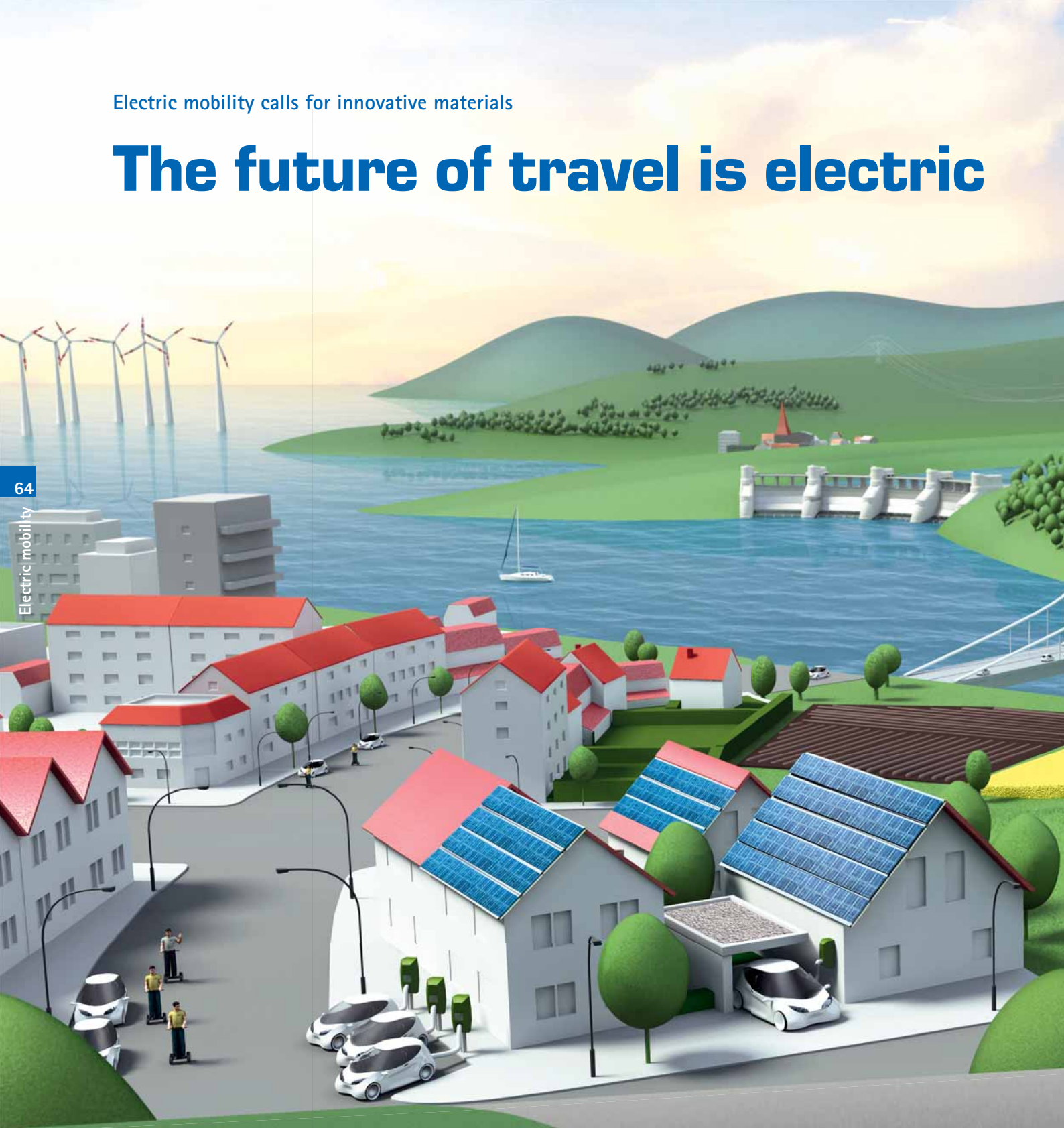
Electric mobility calls for innovative materials

The future of travel is electric



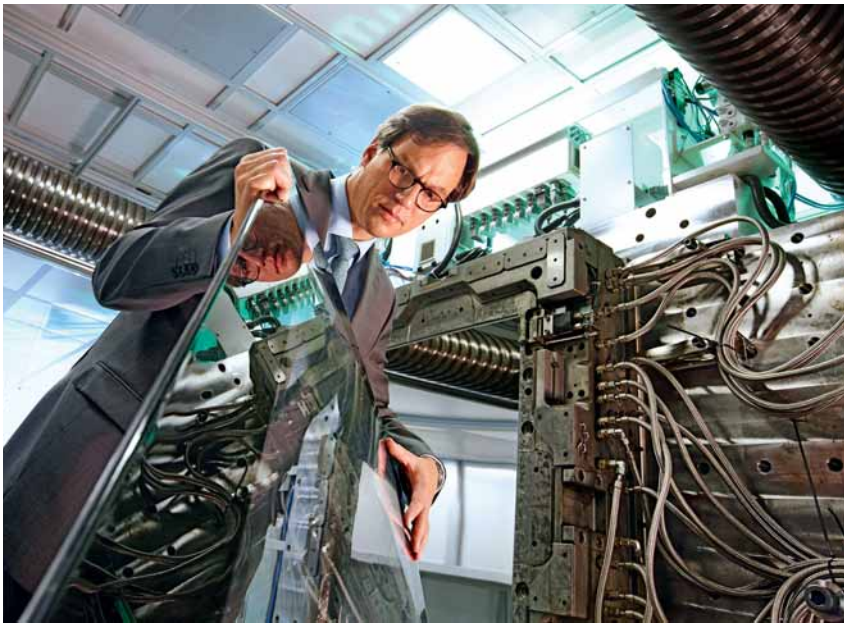
Over the next decade, cars will undergo a greater transformation than in the last hundred years, with their drive systems, design and materials changing fundamentally. The push toward electric mobility presents carmakers with completely new challenges. Vehicles don't just have to be lighter – high-tech batteries also make the car a true electrical appliance. Meeting these challenges calls for innovative materials and comprehensive solutions as offered by the global team of automotive experts from Bayer MaterialScience. These range from electric charging stations and materials for batteries and bodywork parts to special raw materials for adhesives and coatings. Innovative Bayer materials are also enabling further expansion of renewable energy sources, such as electricity generated by wind and solar power.

Animated graphic on the web:
bayer.de/r011

Sunroofs – *Bayer researchers are using innovative photovoltaic modules and solar air collectors that also serve as roof coverings to enable solar energy to be used for powering private electric cars (see also page 40).*

Electricity creates mobility – roads are becoming quieter, and in the future cars will drive without producing any exhaust gases. In many large cities, small numbers of electric vehicles are already buzzing through the heavy traffic of gasoline and diesel cars. But climate protection and shrinking oil reserves are now pushing carmakers throughout the world to put electric mobility in the fast lane. First and foremost, the new drives reduce reliance on oil. And charged with energy from wind, solar or hydroelectric power, electric cars substantially reduce CO_2 emissions. Some carmakers are now already manufacturing electric cars in series production, though still in small volumes.

As promising as this development is, numerous problems need to be solved before these quiet, eco-friendly vehicles can become widely established. "It's not enough to simply replace the combustion engine and fuel tank with an electric motor and battery," says Herbert Radunz, Head of Industrial Marketing Automotive at Bayer MaterialScience. "People also want to cover longer distances easily without constantly stopping to recharge. If electric cars can manage that, they can also gain a foothold in the mass market." Based in Leverkusen, Radunz coordinates the Group's global focus in the automotive industry and thus also the development activities for electric mobility. The company operates competence centers for the automotive industry in all three regions (America, Europe and Asia). Bayer researchers are harnessing their material know-how to develop new materials for lighter vehicles and more powerful batteries, among other things. "Current trends such as lightweight construction are being expanded further by electric mobility," says Dr. Joachim Simon, Head of Automotive and Transport at Bayer MaterialScience's Polycarbonates Business Unit in Leverkusen. In his view, cars will become genuine electrical products in the future. This will result in a completely new set of requirements.



The team of lightweight construction experts at Bayer MaterialScience headed by Dr. Joachim Simon plans to make new vehicle concepts possible with exterior components and roof elements made of Bayer materials.

High battery weight offset by lightweight body

"Although electric drives are highly efficient, the storage capacity of today's batteries is still far from adequate, and they are also extremely heavy," says Radunz. For a range of 150 kilometers, an electric car needs batteries that can weigh several hundred kilograms. By way of comparison, an average vehicle with a gasoline combustion engine only needs to carry approximately five kilograms of fuel for the same distance, because a 90-kilogram battery has roughly as much energy as a liter of fuel. Electric cars therefore need to be "slimmed down." The heavier they are, the faster the battery discharges, thereby reducing the range. "A lightweight body can offset the weight of the battery. And if the vehicle as a whole weighs less, the battery can also be smaller, as less mass needs to be transported," says Radunz. The "diet" therefore pays off in several ways, including financially. This is because batteries are currently still the most expensive element of electric mobility. "Lower costs for batteries will play a key role in making vehicles affordable and therefore establishing electric mobility on a broad scale," says Holly Lei, Simon's colleague in Shanghai.

Up to now, most vehicles still largely consist of heavy steel. Bayer researchers are therefore making cars lighter with plastics such as polycarbonate and polyurethane (PU). "Polyurethane weighs much less than steel and around half as much as aluminum. Yet polyurethane bodywork parts offer optimal protection to the vehicle occupants in a crash," says Jörg Palmersheim, an expert in polyurethane applications in automobiles at Bayer MaterialScience. Bumpers, fenders and door sills have been made from polyurethane in the past. "We're working on producing entire car roofs from this material – making

Checking out the results – at Bayer MaterialScience's Polymer Innovation Center in Shanghai, development engineer Yilan Li checks freshly molded headlight inserts made from lightweight plastics.

them lightweight but nevertheless strong and safe," he says. Plastics are particularly robust when reinforced with carbon fibers, for example. With carbon fiber-reinforced plastic, or CFRP for short, carmakers can achieve weight reductions of up to 80 percent over steel. The material is already tried-and-tested in Formula 1. The safety cell of race cars – the monocoque – consists entirely of CFRP, for example, and has already saved many drivers' lives in crashes.

Innovative material concept – aluminum with nanotechnology

In the future, a car's occupant cell could also be made of CFRP. "But this doesn't just help electric cars – innovative lightweight construction concepts also reduce fuel consumption and emissions for vehicles equipped with combustion engines, thus playing a key role in climate protection," says Bruce Benda, Vice-President, Automotive Key Account Management at Bayer in Pittsburgh, United States.

The new materials are also changing production processes, as more plastic in exterior automotive components is leading to increasing use of new bonding technologies, too: "In the future, bonding will be used even more than welding or riveting," says Dr. Lothar Kahl, responsible for coating/adhesive activities in the automotive sector at Bayer MaterialScience. Bayer development engineers are therefore working on eco-friendly, high-performance, polyurethane-based adhesives for plastic components. Polyurethane, too, will play an even greater role in coating car bodies in the future, and this will help cut energy consumption in vehicle production. "Most of the energy used in automobile manufacturing goes on the coatings because they cure at temperatures of up to 200 degrees Celsius," says Kahl. However, plastics are processed at much lower temperatures. With polyurethane-based coating systems, Bayer's materials experts can achieve the required quality at just 80 degrees Celsius.

In addition, plastics do not need a layer of anti-rust protection. The number of paint coats can therefore be reduced, markedly decreasing CO_2 emissions in automobile production.

Yet, in slimming down the cars of the future, Bayer researchers are not just using plastics:

Electricity from wind – *Bayer polyurethanes ensure the rotor blades of innovative wind turbines are exceptionally strong and also enable a unique aerodynamic design (see also page 7).*

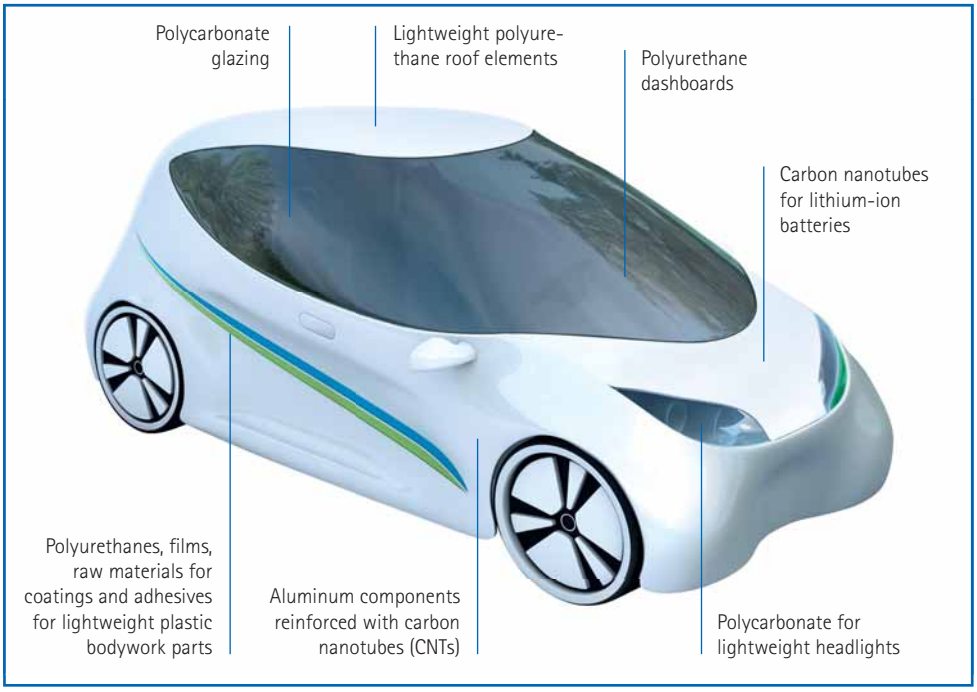
Photos: Peter Ginter (6)/Bayer AG, SAIC (1)

Quality control – if the aim is to make cars lighter by using plastics, innovative approaches to coating are required. Laboratory engineers Michael Chen (left) and Daogui Li (right) assess a freshly coated fender at Bayer MaterialScience's Shanghai research center.

"Although composite materials such as CFRP are promising, they're still very expensive in production. Aluminum also has great potential as a material for lightweight construction in specific applications," says Dr. Daniel Rudhardt from the Carbon Nanotubes group at Bayer MaterialScience. This is because the strength of aluminum could still be increased to an exceptional degree by pulling something out of the nanotechnology box of tricks. Bayer researchers are looking to further optimize the properties of the metal with carbon nanotubes, or CNTs for short. Baytubes™ – carbon atoms linked together like a honeycomb – are about ten thousand times thinner than a human hair and yet are exceptionally strong. And with this property, CNTs can also enhance other materials: "We're working to strengthen aluminum with our Baytubes so that it becomes as hard as steel," says Rudhardt. "If this is successful, it will revolutionize automotive technology."

Baytubes™ boost lifespan of lithium-ion batteries

And nanotubes can do even more – they also extend the lifespan of lithium-ion batteries for electric cars, as they conduct electricity extremely effectively. While driving – i.e. when the battery releases electricity – lithium ions move from one electrode to another. When the vehicle is idle, the charged particles are stored in a graphite electrode. However, over time, small cracks appear there that break the electrical contact and, as a result, the battery's storage capacity decreases. This is something that Bayer researchers aim to prevent by using CNTs. "Thanks to their elongated form, carbon nanotubes wrap around the graphite electrode like



High-tech materials for electric cars – Bayer MaterialScience material specialists offer numerous innovative approaches to future electric mobility, ranging from batteries, raw materials for coatings and adhesives to bodywork parts.

spaghetti and ensure a reliable flow of current, even if there is a small amount of damage," says Rudhardt. And the benefits don't end there – CNTs can accommodate more lithium ions than graphite because they offer a larger surface area thanks to their three-dimensional, tubular shape. Bayer experts are therefore replacing a portion of the graphite with nanotubes, thus enabling the battery to store more energy while weighing the same.

Batteries also have to meet extremely strict safety requirements. "Although the chemistry is the same as in a laptop lithium-ion battery, the dimensions are not comparable," says flame retardance expert Dr. Claus Rüdiger. A computer stores less than 100 watt hours, whereas an electric car battery stores several thousand. "Even the small storage devices in a notebook can explode if damaged and set fire to the whole appliance. This must not happen in a car, even in the event of an accident," he says. He and his colleague Roger Lian in Shanghai head up the international Bayer team that is therefore also developing special plastics for the outer casings of new high-performance storage devices. The main requirements are for them to be strong and flame-retardant.

Optimal thermal management for the electric cars of the future

Designed to deliver peak performance and ensure safety, the battery doesn't provide energy for just the vehicle's drive system, but also for the air conditioning, for instance. Some questions remain unanswered when comparing electric cars to gasoline-powered vehicles: "The combustion engine offers one key advantage despite its low efficiency. In reality, it's a rolling heating system, and the abundant heat generated by the engine can easily heat the interior. An electric motor, in contrast, emits hardly any usable heat," says Volkhard Krause, Head of the Automotive Glazing team.

Automotive engineers therefore need to develop new ideas to ensure heating and air-conditioning systems do not consume too much of the useful battery current. One potential solution is for the vehicle interior to be heated to a comfortable temperature while the car is still at the charging station. Improved insulation would then ensure a stable environment during travel. However, "the glazing is the weak spot – a car's interior quickly heats up through the glass in the summer and loses heat through it in the winter," says Krause. The trend toward large panoramic roofs could therefore lead to an energy problem in electric cars. But Bayer materials experts have also developed an alternative solution for this. They are replacing the glass in roof modules with the transparent Bayer polycarbonate Makrolon™, which offers significantly better heat insulation. Using polycarbonate glazing also cuts weight substantially, and not just in the roof area. Specialists from the Bayer MaterialScience glazing team have already developed a prototype for a complete rear hatch with a plastic/metal composite, using polycarbonate for the hatch glazing, among other things. Tail and brake lights, turn signals and high-mount brake lights are located behind the outer shell, which is made completely of Makrolon™. Overall, this innovative design weighs up to 40 percent less than the conventional version with metal and glass, and also helps ensure electric cars do not need to be charged up so often from the outlet.

And as each vehicle is far from having its own garage to park in, electric mobility in the future also needs a public infrastructure, such as electric charging stations. The charging posts of these are still largely made of metal, but the polycarbonate Makrolon™ offers a number of advantages here: firstly, it enables disruption-free wireless communication between the driver and the charging station via RFID and cellphone NFC (radio frequency identification and near field communication) systems. Secondly, compared with metal it permits great design free-

Solar aircraft – *the ultra-light "Solar Impulse" aircraft is set to fly all around the world powered only by solar energy. Products such as special carbon nanotubes from Bayer – Baytubes™ – help cut the aircraft's weight and ensure greater stability.*

In the fast lane – Hans-Peter Neuwald, automotive expert at Bayer MaterialScience, coordinates an international team of researchers and developers. They are working together on innovative solutions for batteries, adhesives, coatings and bodywork parts to ensure electric cars will also be able to cover longer distances in the future without stopping to recharge.

Interview: Dr. Xu Kangcong

"The market needs to be patient and wait for progress to become apparent."

Dr. Xu Kangcong is Chief Engineer for electric vehicles at Chinese automotive manufacturer SAIC Motor Passenger Vehicle Co. research *spoke to him about electric mobility.*

Automotive expert – Dr. Xu Kangcong has produced over 18 nationally patented inventions and drafted several national standards.

What are currently the biggest obstacles to establishing electric mobility on a widespread basis?

The core technologies for electric cars, such as batteries and battery management systems, are available. However, the cost of constructing an electric vehicle is relatively high due to the enormous initial investments. Another factor is the long lead time for electric cars – nowadays, it takes three to four years to develop a completely new model and if you move away from the traditional design, it takes even longer. The market therefore needs to wait a while for progress to become apparent.

What possibilities do you see for extending the electric car's range?

The distance an electric car can drive depends on the battery's energy density. Next-generation batteries with an energy density twice as high as existing electric car batteries are currently being developed in the automotive industry. This means doubling the range and halving the costs.

Do you see solutions for cutting battery charging time?

Charging takes several hours under current technical conditions. Even fast charging, where a battery is charged to 50 percent, still takes twenty minutes. Car owners can charge their cars at work, in designated parking spaces or at home, for example. Numerous charging stations and facilities will be made available in public areas.

When do you believe the electric car will achieve its breakthrough?

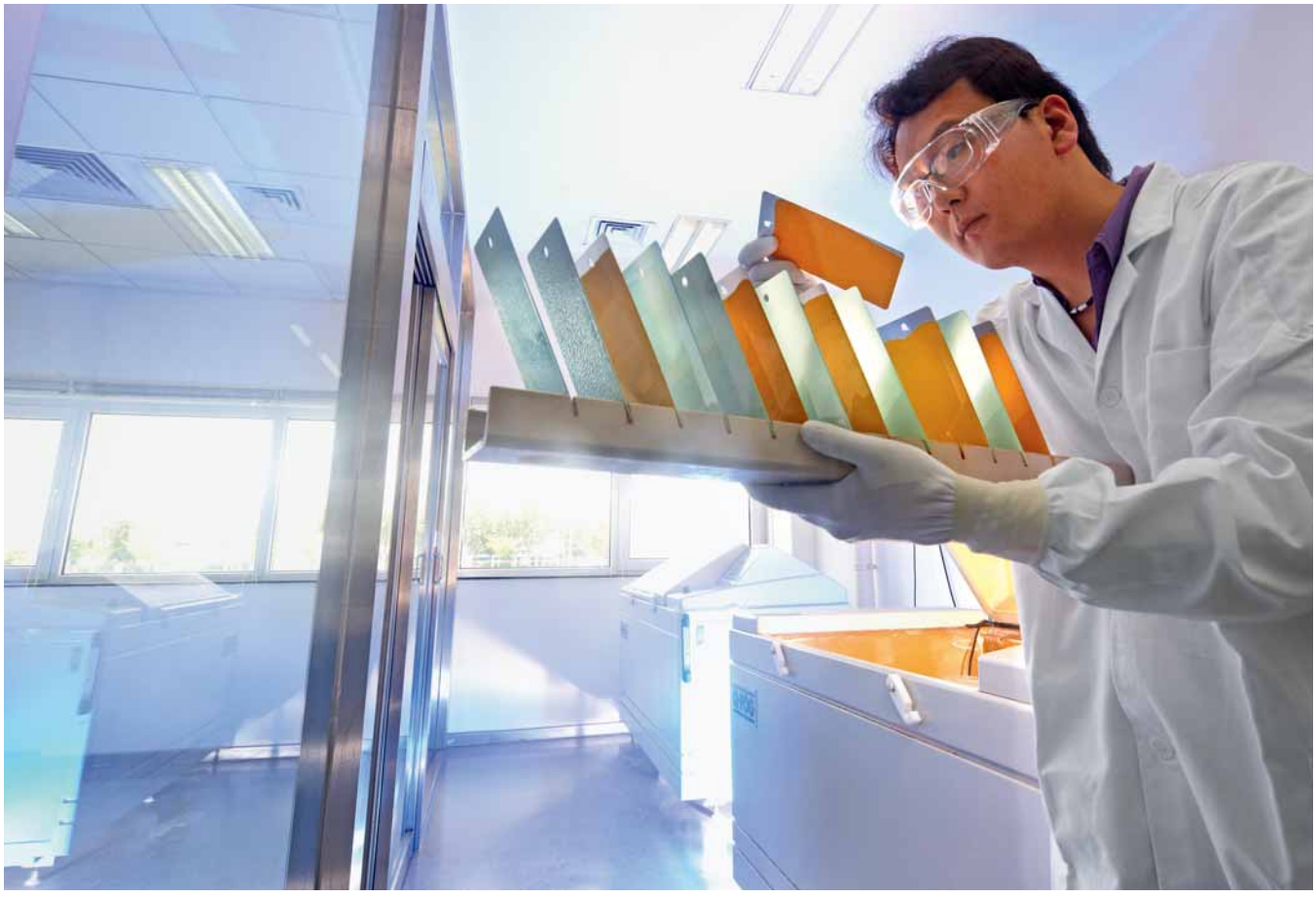
The market for electric cars will grow slowly with the development of a dynamic battery. Electric cars are regarded as commuter vehicles at the current stage of development. They aren't suitable for long distances and won't replace cars with combustion engines so quickly. Conventional, hybrid and electric cars will coexist for a long time yet.

How will mobility change in the future?

Electricity is an excellent energy source – perhaps the optimal energy source for cars. Electric cars in China are currently running on lithium batteries whose energy is largely generated at coal-fired or hydroelectric power plants. Other technologies for producing and storing electricity, such as hydrogen and nuclear power, are still in development.

Electric mobility in China – large numbers of Chinese are already using electric vehicles, but these are still mainly two-wheelers, such as scooters and e-bikes. Nonetheless, experts also expect to see an e-mobility boom in the automotive sector.

This interview represents the personal opinions of Dr. Xu Kangcong and does not reflect the position of SAIC Motor Corp. Ltd.



Coatings under climatic stress – new materials for coating plastics need to withstand extreme temperatures and weathering. That's why laboratory engineer Wen Xu tests material samples in the climatic chamber at Bayer MaterialScience's Polymer Innovation Center in Shanghai under the toughest conditions.

dom, so it can be used not only to build the casing but also the transparent display, which will make a flexible, modular structure for charging stations possible. One side of the station could then be used to charge the batteries of an electric car while on the other side an e-bike is charging. In fact, charging stations made of Makrolon™ can already be seen in the Netherlands, where e-bikes are in widespread use, as well as elsewhere in the world.

Filling up with electricity at Makrolon™ charging stations

"Charging stations made of Makrolon are extremely robust," says Dr. Thorsten Niklas, a polycarbonate expert at Bayer MaterialScience. "Makrolon is not only resistant to subzero temperatures, wind and rain, it also offers protection against vandalism." Materials from Bayer MaterialScience are therefore found in all aspects of electric mobility – from vehicles and batteries to charging stations. Radunz sums up the objectives of Bayer MaterialScience in the following way: "With our innovative system solutions and services, our aim is to continue to be the partner and supplier of choice for the automotive industry in the future – for the entire value-added chain, from parts and systems suppliers to the automotive manufacturer." After all, the design of electric cars still barely differs from today's conventional vehicles with combustion engines. Electric vehicles largely continue to be developed and produced in the traditional way. "However, we expect to see fundamental changes in material usage and production processes in the long term as a result of completely new vehicle concepts," says Radunz. The global E-mobility team at Bayer MaterialScience is already working on this.

www.research.bayer.com/e-mobility
Further information on electric mobility

Harnessing electricity – *the Bayer plastic Makrolon™ is ideal for robust, cost-effective charging stations. It doesn't just withstand subzero temperatures and rain – it also offers protection against vandalism.*