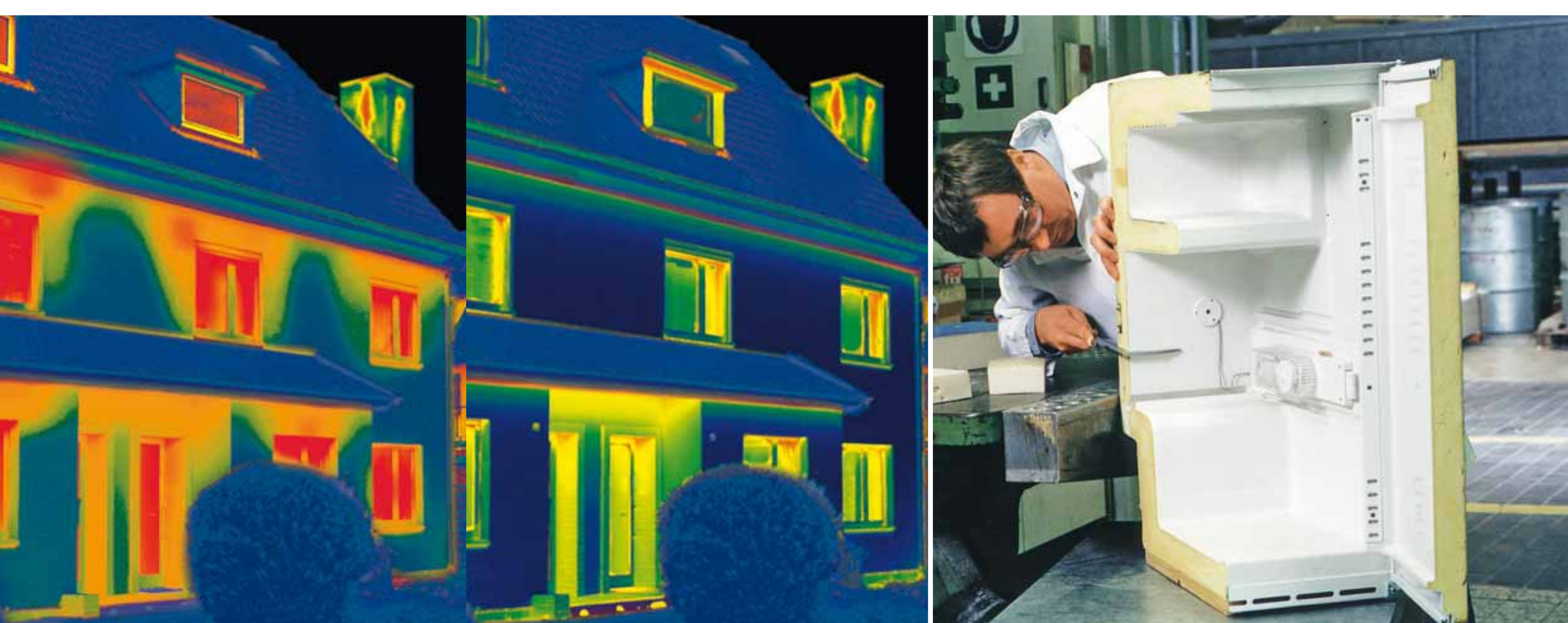
Nanofoams for particularly efficient insulation

Bayer researchers are also working on developing foams made of renewable raw materials, such as polyols derived from soybean oil or sugar (see also *research* 20, page 16: "PUre Climate Protection"), for customers who request them. Various methods exist and Bayer holds a patent on a very promising one: an insulation panel containing up to 30 percent renewable raw materials, which currently is being introduced in California, where it is subsidized. Using renewable raw materials to manfuacture the isocyanate in polyurethane is likely to be more difficult, however. "But the universities have ideas for making isocyanate from lignin, an element of wood, although they still have a long way to go," Brassat says.

Also to benefit from the new insulation materials are refrigerators and freezers, which are responsible for a large percentage of the energy consumed by modern households. The thermal conductivity of the rigid polyurethane foam insulation used in these appliances needs to be as low as possible. "A detailed study by Bayer MaterialScience now confirms that we have not yet exhausted the potential of existing rigid foam systems in the BAYTHERM product family," says Dr. Reinhard Albers, Technical Head of BaySystems Technical Thermal Insulation in the Polyurethanes Business Unit. The Bayer researchers want to further reduce the thermal conductivity of polyurethane rigid foams used in refrigeration system manufacturing by intelligently selecting the individual material components. In the long term, however, Albers is hanging his hopes on his colleague Dr. Stefan Lindner, who is exploring new dimensions in thermal insulation with nanofoam. The materials specialist is developing a polyurethane foam with double the insulation capacity. It would slash the energy consumption of refrigerators in half and, thanks to a thinner insulation layer, make more room for storing everything from milk to zucchini.

Classical polyurethane foams, like those used to insulate refrigerators, have pores measuring 150,000 nano-

Thermal bridges: With a thermal imaging camera, the poorly insulated sections of a building where heat escapes clearly show up red. Rigid polyurethane foams are ideal insulating materials. They also help to keep the energy consumption of refrigerators at a low level.



meters. Lindner wants to develop pores smaller than 150 nanometers. Three years ago, he came across a patent submitted by Professor Reinhard Strey of Cologne University's Institute of Physical Chemistry (see also "Interview"). His Principle of Supercritical Microemulsion Expansion (POSME) describes the use of microemulsions to produce foams. The oil-in-water microemulsions contain tiny droplets of compressed CO_2 encapsulated in surfactants. The droplets cause the oil and water, two normally immiscible liquids, to blend. The CO_2 serves as the blowing agent in the foaming process. The trick is to apply Strey's principle to the polyurethane starting materials, isocyanate and polyol: to mix the components under high pressure, then reduce the pressure so the CO_2 bubbles can expand, while the polymer chains crosslink within 30 to 60 seconds to form a rigid foam.

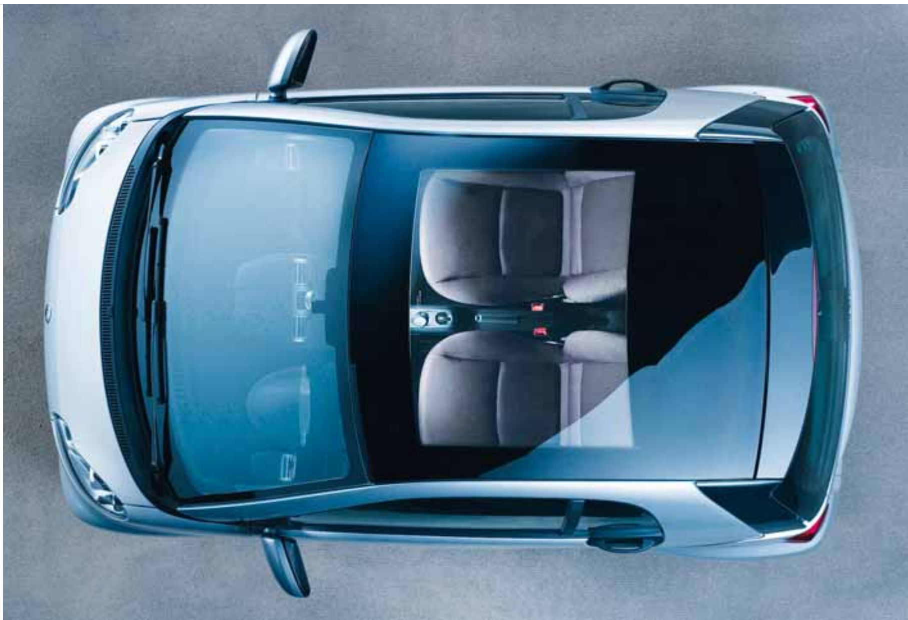
Lindner sees a lot of work ahead of him. At the pilot plant in Leverkusen, his team has built a system that processes all the ingredients at 200 bar. Right now, they are fine-tuning the process parameters for generating nanopores of the targeted size. Professor Strey's lab is improving the microemulsions and the Essen-based company CAM-D Technologies is using computerized molecular modeling to analyze the conditions under which the nanopores are best produced. But Dr. Wolfgang Friederichs, Global Head of Polyurethane Product Research at Bayer MaterialScience, warns against too much euphoria: "Research on nanofoams may take years, but we're optimistic that the project will ultimately be a success and achieve a real breakthrough in climate protection."

30 percent lighter than polyurethane in car roofs

The automotive industry is looking for a similar breakthrough, because low fuel consumption helps the environment and puts money in the pockets of car owners. Apart from drive concepts, the most effective means of lowering fuel consumption is to reduce vehicle weight. Engineers would like most of all to get rid of excess weight in the roof, particularly since top-heavy cars are also more difficult to control in fast turns. Peter Plate, Head of BaySystems Composites at Bayer MaterialScience, wants to eliminate up to 30 percent of total weight with a clever roof design. He demonstrates polyurethane samples from the Bayer product range: everything from flexible, rubber-like sheets and lightweight foams, to panels as hard as ceramic tiles. "We're combining three custom polyurethane grades to make automotive roofs lightweight but stiff."

At the pilot plant in Leverkusen, the team has access to scale polyurethane processing facilities and has already built and successfully tested functional samples there. In the process, a robot first sprays a layer of Multitec® rigid plastic, two millimeters thick, into the bottom of a mold. This layer will ultimately become the surface of the roof and be painted at the end of the manufacturing process. The relatively thin Multitec® layer with its high-quality optical properties is followed by an extremely rigid, glass fiber-reinforced polyurethane layer made of the Bayer spray system Baypreg®. The finished sandwich element covers most of the roof surface and is extremely light but still rigid. Finally, the robot sprays a solid

Materials experts Dr. Wolfgang Friederichs and Dr. Stefan Lindner (photo below, right to left) are developing lightweight nanofoams for thermal insulation. Automotive engineers are already using Makrolon® as a material for car roofs that saves weight and provides better all-round vision.



edge of Baydur® or Baypreg® around the entire component that adds to its rigidity and incorporates mounting elements. This solid edge is a blend of polyurethane and glass fiber chips, which are cut and mixed in during spraying. All three materials are nothing new in automotive engineering: the thermoset is used to line wheel housings, Baypreg® for trunk flooring and Baydur® for instrument panels. "The combination, however, is a real innovation and technically sophisticated," Plate points out. He and his team must now prove that the roof sandwich element is stable in a crash and won't injure passengers.

In addition to reducing weight, the polyurethane sandwich roof would have a positive side effect for automotive manufacturers. Until now, steel roofs had to be welded to the body at the beginning of assembly. In contrast, the plastic roof is simply placed on top at the very end, enabling the seats and instrument panels to be lowered into the interior from above, through the larger roof opening. In other words, each vehicle is a convertible as it moves down the assembly line, until the right roof type is mounted. "This change could streamline the process and may even lower total cost below the current level, since it will reduce assembly time on the line and the number of body-in-white variations," Plate explains. He expects to see prototype and low-volume sports car production in the next 18 months, and regular production vehicles in about six years. To reach this goal, the Bayer specialists already are collaborating closely with automotive manufacturers, suppliers and testing institutes, because development work already is in full swing for vehicles scheduled to go to market in 2015.

Lightweight Makrolon® replaces glass in car windows

Car roofs made of transparent Makrolon® polycarbonate from Bayer have advanced a step further: they already are incorporated in production vehicles, such as the new Smart. Even the first two-seater model had rear side-glazing made of Makrolon®. This plastic increasingly will replace glass, because it is significantly lighter: it realistically can cut weight by about 40 percent. The automotive industry currently consumes 3,000 tons of polycarbonate a year, three-fourths supplied by Bayer. "This figure will likely rise to some 100,000 tons in ten years," predicts Volkhard Krause, Head of Automotive Glazing at Bayer MaterialScience.

The roof on the Smart weighs only eight kilograms; its glass counterpart would push the scale up to 13 kilograms. The transparent roof not only gives Smart drivers a clear view, it's also good for the climate. According to a study by GUA consultants in Vienna, each kilogram of polycarbonate in a motor vehicle reduces CO_2 emissions by 14 to 22 kilograms compared to glass, based on a total mileage of 150,000 kilometers. For 100,000 cars – that's how many Smarts are built a year – the total reduction would be up to 170,000 tons.

www.bayer.com/en/Climate-Program.aspx
The Bayer Climate Program Brochure shows further examples of the company's innovative work in climate protection.

Composite polyurethane panels incorporating glass fibers reduce weight and increase strength in the roofs of Berlin subway trains. The sandwich panels are exceptionally stiff despite their low weight.

An efficient team: Rüdiger Utsch, Joachim Kleser and Dr. Saskia Rühmer (left to right) are developing innovative energy-saving concepts for the construction of industrial and office buildings.