

# performer

The PLEXIGLAS® molding compounds magazin

2010.02



## Energy

**Lightweight:** Conserving resources with lightweight solutions

**Light guide:** Cutting power consumption with LED TVs

**Light-transmitting:** Storing solar energy with the world's largest lightweight solar module

# “Wasting energy is nothing other than throwing away scarce resources.”

Klaus Töpfer, former German Environment Minister

Dear Readers:

Making efficient use of energy and conserving resources are important aims, not just with regard to the international climate treaty, but as part of our social responsibility. Since fossil energies are finite, we have to look for alternatives. The first steps have already been taken.

This issue of perFormer shows how newly developed products and proven material, used in intelligent applications, can contribute to generating energy or reducing consumption. Energy and resource efficiency is relevant to a broad range of uses. From regenerative energy technology to lightweight construction, lighting or material development, our expertise enables us to put the properties of PLEXIGLAS® to specific advantage.

Take big-screen LED televisions, for instance. In these, PLEXIGLAS® POQ66 serves as the light guide plate for a uniformly illuminated picture. The material's low refractive index and high light transmission mean the television requires less energy than with other materials.

The high light transmission of PLEXIGLAS® was also crucial for the world's biggest lightweight solar module, where it boosts the panel's efficiency yet is much lighter in weight than glass.

Weight is a crucial factor in relation to energy consumption, especially in vehicles. That is why lightweight construction is gaining ground, not just for car bodies. Glazing made from PLEXIGLAS® also goes a long way to reducing weight.

These are just some of the themes waiting to be read in this issue.



I wish you a light-hearted but energizing read!

Michael Träxler  
Senior Vice President  
Acrylic Polymers Business Line



## Boulevard

Large doesn't have to be heavy. The repertoire of weight reduction. **4**

### Boulevard

- 4 Showcasing lightness
- 5 Of dots and surfaces

### Cover Theme

- 6 Energy for the long term

### Technology

- 11 The influence of mass
- 14 Initiating the weight spiral
- 15 The wondrous world of windshields



## Cover Theme

Making efficient use of resources and renewable energies. The energy supply of the future. **6**

### Application

- 18 Top performer
- 20 Efficiency comes to TV screens

### Development

- 22 Symbiosis of wood and PLEXIGLAS®



## Technology

Conserving resources by lightweight means. The influence of mass. **11**

Would you like to learn more? You will find further information on PLEXIGLAS® molding compounds on the Internet at [www.plexiglas-polymers.com](http://www.plexiglas-polymers.com). Please send your questions or suggestions on the topics presented in this magazine by email to [performer@evonik.com](mailto:performer@evonik.com)

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Gregor Hetzke, President of the Performance Polymers Business Unit at Evonik Industries, and Rudolf Blass, Manager of the Automotive & Surface Design industry segment in the Acrylic Polymers Business Line, with a lightweight PLEXIGLAS® windshield.

## Showcasing lightness

Evonik has opened a lightweight construction studio in Darmstadt, where the company presents its expertise in lightweight construction applications and offers facilities for talks with its customers.

**“With our new lightweight construction studio, we are sending clear signals** that we intend to grow our business further in the promising market for lightweight components made from PLEXIGLAS®, ROHACELL® and VESTAMID®,” explained Gregor Hetzke, President of the Performance Polymers Business Unit at Evonik Industries. “Developing lightweight components is one of the core elements of our innovation initiative.”

**The lightweight construction studio offers customers a direct comparison:** The windshield made of glass stands next to the outwardly identical but lightweight PLEXIGLAS® version, and the conference table proves that large doesn’t have to mean heavy. “The applications for our products are often not visible at first glance. But at the lightweight construction studio, we now show what can be achieved with our materials,” explains Rudolf Blass, Manager of the Automotive & Surface Design industry segment in the Acrylic Polymers Business Line. “This helps us to enter into much more concrete discussions with customers and discuss themes and projects in greater depth.” Visitors to the studio so far are impressed by the variety of exhibits, ranging from a complete car to a satellite launch vehicle component. “You see, most customers only know PLEXIGLAS® from their own seg-

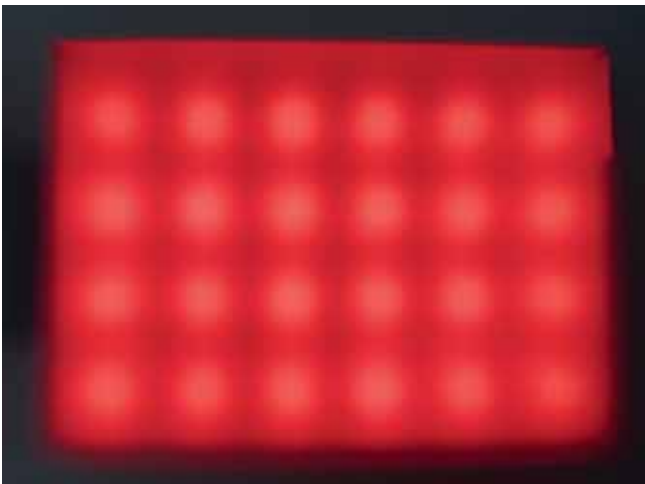
ment of industry,” Blass goes on to say. “Here, they are able to see other applications and get inspiration for innovative lightweight construction solutions.” As a side-effect, visitors can also discover Evonik materials in many features of the studio design. These include the platforms beneath the cars, the rear projection screen in the conference area and the signpost columns at the entrance. – ck



A closer look at lightweight construction technology, from the engine to the windshield.

# Of dots and surfaces

Evonik has further developed its diffuser molding compounds (df) especially for thin-walled direct lighting with LEDs.



Slimline construction: LEDs are visible through the material as spots of light.



With the new PLEXIGLAS® molding compound: better light distribution

**Light-emitting diodes (LEDs) are the highlight among illuminants.** They offer convincing advantages like low power consumption and much longer service life than conventional sources of lighting such as light bulbs, energy-saving lamps and fluorescent tubes. Climate protection considerations and constantly rising electricity prices create a strong demand for energy efficiency, which is why more and more lighting systems are being manufactured with LEDs. Evonik therefore spent several months developing a special PLEXIGLAS® molding compound that is perfectly suited for use with LEDs, for example for backlit lighting covers, tubular lamps and the structural lighting that is typical of the Asian market.

## Very much in demand: Flat design, high luminosity

LEDs offer another advantage as well as their high energy efficiency: flatter shapes. "The PMMA cover can be installed closer to LEDs than to fluorescent tubes because the diodes emit less heat," says Michael Zietek, Manager Business Segment Optics, Surfaces and Lighting in the PLEXIGLAS® Molding Compounds Product Line at Evonik. "The molding compound remains stable despite its proximity to the light source. So LEDs make it easier to manage heat."

The slimline luminaires not only look elegant and classy, the new PLEXIGLAS® molding compound also makes it possible to realize new lighting options. Optimized wall thicknesses of just

a few millimeters are conceivable. High luminous efficiency is achieved in a small space because these covers absorb hardly any light.

## High transmission and diffusion prevent hot spots

The flat lamps and the type of illuminants used make new demands on the molding compound, which Evonik took into account during further development. There should be no hot spots, for one thing – undesired fluctuations in luminance that allow individual light sources to be perceived as spots through the material. So the challenge when continuously reducing the wall thickness was to achieve sufficiently high transmission combined with maximum diffusion. The essential feature are the PMMA beads embedded in the molding compound, which distribute light evenly. That works by precisely adjusting the diameter of the beads and the light refraction. "We have developed a special formulation for the required wall thickness range, where we have more than 60 percent transmission, but at the same time very high light diffusion. This means we can avoid fluctuations in luminance," Zietek explains. "The new PLEXIGLAS® molding compound offers developers in the lighting industry greater scope for creating fantastic new forms of lighting." – cat



# Energy for the long term

Future energy supply faces two major challenges. We must drastically reduce man-made CO<sub>2</sub> emissions if we want to avoid the worst impacts of climate change. Added to this, the fossil energy sources (petroleum, natural gas and coal) are finite. The International Energy Agency (IEA) estimates that the reserves proven to exist so far around the world will suffice to supply the world with oil for another 40 years, if consumption stays at the present level. But at the same time, the IEA expects the consumption of raw materials to continue to rise up to 2050.

On the subject of climate change, the Agency writes in its World Energy Outlook 2009: "If the world wants to reduce the likelihood of temperatures rising by two degrees Celsius to 25 percent, CO<sub>2</sub> emissions for the entire period from 2000 to 2049 must not exceed one trillion tonnes. From 2000 to 2009, global emissions equalled 313 billion tonnes of CO<sub>2</sub>." That means one third of that volume has already landed in the atmosphere.

## The end of oil

It would be wrong to imagine that oil flow will come to an abrupt end. Instead, at some point maximum production will have been reached, known as "peak oil". After this, there will be a gap in supply. The German Federal Institute for Geosciences and Natural Resources (BGR) estimates that peak oil will be reached in 2023, factoring in growing consumption. Reserves might be expanded by developing as yet untapped oil and gas fields, mainly in the deep sea, and by developing oil sands.

In this way, BGR says, the point in time when peak oil is reached might be delayed until about 2030 or 2035.

The situation is less tense when it comes to other non-renewable raw materials. Reserves of natural gas will not run out until mid-century, given the same rate of production, according to BGR estimates. Coal reserves and re-

sources will last for another 125 years, and lignite even longer, provided consumption remains at today's level. However, these sources of energy also cause the highest CO<sub>2</sub> emission. Uranium deposits will be available for a very long time. The greatest pressure for harnessing alternative energy sources exists with regard to petroleum.

## Long-term substitute for oil and coal

Renewable energies have gone from being a niche technology operated by idealists to an industrial-scale sector of the economy. Wind and solar energy are booming, also thanks to promotion programs in Europe and the USA. Emerging economies like Brazil or Indonesia export large volumes of vegetable oil that can be used as biofuels. Renewable energies already cover 10 percent of Germany's primary energy demand. The lion's share is made up of heat production using biomass. Wind power plants produced 37.8 billion kilowatt-hours of electricity last year – enough to supply 10 million households. The German government intends to raise the contribution made by renewable energies to overall power consumption in 2020 to at least 30 percent, and to increase it thereafter.

But experts have long harbored much more ambitious goals. "In my view, modernizing electricity supply can



In the Emirate of Abu Dhabi, the world's first climate-friendly city is taking shape. Masdar City is to be operated entirely with renewable energies and produce virtually no waste or CO<sub>2</sub> emissions.



With its huge bucket wheel excavators and furrowed landscapes, lignite mining for the production of electricity is particularly harmful to the climate. The future is also uncertain for the oil industry. There is no knowing how long oilfields will supply the coveted raw material.

only mean providing 100 percent of power through renewable energies," said Jochen Flasbarth, President of the German Federal Environment Agency, in March to representatives of the energy industry at the summit of German energy supply companies (EUV). A series of studies published in the past year demonstrate how this can be achieved. The Potsdam Institute for Climate Impact Research (PiK) joined forces with PricewaterhouseCoopers, for example, to outline the steps that would be necessary to convert electricity supply in Europe and North Africa to a system that produces zero percent greenhouse gases and 100 percent renewable energy within 40 years.

### Electricity plays a key role

The importance of electricity generation will continue to grow, according to the authors. "As a rule, electricity can be used in all areas," says Johan Lilliestam at PiK, one of the authors of the study. "Cars can be used for traffic in the city as soon as the battery issue has been resolved," says Lilliestam. Transport alone accounts for roughly 70 percent of overall oil consumption. "In the future, we will have to consider very carefully the most valuable uses to which biofuel and biomass can be put. Individual transport is certainly not one of them," Lilliestam continues. Electricity could in principle also be

used to heat buildings, as is already quite customary in Sweden and Norway.

Whereas technologies for generating and storing renewable energies are more or less known, the climate scientist sees setting up the required electricity grid as the biggest problem. "We need a supergrid with direct current lines across large distances," says Lilliestam, "and they cannot be installed at short notice." For one thing, it takes a long time to install high-voltage lines owing to protests and civil initiatives. On the other, the lines would run through many different sovereign territories. The ultimate challenge would be to simplify procedures and create acceptance.

### Rediscovering the concept of energy saving

Another aspect of sustainable energy supply is often overshadowed by the boom in renewable energy: the need to save energy. This is part of the climate package adopted by the EU at the end of 2008. By 2020, renewable forms of energy are not only to provide 20 percent of final energy consumption, but primary energy demand is also to be cut by 20 percent as compared with forecasts for 2020. "That is surely less well known that the other 20 percent targets," says Stefan Thomas at the Wuppertal Institute for Climate, Environment and Energy. Eight years ago, he and



To safeguard the world's energy supply in the future, it is not enough to rely on alternative technologies. Existing resources must also be handled responsibly.

his colleagues published a study on energy efficiency with the appropriate title *Die vergessene Säule der Energiepolitik* (The forgotten pillar of energy policy). In this, the scientists reminded readers that energy efficiency is often cheaper and more socially compatible than energy consumption. "Interest in this theme has grown again in the last three years," Thomas reports. The growing importance of climate policy played a major role in this context, he said, as did the rising oil price and the disputes between Russia and its neighboring countries that temporarily interrupted gas supplies.

The enormous potential offered by energy efficiency extends across many areas of life and economic sectors. In some of these, governments and the EU have already introduced regulations. "The ban on incandescent bulbs was only one of some 30 EU regulations that are currently being prepared or have already been applied," Thomas says. Soon, only refrigerators and freezers with an energy efficiency rating of A will probably be allowed. The same applies to circulation pumps for heating systems. The standby consumption of electronic appliances will have to be less than one watt in the future. German regulations for new buildings and building renovations were also tightened last year. And from 2020, public buildings may only be built as passive houses.

### Savings of 50 percent are possible in all areas

In private households, hot water and heating account for almost 90 percent of energy consumption. Even in existing buildings, it would be possible to save three quarters of heating energy by installing heat insulation and better heating systems. There are practically no areas where potential has already been exhausted. From heating and electrical appliances to lighting and heat insulation, "savings of 50 percent are nearly always possible," Thomas says.

Potential also exists for saving electricity in the industrial sector. The German Federal Ministry for the Environment estimates that industry could reduce its energy consumption under reasonable economic conditions by 20 to 40 percent by 2020. Electric drives, for example, account for two thirds of electricity consumption. The use of speed control would enable a 15 percent reduction in consumption, corresponding to an overall volume of 4,000 megawatts.

A lot of energy can also be saved for large-scale lighting installations – such as for advertising or fixtures on corporate buildings. Modern illuminants like LEDs (light emitting diodes) use a fraction of the energy required by fluorescent tubes. Together with a cover that transmits plenty of light and diffuses the light effectively, large surfaces can be lit up just as brightly with fewer LEDs.



Sun, wind, water and biomass are among the many alternative sources of energy that are already being used. Solar power in particular is gaining in popularity, not just in private households. A gigantic solar power station on Piz Nair in Switzerland also collects solar energy.

### Lightweight construction for aircraft and vehicles

A little more energy savings potential can also be squeezed out by material efficiency and lightweight construction. Fiber composites, for example, are intended to make aircraft, vehicles and machine elements lighter. "The rule for a conventional mass-produced car is that every 100 kg of vehicle weight than can be saved translates as 0.3 liters less fuel per hundred kilometers," says Stefan Tröster at the Fraunhofer Institute for Chemical Technology ICT. "Our research aims to make car bodies-in-white that now weigh 500 kg, thirty percent lighter." That would correspond to a good half liter per 100 kilometers.

The new materials are still too expensive for mass-produced automobiles. The aviation industry plays a pioneering role in this field. "Large volumes of carbon-fiber reinforced plastic are already being used in the Airbus A380 and the Boeing Dreamliner," Tröster says. Research is focusing predominantly on reducing the cost of manufacturing processes.

### Energy source "negawatt"

If it were up to Stefan Thomas at the Wuppertal Institute, German determination to save energy could be strengthened even further. "So far, there is sadly no in-

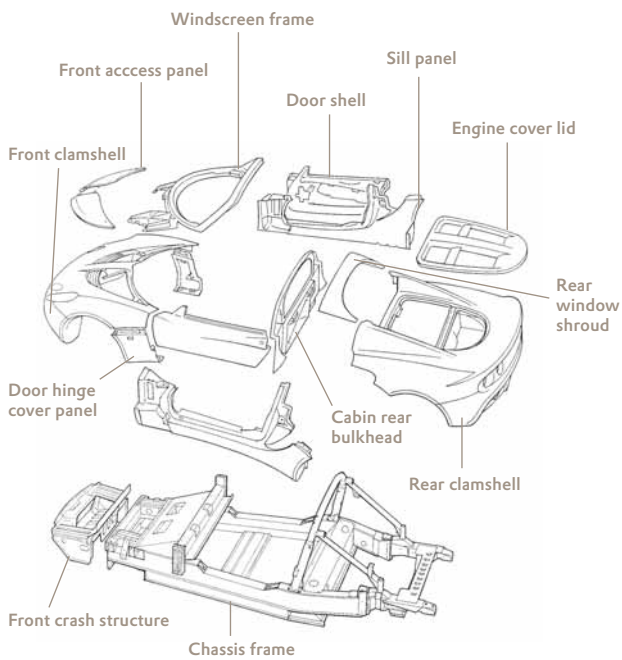
strument in the field of energy efficiency that is similarly effective to the German Renewable Energy Sources Act (EEG) for expanding renewable energies," Thomas says. "In Denmark or the UK, the energy industry is instructed to support its customers in the economical use of energy. The energy companies are obliged to furnish proof of savings."

American physicist and environmental activist Amory B. Lovins is considered the spiritual father of this process. In the late 1980s, he advanced the surprising theory that energy savings should not be seen as a dent in sales, but as a valuable economic commodity. He coined the term "negawatt" in this context – savings in wattage. Lovins' glowing example is the Southern California Edison Company: The US electricity supplier once gave its customers 800,000 energy-saving lamps for free because that was cheaper in the long run than making new investments in its own power plants and paying the operating costs for those plants. So the energy saving was not only worthwhile from the clients' point of view, but also for the supplier. Lovins took the idea one step further: Really speaking, he said, there should be dedicated markets on which negawatts are traded just like copper, wheat or pork sides. – Martin Kaluza

# The influence of mass

Conserving resources and saving energy are both possible with lightweight construction. There is enormous potential for weight savings and thus for the responsible handling of raw materials especially when it comes to mobility. Materials from Evonik are already part of various low-mass solutions.





From the chassis via the outer skin to the engine compartment, many heavy components in cars can be replaced by lightweight but equally safe elements. Lighter cars consume less fuel and can also accelerate more easily. Good news not just for race car drivers!

Lightweight construction is booming, a development that is driven by the awareness of finite resources and growing environmental consciousness on the part of consumers. From the aviation and aerospace industry to architecture, solar plants or the automotive industry, experts everywhere are looking for lightweight solutions.

The aim is to achieve the same or better results using less material and at lower weight. That saves resources in production and also reduces the burden on the environment in the long term, because weight that does not exist doesn't need to be moved. "Lightweight construction is a sub-aspect of the mega trend towards energy efficiency and the conservation of resources. And we have the materials that make a major contribution in this field," explains Rudolf Blass, Manager of the Automotive & Surface Design industry segment of the Acrylic Polymers Business Line. This knowledge of the material's special properties is combined within a competence team whose members come from four different business units at Evonik. "That means we can concentrate on several factors at the same time, which helps us to achieve the lightest possible solution especially in the automotive sector," Blass says. But the core of a satellite launch vehicle made from ROHACELL® rigid foam, which is extremely stable as well as lightweight, was also shot into space with the greatest of ease. And PLEXIGLAS® makes for lightness in the world's largest lightweight solar module too.



### Putting cars on a diet

The automotive sector has a particularly large number of areas in which lightweight construction offers savings potential. "Apart from an improved drive assembly, vehicle weight can do most to reduce a car's fuel consumption," explains Klaus Hedrich, Manager of the Automotive Industry Team at Evonik. "If we can succeed in making a vehicle 35 percent lighter, that saves 25 percent fuel." The result is even better if the rolling resistance and air resistance are also optimized. The aim is not just to replace individual components with lighter-weight ones in existing models. "That's only one step on the way to completely new models with optimized lightweight construction," Hedrich explains. But even this interim step offers savings. A model calculation for a Golf VI shows that a lightweight car body saves one liter of gasoline per 100 kilometers. And there is a corresponding two-digit reduction in CO<sub>2</sub> emissions.

### Lightweight construction of the future

New models whose construction bears in mind all the advantages of lightweight components can be made lighter still and save even more energy. "By doing this, the empty weight of a car can be reduced to less than 1,000 kg," Hedrich says. "This is especially exciting for electric cars, where weight is even more crucial than in cars with conventional transmissions." Lower weight also means a

smaller battery is needed for the same driving performance. "That makes electric cars financially interesting for consumers even without government subsidies," the expert forecasts.

### Reducing weight doesn't come easily

While the A 380 passenger aircraft already consists of 40 percent lightweight components, the automobile industry is not yet in a position to mass-produce vehicles with lightweight elements. The challenge lies with suppliers. "So far, there are no companies that can economically produce lightweight parts in large series. It's not easy to switch from making small numbers of large components to mass-producing small components," Hedrich tells us. That is why Evonik is working directly with automotive manufacturers on various development projects to come up with an economical solution. "The automotive industry can only launch mass production of lightweight vehicles if we work together to produce large numbers of components at reasonable cost and constant high quality. So going light is far from easy. But we and our partners are well on the way towards a resource-conserving and energy-saving future." - ck



## Potential for lightweight construction in automobiles

- **60 %** Sandwich composite technology with PMI core and ultra-thin EP/CF skins replaces sheet metal
- **50 %** Heat-resistant PPA parts in the engine compartment replace cast aluminium parts
- **40 %** Multi- and single-layer sheets of coated PMMA replace glass windshields
- **33 %** PA primer on deep-drawn steel or aluminium produces an extremely strong hybrid component. Lower wall thicknesses reduce the component weight

# Initiating the weight spiral

A leader in lightweight vehicle construction, Lotus is always coming up with new ideas. Jason Rowe, Chief Engineer Materials and Manufacturing Engineering, discusses opportunities and problems in lightweight construction.

"Design changes have to be made to optimize the material properties."



## Mr. Rowe, what role does lightweight construction play in vehicle development?

Reducing vehicle weight has for some years now been one of the main responses of OEMs to the challenges surrounding the issues of climate change and CO<sub>2</sub> emissions. Designers are optimizing the materials used and choosing materials on the basis of enhanced specific stiffness or strength properties.

Simply replacing existing parts with lighter-weight ones is not the ideal solution. Design changes have to be made to optimize the material properties. The latest body-in-white constructions have been further enhanced using design and manufacturing CAE tools.

In addition to selecting the right material, manufacturers are also reducing any superfluous material. Where economic circumstances allow, the OEMs have additionally started to utilize exotic materials – everything from stronger steel to aluminum and magnesium or composite materials.

## What are the major challenges?

Non-traditional materials pose a big challenge to the major high volume carmakers. Challenges include developing overall manufacturing processes geared to the production of components in large quantities.

Mass production operations do not always fit well with the use of exotic materials. OEMs respond to this dilemma by questioning their standard production process and seeking alternative solutions, such as using painting operations that function at lower temperatures or ready-colored components. This rethinking process paves the way for more new material technology still. When engineers think about weight reduction, they normally think carbon fiber. But the high cost of this material restricts them using it. OEMs are increasingly collaborating with material manufacturers to make innovative materials more affordable.

## What are the other ways to save weight?

The vehicle body may be a major focus in this respect, but it is only one of several. Another is the electronic systems in the vehicle's interior. When you consider just how much electronics is in a car seat these days, it makes you realize that this is a weight factor not to be ignored. That is why the industry is doing research into so-called intelligent materials such as shape memory alloys that respond to electric impulses, heat or magnetic impulses. Systems based on such memory alloys might replace heavy electric motors. As soon as vehicles become lighter overall, the weight spiral will take on momentum: smaller, lighter engines will become an option, and it will even be possible to downsize brakes and other components.

## How will lightweight construction evolve looking forward?

Manufacturers will be using more and more of these exotic materials. They will also see digital technologies further optimizing material integration and digital data being incorporated better still into the development process. There will be increasingly frequent use of computer programs feeding empirical data into the models to improve their accuracy. This could result in less prototypes having to be built, since developers will employ on-screen validation. Vehicle life cycle analyses, too, will gain currency in the industry and will influence our material choices.

## What does this development mean for consumers?

They will benefit from better fuel economy and lower taxes. Apart from an increase in component cost for the OEMs there are no drawbacks involved, since lightweight vehicles will need to be just as safe as conventional models, and nobody will be willing to forfeit comfort. For there is, of course, another way of reducing weight: smaller cars with less elaborate fittings, but that is not what buyers want right now.

## What is your vision of "lightweight construction 2040"?

I believe that it will become more difficult to find large weight saving opportunities, as the amount of weight that can be removed will be limited by the safety requirements and ride and handling targets of the vehicle. I think the industry will continue to invest a lot in engineering that reduces CO<sub>2</sub> generation. Weight reduction is a major contributor to achieving that aim, but other aspects will also be increasingly important over the coming 20 to 30 years. More efficient drive trains and clean fuels, for example.

# The wondrous world of windshields

PLEXIGLAS® glazing not only reduces weight and energy consumption in cars, but also ensures a clear view and safety in the air and under water.



The white Lotus speeds along the racetrack. Its driver keeps his eyes glued to the road. This is by no means the first time he has driven here, but now he is looking for the first time through a PLEXIGLAS® windshield and putting it to a practical test. The racing car itself is already a lightweight since it incorporates many components made of PLEXIGLAS® and other Evonik materials. The new windshield makes it 5.5 kg lighter still, i.e. the PMMA windshield weighs around 45 percent less than one made of glass. And that means the vehicle uses less gasoline, an effect that is of interest not just for sports cars. "That's why we want to promote PLEXIGLAS® as a material for transparent glazing by means of our Automotive Glazing Initiative," explains Rudolf Blass, Manager of the Automotive & Surface Design industry segment in the Acrylic Polymers Business Line. "Our material has already proved its worth in various forms of transportation, lightens the burden on the environment through its low weight and offers the automotive industry new options for developing models." This gives designers much greater creative scope than with conventional materials, and also has a positive influence on the acoustics inside the car.

### From airy heights to cool depths

For decades, aircraft passengers have looked out through windows made of PLEXIGLAS®. It also provides a clear view in submarines and sports aircraft. It protects motorcycle riders from stone chips, and campers look through PLEXIGLAS® windows to appreciate the sunrise and the holiday landscape around them. In these applications, the material has been used for years in permanent service and has to withstand extreme pressure, huge temperature fluctuations and direct exposure to sunlight at altitudes up to 10,000 meters. "These applications show how resistant our PLEXIGLAS® is, and demonstrate our many years of experience with glazing," Blass explains. "We would like to put this know-how to greater use in the automotive sector, amongst other things to conserve resources and save energy through lightweight construction." The material's light weight in particular can help front and rear windshields, side windows and panoramic roofs make a crucial contribution to building lighter and more energy-efficient cars. "While that is important for cars with conventional transmissions, it is even more important in electric cars," Blass tells us. "I don't mean converting existing models, I am referring to new vehicle designs that unite all



#### On land: automobiles

*Special types of stress:*

Strong vibrations, stone chips, alternating weather influences

*Advantages of PLEXIGLAS®:*

Impact-resistant, high surface hardness and scratch resistance, resistant to UV light and weathering, durably transparent, low weight, saves fuel



#### Mobile homes

*Special types of stress:*

Strong vibrations, stone chips, alternating weather influences

*Advantages of PLEXIGLAS®:*

Resistant to UV light and weathering, impact-resistant, high surface hardness and scratch resistance, durably transparent, low weight, saves fuel



#### Motorcycles

*Special types of stress:*

Pressure through strong headwind, strong vibrations, stone chips

*Advantages of PLEXIGLAS®:*

Impact-resistant, resistant to UV light and weathering, resistant to chemicals (gasoline and alcohol), high surface hardness and scratch resistance

the advantages of electronic transmissions and light-weight construction in one energy-saving vehicle."

### Glazing comes in different guises

There is no perfect solution that fits all types of glazing, because the requirements to be met by the material vary too much in each individual application. All combinations are conceivable, from small and straight to as big as possible, curved and colored. To be able to cover the entire spectrum, Evonik is pursuing two lines of development, and is developing both monolithic systems and multilayer systems with different transparent materials. The monolithic solution has already passed official tests: "We received the ECE R43 certification from the Materials Testing Institute in Dortmund for a 5 mm thick coated sheet of PLEXIGLAS®," Blass says. The tests included the material's flexibility as well as its resistance to moisture and weathering. In another test, a ball weighing 227 grams was dropped onto the sheet from a height of four meters. The sheet neither splintered nor did the ball penetrate the sheet. Various chemicals also had no effect on the sheet. The certification confirmed by these tests already covers most of the numerous requirements and forms the basis

for further tests. Apart from the legal regulations, specific criteria laid down by the automobile manufacturers determine the performance a material has to show. Since these criteria are not general and are subject to constant change, Evonik is also working on its own test procedures and at the same time developing the material further. As Blass explains: "We are trying to keep a few steps ahead and looking for solutions on behalf of our customers that may only be of interest in a few years from now. This is how we continually drive innovations in automotive glazing." One element of this strategy is also to provide PLEXIGLAS® with additional functionalities, as has already been achieved with the non-transparent, heat-reflecting material PLEXIGLAS® CoolTouch®.

To promote even more rapid implementation of this strategy, Evonik recently entered into a development cooperation arrangement with a glazing systems manufacturer. Parallel to this, tests are being conducted on the Lotus windshield, so the driver has a few more laps ahead of him yet. – ck



#### In the water: submarines

*Special types of stress:*

Exposure to strong alternating pressure, temperature fluctuations, water friction

*Advantages of PLEXIGLAS®:*

Durably resistant to strong fluctuations in pressure and temperature, durably transparent, easy to form and therefore highly suitable for hydrodynamic applications, weather-resistant (supports durability in water).



#### In the air: passenger aircraft and sailplanes, helicopters

*Special types of stress:*

Pressure at up to 10,000 meters altitude, extreme levels of UV light, wide temperature fluctuations, alternating weather influences

*Advantages of PLEXIGLAS®:*

Withstands permanent alternating pressure loads of 1 to 0.2 bar and temperature fluctuations between -55°C and +40°C, low weight, resistant to UV light and weathering, easy to form (for heavy, biaxially curved parts for aerodynamic applications), special material grade complies with international aviation standards

# Top performer

The world's largest lightweight solar module with a cover sheet of extruded PLEXIGLAS® Solar weighs in at only 80 kilograms, but is more efficient than a module with a cover made from a different plastic.



The new lightweight solar module produced by the Sunovation company with PLEXIGLAS® Solar and presented in June holds the record in terms of surface area. Measuring 1.58 by four meters, it is the world's largest lightweight solar module. That makes it a real flyweight. Compared with a glass/glass module of the same size, it offers a weight reduction of more than 60 percent. That means the solar module measuring about six square meters weighs only 80 kg, a weight than can easily be carried by two workers. It is therefore easier to handle than glass modules, which can often only be moved using heavy machinery. The solar module is protected by a cover sheet made of PLEXIGLAS® Solar. "PMMA achieved much better test results than other plastic materials. The module's output of ~880 Wp is much higher than that of a cover made from other high-performance polymers," says Peter Battenhausen, Business Development Manager in the Acrylic Polymers Business Line at Evonik. This is because PLEXIGLAS® shows very high transmittance of over 92% and absorbs virtually no radiation.

#### Only the right photons get through to the cell

"We have adjusted the transmission properties of PLEXIGLAS® Solar to the spectral response of a photovoltaic cell in the UV range," Battenhausen explains. "We protect the plastic material and the cell and achieve

optimized energy conversion efficiency, which means that only photons that the cell can actually convert get through to the cell." For example, if light of shorter wavelength that can no longer be converted falls on the cell, this produces heat, which is counterproductive for the cell and the material. This does not happen with PLEXIGLAS® Solar.

In addition to the higher efficiency of the module, the material is resistant to weathering and UV light, and very durable. PMMA has already been used for over 15 years for some concentrated photovoltaic (CPV) systems.

#### A must for solar modules: longevity

Longevity is especially important in view of the guarantee on solar modules, which prescribes defined module efficiency even after years of service. "Covers made from other plastics are far less weather-resistant than PLEXIGLAS®. This can mainly be seen from the fact that transmission drops in the course of time. And that has a direct effect on power generation," Battenhausen says. "PLEXIGLAS®, on the other hand, withstands heat, rain and hailstorms. It protects the module adequately from all winds and weathers." – cat



## Lightweight solar modules in use

Overhead constructions in particular benefit from the new lightweight module. This means the supporting structure can be less obtrusive, and solar modules can be integrated in a more individual way, for example in football stadium or shopping mall roofs. The reduced requirements for structural engineering have a positive effect on the budget. Lightweight modules save resources and reduce CO<sub>2</sub> emissions in mobility applications.

But the solar module is not only used for photovoltaics: it can also be used to create semi-transparency. For this, the PV cells are spaced at larger intervals, creating an attractive chessboard pattern of light and shade. Installed as a skylight, the solar module provides both a shading and a heat-insulating effect.

# Efficiency comes to TV screens

Manufacturers of flat-panel displays are producing more and more LED televisions. These require a light guide plate of PMMA, since LED edge lighting only works with this material. Absorption and diffusion losses within the light guide are absolutely minimal.



Just like every garage needs a car, every living room cries out for a television, a shiny piece of the latest technology with an impressive look and a sound to match. An estimated 188 million LCD televisions will be sold in 2010, and the proportion of LED TVs among them is growing from more or less zero percent last year to over 20 percent. And the market segment is expected to expand further. The new models increasingly incorporate LEDs, which are replacing cold cathode fluorescent lamps (CCFL). One reason for this is that LEDs save much more electricity. They also take up less space inside the appliance, especially with the so-called edge-lit configuration. Here, LEDs couple light into the edges of a light guide plate to illuminate the display. That calls for far fewer light sources than direct backlighting, but makes stringent demands on the transmission of the light guide plate, the key component of a backlight unit. "Light guide plates for this application can only be made from PMMA because of the required material properties," says Dr. Alexander Laschitsch, Manager of the Optically Functional Materials Segment in Business Development at Acrylic Polymers. "Only this highly transparent material can be used for the edge-lit LED backlight units, which are much more energy-efficient than the previous technology."

Each LED television that functions with backlighting incorporates an average of two and a half kilograms of PMMA, PLEXIGLAS® POQ66, in the form of the light guide. This is about four millimeters thick; the surface area depends on the screen size. The most frequently sold appliances are 40" to 46", though the trend is moving towards even bigger sets. Demand shows that PMMA is being increasingly used for LED televisions. Experts estimate that the annual PMMA requirement for light guides in televisions, together with the "basic requirement" for notebooks and monitors, will double within the next five years.

This demand is partly due to the material's high transmission. "Our optical molding compounds are absolutely pure and clean," explains Laschitsch. "There are practically no losses due to light absorption or diffusion." What's more, their optimal refraction ensures high light transmission. "PLEXIGLAS® has the lowest refraction index (1.49) of all commercially available transparent plastics. The Fresnel reflection when light enters the light guide plate is only 3.8 percent," says Laschitsch.

## Surface structure reflects light rays

A surface structure is applied to the back of the light guide plate so that light is uniformly emitted across the entire surface towards the viewer. This gradient structure causes laterally impinging light rays that meet one of these dots to be emitted towards the front. To illuminate the picture evenly, the dots in the center are larger than at the sides. A particularly large amount of light is guided towards the center, which has to be brighter than the edges because viewers normally face the screen straight on.

Apart from high transmission, it is important for the material not to alter the colors of the image, which is meant to appear as realistic as possible. As a neutral-colored material, PMMA has no influence on colors, and especially not on the yellowness index. Some plastics are prone to yellowing in the course of the years, and the TV picture suffers in consequence because white colors take on a yellowish tinge. PMMA, by contrast, shows no yellowing and colors remain just as vivid as on day one.

## Research cooperation with AU Optronics

To obtain detailed information on the future requirements for light guide plates, Evonik has been cooperating since the beginning of last year with AU Optronics (AUO), a manufacturer of LCD flat-panel displays in Taiwan that also produces light guide plates from PLEXIGLAS® molding compounds. AUO has to retain the material's high purity during extrusion, so the light guide plates are always produced on the same extruders, which are used only for this material. Traces of colorants from other products, for instance, could contaminate the sheets even if the machine was cleaned first. "This cooperation benefits all our customers," Laschitsch says. "We are currently testing new structures that are meant to improve light output. The new 3D televisions, in particular, require more light from the backlight unit, if possible combined with further energy savings." - cat



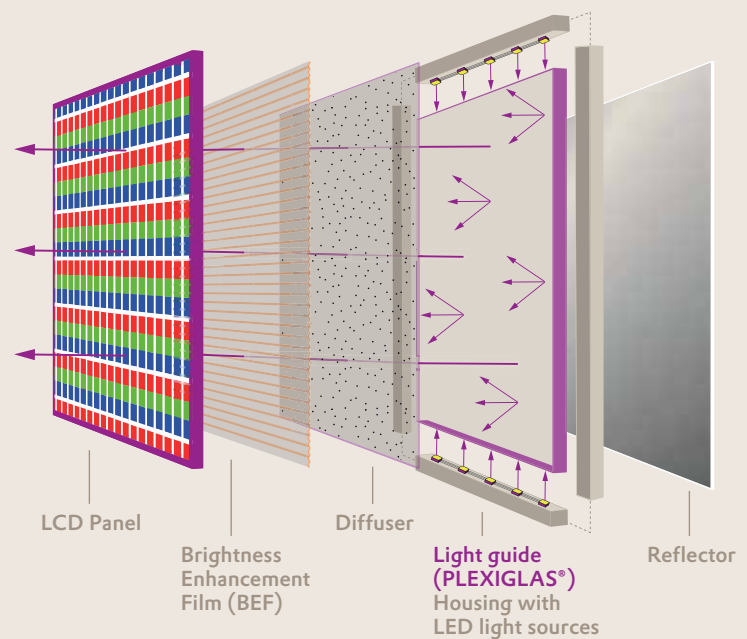
## Backlight Unit

### Light guide material

Light guide plates are made from PLEXIGLAS® POQ66. They are only four millimeters thick and are suitable for displays sized 32 to 55 inches.

### Current developments

In the future, Evonik will work with laser structures that replace the printed dot pattern on the light guide plate. Light output can be calculated even more exactly by means of the clearly defined microstructures. So far, light has been reflected by white-colored dots that only diffuse the light.



# Symbiosis of wood and PLEXIGLAS®

Wooden flooring creates a pleasant ambience and is especially popular in outdoor areas. But these require a great deal of care. The union of PLEXIGLAS® and wood retains its effect on a durable basis.

Renewable raw materials combined with the properties of PLEXIGLAS® – that's what makes the new solution for Wood Plastic Composites, or WPC for short, so special. The extrusion experts at Reifenhäuser and the material specialists at Evonik joined forces to develop a new process that conserves resources, saves energy and creates a product of lasting high quality.

"The one company has what the other needs." This is how Thomas Eisemann, Sales Manager Extrusion Center at Reifenhäuser, sums up cooperation with Evonik. "We have the technological and process expertise for producing WPC. Colleagues at Evonik contribute the raw material and formulation know-how. That is precisely the symbiosis each of us was looking for and that is needed to develop a new material." The aim of the partnership was to develop a production process that suits the material, in order to produce environmentally friendly, UV- and weather-resistant WPC. "In cooperation with Reifenhäuser, we are pursuing our strategy of developing solutions for the market together with partners from industry," explains Michael Träxler, Senior Vice President of the Acrylic Polymers Business Line at Evonik.

## Stability for domestic wood varieties

WPCs are mainly used for patio floors, where they are exposed to sun, heat, rain and cold all year round, which means permanent stress for the material. "Whereas tropical timber is often used for classical panel flooring on patios, WPCs use domestic wood varieties that would be too soft and not durable enough on their own," explains Carlo Schütz, head of the architecture team at Acrylic Polymers. "By combining them with plastics, we can give them the required stability and durability." This will soon also be possible with PLEXIGLAS®, whose specific properties ensure a long service life.

"The PMMA-based WPC panels that come out of our machines are meant to retain their surface properties after ten years of service, even when exposed to high levels of UV light, which was a problem in the past," Eisemann explains. The results of initial tests are promising. Other characteristics of WPCs were further developed. "Meanwhile, our end product shows the same mechanical properties as wood, and is much more rigid than other, conventional WPCs," Schütz explains. "We

have also got the hygroscopic properties under control, and the material is moisture-resistant in all geometric dimensions. This makes it ideal for technical WPC profiles."

## Good combination

To unite a natural material like wood with a plastic like PMMA, two crucial parameters have to be borne in mind. The natural fiber must not be damaged during heating, but the plastic must be melted. "The melting point of PLEXIGLAS® is higher than that of the polyolefins we use previously," Eisemann explains. "So we developed a patented direct extrusion process that is gentle on the natural fiber yet still capable of melting the PLEXIGLAS®." The special feature is that the melting and mixing processes are performed separately. That means the natural fiber is only added once the PLEXIGLAS® molding compound has melted. "Since PMMA acts more abrasively than polyolefin during extrusion, we also developed screws, cylinders and dies that are customized for the material from a special metal alloy," says Eisemann, describing the special features of the new unit.

While the engineers at Reifenhäuser were perfecting the process, the specialists at Evonik were modifying the PLEXIGLAS® molding compound. Its molecular structure was altered so that the polymer building blocks can unite better with wood fibers. "This precisely adjusted combination of machine, process and specialty polymer made the union of these materials possible in the first place and ensured that the good properties of PLEXIGLAS® could be

What looks like varnished wood is much more weather-resistant: PLEXIGLAS® Wood combines wood with PMMA.





The edge of a pool with wooden flooring looks natural. But the material requires lavish care due to its exposure to sun, rain and pollutants.


transferred to the WPC product," Schütz explains. "This gave rise to high-performance PLEXIGLAS® Wood, which is a global novelty."

### Energy-saving production

The long service life of the new WPC combined with the predominant share of natural fibers help to protect the environment. Added to this is the new production process. The patented Reifenhäuser direct extrusion process is the only one that provides a successful union between PMMA and wood, without the wood fibers burning at the high melt temperature of PMMA. Yet the process consumes less energy than the widespread two-step extrusion process. "In our process, the material is only heated once," Eisemann tells us. "That saves about 0.5 kilowatt-hours of electricity per kilogram." Profitability was significantly increased as compared with the conventional direct extrusion process because the dwell time of the wood/plastic

blend in the extruder could be reduced by separating the melt process. That leads to higher output per unit of time. For companies that would like to use this adjusted combination of machinery and material for their future production, there is the added benefit that initial investments are lower than for the conventional two-step process. That clears the way for resource-conserving, energy-saving and profitable production.

The Evonik Acrylic Polymers Business Line will launch the world's first WPC patio panel based on PMMA/PLEXIGLAS® Wood in mid-2011. - ck



## Light weight and crystal-clear: PLEXIGLAS® for automotive glazing

Monolithic or multilayer systems based on PLEXIGLAS® for automotive glazing provide:

- Less fuel consumption and reduced CO<sub>2</sub> emission due to 40–50% weight reduction compared to glass
- Improved driving dynamics
- Good options for function integration

Approval in accordance to ECE R43 for side, backlight and roof screens

Further information:

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[www.evonik.com/automotive](http://www.evonik.com/automotive)