WACKER WORLD WIDE MAGAZINE

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WACKER

DRIVING ELECTRICITY INTO THE FUTURE

Silicones for Electromobility

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SILICONES FOR A NEW ERA

Dear Reader,

Silicone rubber compounds probably have the broadest application range of all elastomers. They can withstand high temperatures, and boast outstanding resistance to oil and media as well as exceptional sealing and damping properties – even when subjected to high levels of dynamic or constant stress. What is more, their properties can be adjusted to match highly specific applications. This exceptional property profile makes silicone elastomers ideal for the rigorous demands of the automotive industry. Today, every automobile contains several kilograms of silicone.

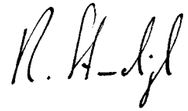
Many areas in which silicones are used – such as for vibration dampers, sealing mats and airbag coatings – will remain unchanged as the automotive industry gradually shifts to electric drives. Others – like hoses for turbochargers – will no longer be needed in electrically powered vehicles.

But e-mobility will also open up new application areas for the automotive sector and its chemical-industry partners. One of the challenges facing both engineers and chemists, for example, is how to dissipate the heat generated by electric drives, batteries and their power electronics. The lithium-ion batteries in use today deliver top performance only at temperatures between 20 and 35 °C, which means they need to be kept in that range. WACKER has developed innovative heat-conducting gap fillers made of silicone to connect the battery modules to the temperature-control system. These silicones are truly high-performance plastics, and we tailor them to the specific needs of our customers.

We are already developing other, highly specific materials of this kind – in preparation for the large-scale production of electric vehicles. With our made-to-measure product portfolio, we aim to support our partners in the automotive industry as they enter the era of e-mobility.

You can read more about this topic in the 20-page article in the center of this edition of our corporate magazine.

I hope you enjoy reading this issue.



Dr. Rudolf Staudigl
President and CEO of Wacker Chemie AG

Dr. Rudolf Staudigl
President and CEO of Wacker Chemie AG

"This exceptional property profile makes silicone elastomers ideal for the rigorous demands of the automotive industry."

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ELECTROMOBILITY

CUSTOMIZED SILICONE PRODUCTS FOR A NEW ERA

Electromobility is gathering momentum – and WACKER is supporting Germany's automakers with just the right products: its silicone-based gap fillers and heat-dissipating adhesives ensure effective heat management in electric motors, batteries and power electronics. Encapsulants protect inductive charging systems and sensors for driver assistance.

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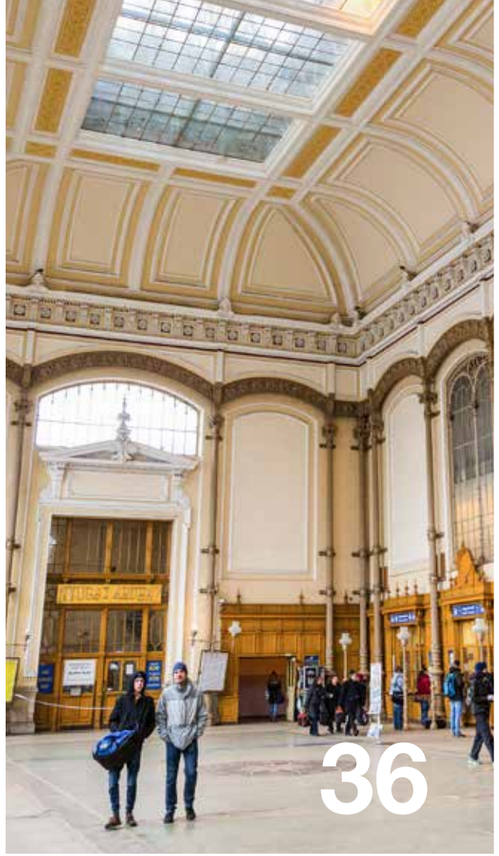

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WACKERWORLDWIDE

WACKER has production sites, application technology centers, subsidiaries and sales offices on every continent. Here is a selection of news and interesting topics from the Group's four business divisions.

1 ADRIAN

At the beginning of 2018, WACKER's US site in Adrian, Michigan, passed a comprehensive social responsibility audit successfully. Proceeding according to the SMETA (Sedex Members' Ethical Trade Audit) process, the auditors investigated issues such as working conditions, occupational health and safety, environmental management and corporate ethics at Wacker Chemical Corporation. The company's environmental guidelines and programs and its site neighborhood programs earned special praise. WACKER has made the results of the audit available to interested customers in the Sedex database. Sedex (the Supplier Ethical Data Exchange) is an online platform disclosing a company's social and ethics-related processes throughout the supply chain.

2 MUNICH

79 young people from across Bavaria presented their scientific and technical projects to a specialist jury and the public at the Bavarian "Young Scientists" competition in March. Topics ranged from analytical methods to prevent the spread of bark beetles through to the search for heavy neutrinos in kaon decays. At a ceremony in Munich's Old Congress Hall, the eleven best projects were announced by Auguste Willems of WACKER's Executive Board, Prof. Wolfgang Heckl, the Deutsches Museum's director general, and Delia Tietge of the "Young Scientists" foundation. The 14 winning young scientists will represent Bavaria at the national competition in Darmstadt in May. WACKER has supported Young Scientists for many years and organizes the Bavarian competition every two years.

3 BENBEN

It was in Cairo that American scientist Frank Shumann developed one of the world's first solar systems in 1913. That's hardly surprising, as Cairo's location in the earth's sun belt is ideal for solar technology. The government of Egypt is planning to generate at least 20 percent of its electricity with solar power by 2022. By 2035, the proportion of energy generated from renewable sources is expected to be as high as 37 percent. The largest photovoltaic system in the world is currently under construction in Benben, north of Aswan. It aims to produce up to 1,650 megawatts of energy from 2019. WACKER is among the world's largest manufacturers of solar-grade polysilicon.

4 LUDHIANA

At the end of 2017, Wacker Metroark Chemicals (WMC), in partnership with its textile distributor H&K Chemicals and Dr. Lal pathology labs, set up a health camp in the north Indian city of Ludhiana for needy locals. The area, which is in the state of Punjab, is predominantly rural and 343 locals took advantage of the free checkups and eye tests on offer. Local doctors carried out blood tests, ECGs, sight tests and other medical services. The health camp in northern India is expected to take place at least once a year and there are plans to hold a similar camp in the south of the country.

5 GANSU

Renewable energy is rapidly gaining impetus in China. In 2009, construction work started on the largest land-based wind park in northern China at the edge of the Gobi desert. In 2010, the first section with a 5.16 gigawatt output went on stream. By 2020, output is set to increase to 20 gigawatts. The wind turbines will then deliver around 50,000 gigawatt hours of electricity per year. WACKER delivers future-oriented technical solutions for power and electrical engineering, including impact modifiers which extend the service life of the rotor blades on wind turbines.

GROUP UPDATE

NEW TECHNICAL CENTER STARTS UP IN ISTANBUL

WACKER opens new test labs for silicones and polymers in the construction, textile, household and cosmetics industries

At the end of last year, Wacker Chemie AG opened its new technical center for construction, textile, household and cosmetics applications in Istanbul. “The increasing volumes customers sell heighten their quality and service needs. Now we can offer even better local support at our new testing facility,” said WACKER Executive Board member Auguste Willems during the opening ceremony. The region’s construction industry in particular is experiencing an upturn, resulting in a growing need for advice.

In the future, silicones for textile, cosmetic and household applications will be tested at WACKER’s new technical center in Istanbul.

At the new center, polymer binders for tile adhesives and exterior insulation and finish systems (EIFS/ETICS) can be tested under different climate conditions. The center has modern lab equipment for in-depth analyses of viscosity, air-pore content, and the curing time of fresh mortar. Moreover, it can test the properties of hardened mortar according to various standards, such as EN 12004 or EN 13499. Testing includes determining adhesive, flexural and compressive strength in addition to water-vapor permeability and impact strength.

The new facility also has a laboratory for silicones used in the textile industry. The lab can extensively analyze customers’ products and formulations to determine their thermal and shear stability, foaming tendency, gloss and color stability, and water repellency or hydrophilicity. It can apply and test different formulations under realistic conditions, such as during padding or exhausting. In addition, the equipment can be used to conduct specific trials for cosmetic and household applications in accordance with local needs.

WACKER AT TRADESHOWS

BATTERY SHOW
Hannover, Germany
May 15-17, 2018
www.thebatteryshow.eu

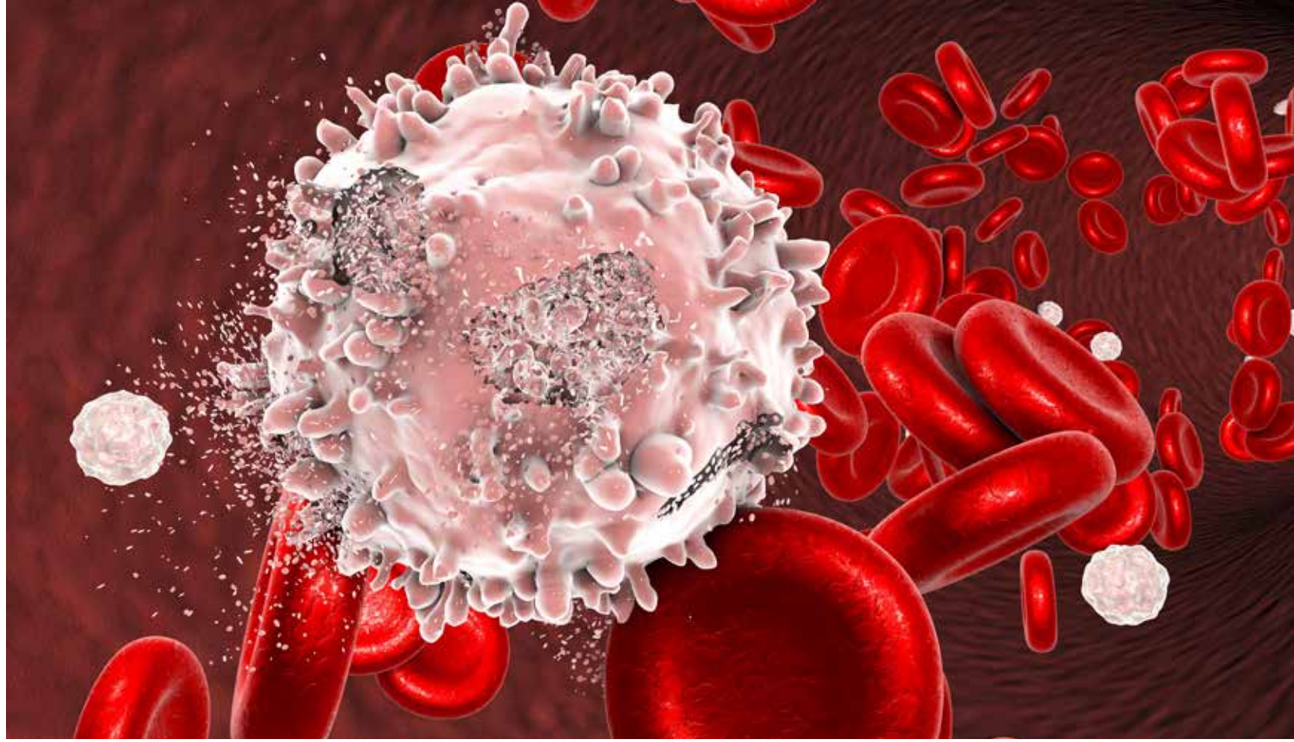
BIO USA
Boston, MA, USA
June 4-7, 2018
convention.bio.org/2018

Incosmetics Korea
Seoul, South Korea
June 13-15, 2018
korea.in-cosmetics.com

GERMAN RUBBER CONFERENCE
Nuremberg, Germany
July 2-5, 2018
www.dkt2018.com

CPhI
Madrid, Spain
October 9-11, 2018
www.cphi.com/europe

FAKUMA
Friedrichshafen, Germany
October 16-20, 2018
www.fakuma-messe.de



Cancer cells in blood: biopharmaceutical medication for treating acute lymphocytic leukemia is one of the products made by Wacker Biotech.

WACKER BUYS BIOTECH PLANT IN THE NETHERLANDS

Acquisition strengthens pharmaceutical protein production

Wacker Chemie AG has acquired a Dutch site for manufacturing biopharmaceuticals, live microbial products and vaccines, plus the associated business, from SynCo Bio Partners Luxembourg S.à r.l. For WACKER, maintaining SynCo’s existing customer relationships is a top priority. Similarly, WACKER is keeping on SynCo’s employees.

“This strategic acquisition is a key step for our ongoing expansion in the high-growth biopharmaceuticals market,” explained Auguste Willems of WACKER’s Executive Board. “The new plant will enable us to satisfy robust market demand today and in the coming years – and strengthen our position as a leading contract manufacturer of microbial-derived biopharmaceutical proteins.”

Founded in 2000, SynCo Bio Partners has some 110 employees and operates two fermentation lines with current capacities of 1,500 and 270 liters. These lines manufacture microbial-derived biopharmaceuticals, not only for clinical testing, but also for the commercial market.

There is a further line of single-use fermenters, which provides additional and flexible production opportunities. SynCo’s service offering is rounded out with a sterile “fill and finish” facility, which enables the complete manufacture of pharmaceuticals from the active agent to the filled product. The facilities meet “Good Manufacturing Practice” (GMP) quality standards, and have been approved by the European Medicines Agency (EMA) and the US Food and Drug Administration (FDA) for the manufacture of specific pharmaceutical proteins.

“Expanding our production capacity strengthens our long-term market position,” said Gerhard Schmid, president of WACKER BIOSOLUTIONS. “The additional fermentation lines double our current capacity, which increases our ability to produce key pharmaceuticals cost effectively, using advanced microbial techniques. We look forward to continuing the comprehensive support for SynCo’s existing customers, while also offering them the proprietary technologies of Wacker Biotech.

SynCo’s expertise in manufacturing live microbial biopharmaceuticals is a valuable complement to WACKER’s know-how as a full-service supplier. Live microbial products represent a promising new class of actives, offering innovative therapies for serious illnesses and new vaccines against diseases such as cholera.

CENTRAL WAREHOUSE IN SOUTHERN CHINA SHORTENS LEAD TIMES

WACKER opens 10,000-square-meter warehouse in Guangdong province

WACKER Greater China's (WGC) South China Hub has officially come on stream in Foshan, Guangdong province, 22 kilometers from the capital city Guangzhou. By transferring the inventory from external warehouses near production sites to a hub close to customers, WACKER Greater China aims to create competitive advantages in southeast China. Featuring over 10,000 square meters and up to 10,000 storage bays, the new hub is an expandable warehouse equipped with a high platform and rack system.

40 percent of WGC's sales volume is generated in Guangdong province, especially in Guangzhou and surrounding cities such as Shunde, Foshan and Shenzhen. "By transferring the inventory to a hub close to customers, we will expedite order-response lead time to further improve customer satisfaction," said Paul Lindblad, president of WACKER Greater China in his speech at the opening ceremony.

Silicones and polymers produced at the Zhangjiagang and Nanjing sites will be shipped directly to this hub, where customers can either collect the product themselves or have it delivered by WACKER. This reduces the distances between the product and customers in southeast China from 1,700 km to 300 km, while order-response lead time could be reduced from a maximum of 19 days to a minimum of 1 day. An SAP terminal with general logistics functions will also be installed for efficient order processing, as well as for tracking inventory and delivery status accurately in the system.

WACKER's new central warehouse in Guangdong province. The Group generates 40 percent of its output in China in this province.

NEW PLANT FOR FUNCTIONAL SILICONE FLUIDS OPENED IN INDIA

Wacker Metroark Chemicals expands production in Amtala

Wacker Metroark Chemicals Pvt. Ltd. has expanded its silicone production facilities at Amtala (in the Kolkata metropolitan area) with a new hydrosilylation plant for functional silicone fluids. Opened in mid-March, the new plant has an annual capacity of more than 6,000 metric tons. The expansion is WACKER's response to growing regional demand for specialty silicones used in textiles and personal care products, in rigid and flexible PU foams, and in agrochemical applications. Investment costs for the plant will total around €6 million.

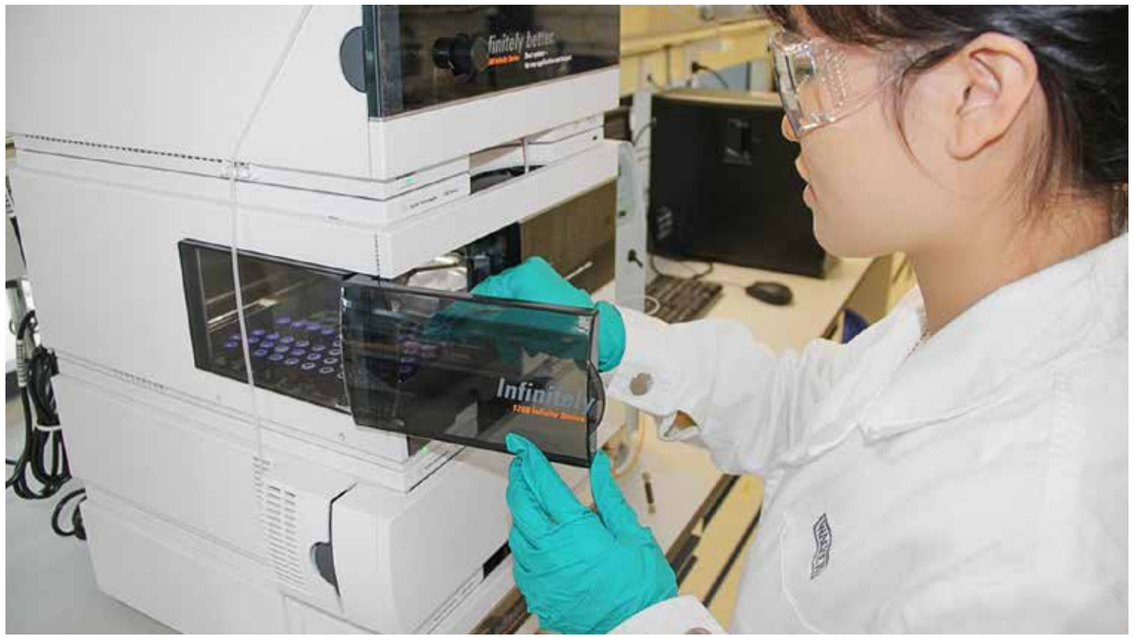
"Expanding these production facilities has broadened our product portfolio, opening up new markets to us in the growth regions of India and Southeast Asia," explained Dr. Christian Hartel, Wacker Chemie AG's Executive Board member responsible for Asia. "This investment underscores WACKER's commitment to Indian markets. It shows that our company is continuously growing its technical expertise and capacities in Asia."

Hydrosilylation is a chemical process in which organofunctional groups, such as glycols, olefins or ketones, are "docked" onto silicones. This is done in order to modify the properties of the end product and render a silicone fluid, for example, hydrophobic (water-repellent) or hydrophilic (water-attracting).

Silicone products resulting from hydrosilylation reduce the incompatibilities between oils and water, thereby improving compatibility with organic systems. One application field for Amtala's new products is polyurethane-based industrial foams, where functional silicone fluids serve as additives for adjusting the cell structure. Such foams are used in the interior trim of cars or in insulation materials. Silicone fluids and silicone fluid emulsions are also used in personal care products (such as shampoos), in fabric softeners and in agricultural applications.

"Our new hydrosilylation plant enables us to address promising new Indian and Southeast Asian markets, where we did not have presence, until now – for example the market for functional silicone fluids with its many sales opportunities," said Soumitra Mukherjee, managing director of Wacker Metroark Chemicals.

Wacker Metroark Chemicals' new hydrosilylation plant at its Amtala site near Kolkata.



The analytical laboratory at the Shanghai technical center. The R&D labs for silicones and the new applications lab for the food industry will be completed this year.

WACKER EXPANDS ITS PRODUCTION AND R&D CAPACITIES IN CHINA

Amid rising demand, the Group is investing €20 million in its Chinese sites

Wacker Chemie AG is expanding its silicone and polymer production capacities and its R&D operation in China to strengthen its market position there. A total investment of €20 million has been budgeted for these expansion projects.

Most of the funds are for technical measures to eliminate production bottlenecks and for capacity growth. One investment focus is the Zhangjiagang silicone site. Building a new production line there will increase the site's output of solid silicone rubber by several thousand metric tons. Another focus is the Nanjing polymer site, where process-engineering improvements for VAE dispersion production are planned. This will increase production capacity by as much as 30,000 metric tons annually. The announced expansion and debottlenecking measures are expected to be completed in the second half of 2018.

"The Greater China region is a key sales market. Accounting for over €1 billion or a quarter of Group sales, the region is WACKER's largest single market," said CEO Dr. Rudolf Staudigl. The demand for silicone and polymer products in China has been growing steadily for years. But with plant utilization already high, simply raising output was hardly feasible. "That's why we are now investing in expanding capacities at our Chinese sites in Zhangjiagang and Nanjing."

A further project is in Shanghai. Paul Lindblad, head of WACKER Greater China, announced the expansion of the company's R&D facilities there. By year-end 2018, Shanghai will have additional silicone labs for developing new products and applications in the coatings, construction and consumer goods sectors. This project also involves enlarging the lab for room-temperature-curing silicone elastomers. It will develop novel adhesives and sealants for the construction industry and industrial applications. An application lab addressing increasingly more sophisticated requirements in the food sector is also being set up. "By expanding our R&D facilities, we are significantly boosting our local innovation capabilities," emphasized Lindblad.

WACKER's winning team: Ina Weber, Irina Seiler and Thomas Eigner with Susanne Engl, head of Idea Management (from left).

At the technical center in Moscow, a lab assistant mixes a low-modulus sealant, based on silane-modified polyether, with a planetary mixer.

FIRST PRIZE AT IDEA MANAGEMENT CONGRESS

Jury-winning improvement suggestion

A team of three from WACKER won the first prize in the Production and Engineering category at this year's German congress of the ZI (Zentrum Ideenmanagement or Idea Management Center). It was held in Fulda at the end of February. Ina Weber (production) and Irina Seiler (lab employee) from Nünchritz, and Thomas Eigner (IT) from Burghausen convinced the jury with an idea that will cut analytical costs by a five-digit amount every year. Their suggestion will also help speed up the process of providing plants with lab results for determining the proportion of trifunctional units in siloxane, a parameter known as the T content. Their solution was to create an intelligent combination of parallel IT systems that weren't previously connected with each other.

"This suggestion is a great example of organizational, cross-site collaboration and of how to come up with ideas at WACKER," said Susanne Engl, head of Idea Management and the Employee Suggestion Program. "Our thanks go to everyone with creative ideas and to supervisors for motivating submitters and helping realize ideas. Their efforts have bolstered their departments' and the company's success."

IDEEN AWARD

Every year, the ZI presents awards to employees whose ideas have made a significant contribution toward the competitiveness and viability of the company they work for. ZI is an interest group that promotes and disseminates idea and innovation management in Germany. WACKER is one of 150 member companies.

WACKER EXPANDS ITS TECHNICAL CENTER IN MOSCOW

New lab for adhesives and sealants opens

WACKER has strengthened its presence in Russia and expanded the service portfolio of its technical center in Moscow. The Group has integrated a new specialist lab there for testing adhesives and sealants. Based on silane-modified polyethers (hybrid polymers), they are mainly used in the construction industry. Moreover, the center's existing labs for dry-mix mortars, paint, coatings and construction silicone applications have been certified as official test labs by Russia's national accreditation agency.

"The market for sealants and adhesives in Russia is full of potential. So, it's important that we support our customers as quickly as possible to meet local market needs," said Dr. Alexander Serov, managing director of WACKER Russia, at the opening ceremony.

WACKER's new facility offers the option of testing and developing sophisticated formulations made with local fillers and additives. Using a modern planetary mixer and an asymmetrical centrifuge mixer, adhesives and sealants with different viscosities and thixotropies can be produced. These products are characterized with the help of a rheometer. Additionally, the lab equipment can determine tensile strength, adhesion, shear strength and Shore hardness.

Russia's accreditation body certified the Moscow center's existing labs for dry-mix mortar, paint, coatings and construction silicones as official test labs in accordance with GOST ISO/MEK 17025. This means WACKER is authorized to issue a report on product test results that is officially recognized in Russia. Customers can then base applications for their products' quality certificates on these reports.

Professor Zhifeng Wang, the vice chair of SolarPACES' Executive Committee, presented the innovation award to WACKER's head of R&D, Dr. Fridolin Stary, Royal Tech CSP's strategy director Dou Huaixin, and WACKER project manager Erich Schaffer (from left).

SILICONE FLUID USED TO GENERATE SOLAR THERMAL ENERGY RECEIVES INNOVATION PRIZE

Technology network honors WACKER and its Chinese partner Royal Tech

WACKER and China's Royal Tech CSP Limited, which has specialized in developing and promoting highly efficient solar thermal power plants, were awarded an innovation prize by the SolarPACES technology network. Since 2016, both companies have been testing a newly developed and highly heat-resistant silicone fluid as a heat-conducting agent for parabolic trough collectors at a solar thermal power plant in Inner Mongolia (China).

Professor Zhifeng Wang, vice chair of SolarPACES' Executive Committee and head of Solar Thermal Energy and Photovoltaics at the Chinese Academy of Sciences in Beijing, presented the technology award at the 23rd SolarPACES Conference in Santiago, Chile.

Most of the heat-transfer media currently in use consist of aromatic hydrocarbon compounds. Because of their limited thermal load capacity, they cannot be used at temperatures exceeding 400 °C. Low temperatures, too, are a problem. Since such media solidify at outside temperatures below 12 °C, solar power stations often have to be equipped with trace heating.

By contrast, WACKER's new HELISOL® silicone fluid withstands operating temperatures of up to 425 °C and remains fluid at temperatures as low as -40 °C, thereby increasing efficiencies and energy yields. Silicones also release less hydrogen than conventional media. Experts therefore assume that the lifetime of the receiver in which the oil circulates will be far longer.

"WACKER and RoyalTech have succeeded in extending the physical limits of heat-transfer media in solar power plants in terms of high- and low-temperature resistance. Operators of large-scale systems can now boost the efficiency and reliability of their systems," said Professor Wang.

WACKER's research head Dr. Fridolin Stary and project manager Erich Schaffer accepted the award. "This silicone fluid sets new standards and makes solar thermal energy even more attractive for operators – both ecologically and economically," said Dr. Stary.

CSP (concentrated solar power) plants capture sunlight in parabolic trough collectors and use it to heat the heat-transfer medium flowing through a vacuum pipe.

SolarPACES

Solar Power and Chemical Energy Systems (SolarPACES) is a multinational research network in the field of concentrated solar power (CSP). Since its foundation in 1977, this platform has shaped research into new technologies and strategies for concentrated solar power. SolarPACES, as a technology collaboration program of the IEA (International Energy Agency), coordinates research by international solar thermal experts. The network currently comprises 19 member states.

The HELISOL® silicone fluid flowing through Royal Tech's solar thermal power pipes makes high efficiencies possible.

Piet van der Slikke (right), CEO of IMCD, accepted the award presented by Executive Board member Auguste Willems (left) at WACKER's headquarters.

WACKER HONORS DISTRIBUTOR IMCD

Distributor's sales of WACKER products top €100 million for the first time

Wacker Chemie AG has honored its longstanding distributor IMCD both for its performance in recent years and for posting WACKER-product sales of €100 million in 2017.

IMDC, a Dutch company that ranks among the top global distributors of specialty chemicals, reported total sales of some €1.9 billion in 2017. It employs more than 2,200 people in over 40 countries.

IMCD received the award for its highly successful and longstanding business relationship with WACKER and for continuously expanding this business. The cooperation has gone from strength to strength, incorporating additional countries and product groups over many years. As a result, last year saw IMCD attaining sales of €100 million with WACKER products for the first time.

WACKER and IMCD began doing business together in 1999 in Western Europe. IMDC's 15 subsidiaries sell WACKER products on all five continents. "IMDC is a prime example of how a good distributor relationship can develop into a strategic partnership that is highly profitable to both partners," said WACKER Executive Board member Auguste Willems.

SILICONE FLUID BASED ON BIOMETHANOL

TÜV certifies use of renewable materials at WACKER; carbon footprint improved by dispensing with fossil fuels

Silicone fluids are used in industries such as cosmetics and consumer goods.

Germany's TÜV SÜD technical inspectorate has certified WACKER's mass balance method for verifying the use of renewable raw materials in silicones manufacturing. The company thus has a recognized procedure for tracking renewable raw materials across its production process, right through to the end product. Given that WACKER included plant-based methanol as a production option this April, it can now offer silicone fluids that are exclusively biomethanol based. Silicones are chemically identical whether they are produced with biomethanol or with petrochemical methanol. But those based on biomethanol have a far better carbon footprint, since no fossil raw materials are used to manufacture the methanol.

The certificates issued in mid-March certify that the mass balance method used by WACKER to manufacture silicones meets the criteria of TÜV SÜD standard CMS 71 concerning the traceability of renewable raw materials. Moreover, several high- and low-viscosity silicone fluids were certified for use in the cosmetics and consumer goods industries. According to WACKER's calculations, around 1.6 metric tons of carbon dioxide can be saved per metric ton of silicone fluid.

"WACKER is the first silicone manufacturer to track the use of biomethanol across all production steps, through to the end product," stressed Executive Board member Auguste Willems. Customers who use our bio-based silicone fluids can increasingly offer sustainable products and significantly improve a product's carbon footprint."

BELSIL® eco silicone fluids: the suffix "eco" indicates that this WACKER product was made from only silicon and renewable raw materials.

FIRST ECO SILICONE FLUID FOR COSMETICS

BELSIL® eco is manufactured with certified biomethanol

BELSIL® eco is WACKER's first silicone fluid for cosmetic applications manufactured exclusively with silicon and renewable raw materials. WACKER is currently the only manufacturer in the world offering silicone products of this kind (see article on the left).

The new BELSIL® eco range currently comprises six silicone fluids. They are linear, unmodified polydimethylsiloxanes (dimethicones) with outstanding low surface tension and good spreading properties. These products cover a particularly crucial viscosity range in cosmetics between 5 and 60,000 centistokes (mm^2/s) and are therefore suitable for formulating moisturizing creams, lotions, sunscreens, shampoos, conditioners and other cosmetic preparations.

Every BELSIL® eco product has a silicone fluid counterpart produced with petrochemical-based methanol. Chemically speaking, both products have the same raw material base and the same properties. This means that conventional silicone fluids can easily be replaced with corresponding BELSIL® eco products. Technical modifications or formulation adjustments are not necessary.

"The demand for cosmetics produced with a view to preserving natural resources is rising steadily," stresses Dr. Robert Gnann, head of WACKER SILICONES. "With our new product line, we are excellently placed to meet this demand. For BELSIL® eco, we use certified biomethanol produced exclusively from plant waste such as straw or grass cuttings."

Since biomethanol is produced solely from renewable raw materials, the carbon footprint of BELSIL® eco products is far better than that of silicone fluids based on fossil raw materials. The process is certified in accordance with TÜV SÜD standard CMS 71 (see article on the left).

OUTSTANDING SUSTAINABILITY RECORD

The Group Scores Gold in EcoVadis Rating

To improve sustainability in the supply chain, the German chemical industry established the Together for Sustainability initiative in 2011. As a member of this initiative, WACKER not only evaluates its suppliers in terms of sustainability, but subjects its own performance to external rating via the EcoVadis platform.

In 2018, the Group was once again awarded an EcoVadis Gold recognition level. WACKER's rating rose from 65 to 72 points. It now ranks among the top 3 percent of highest-scoring companies.

Suppliers are assessed, on the one hand, on the EcoVadis platform when they fill out a questionnaire, which is then evaluated for them. On the other, they are audited by TfS-certified auditing companies.

The EcoVadis questionnaire is based on internationally recognized sustainability standards and the principles upheld by the Global Compact and by Responsible Care®. The evaluation covers 21 criteria. Adapted to the supplier's sector, they relate to the environment, work practices and human rights, fair business principles and sustainable supply-chain management.

EcoVadis specialists analyze the information provided by the suppliers, add their own research findings and summarize the results in a scorecard. In all categories, WACKER's performance was above average, led by its gains in the supply-chain-management rating. WACKER's score means it can offer its customers standardized and recognized certification of its own sustainability performance.

Silicone rubber before delivery: to ensure the sustainability of the supply chain, WACKER joined the Together for Sustainability initiative.

AN ACHIEVEMENT OF OLYMPIC PROPORTIONS

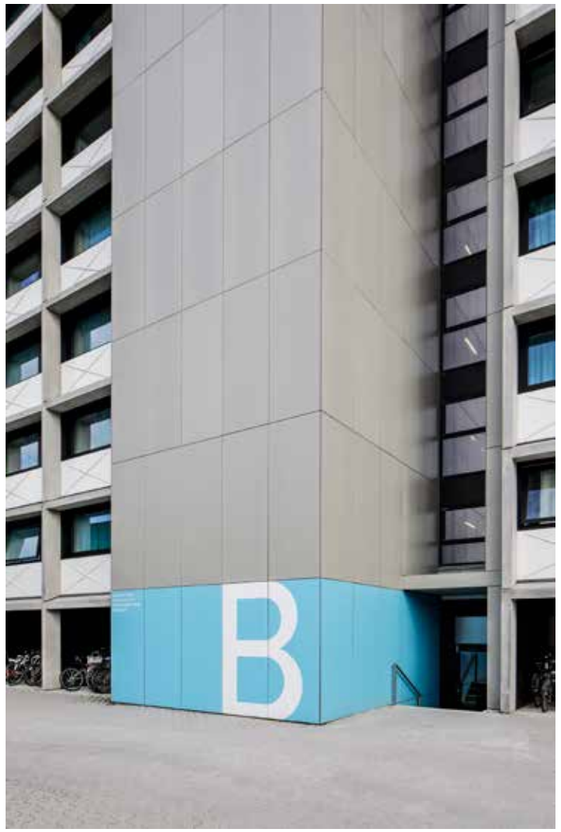
The 1972 Olympic buildings, spectacular in their day and embodying the motto of the Munich Olympics – "The Cheerful Games" – are now to be declared a World Heritage Site. That the architects also had WACKER dispersible polymer powders to thank for making their ambitious plans a reality is a little-known facet of the story.

The Olympic Village in northern Munich: the intelligent-design urban complex ranks among the city's most sought-after residential areas.

"Living in the Olympic Village has cult status."

A one-room, 33-square-meter apartment on the 10th floor in Munich's Olympic Village set a buyer back €195,000 at the beginning of 2018. A steep price for an apartment in one of those typical – and generally unpopular – housing developments of the early 1970s that can hardly be called "villages." At first glance, visitors see a lot of densely packed, prefabricated concrete slabs. A second look, however, reveals sophisticated urban planning: "Living in the Olympic Village has cult status," asserts a Munich real estate report. Some 6,000 residents have lived here for many decades – roughly 90 percent of all moves are simply relocations within the Village.

Like the Olympic Stadium to the south, with its spectacular tent-like roof, Munich's Olympic Village became a designated historical site in 1997. But for the Olympic Village residents' association and the Olympic Park World Heritage Campaign, that doesn't go far enough: they want the Olympic Park, including the stadium and village – described in *Bauwelt* architectural magazine as the "most significant architectural ensemble" created by the Federal Republic of Germany – to be added to the list of UNESCO World Heritage Sites. In late 2017, Munich City Council sought expert advice. Nearly all testimonies recommended applying for the status.



The top-quality cement used for the Olympic buildings – a prestigious project for Germany – still endures after over 40 years.

Munich has been more successful in repurposing its Olympic venues after the games than most former Olympic host cities. A scenario considered highly unlikely 50 years ago, shortly after the Behnisch und Partner architecture firm won the architectural competition for the Olympic complex. Skeptics even doubted whether the spectacular design made of acrylic glass could be built at all. "It wasn't just the tent roof – there were also issues with the concrete and mortar that no one had ever faced before," recalls Karl-Heinz Kranz, who is now 77 years old.

1968 marked both the start of excavation on the Olympic Park and an important year for him personally: Ardex, a construction chemicals manufacturer based in Witten, northwestern Germany, hired Kranz, who was a skilled bricklayer, tiler and master screed layer. Ardex, and Kranz, would later make a small but significant contribution to the construction of the Olympic site – one destined to tremendously expand the scope of the dry-mix mortar industry in the years to come.

LIGHT AND TRANSPARENT

With their light, airy and, in the case of the Olympic Stadium, sweeping architecture, Munich's Olympic venues were designed to symbolize "cheerful games," according to Willi Daume, the then head of the German Olympic Committee.

As the only summer games held to date in postwar Germany, the event aimed to show the world a new, friendly, cosmopolitan face. The organization of the games was pursued as a collective national effort and was enthusiastically supported by virtually all Munich's citizens.

Karl-Heinz Kranz was one of the many thousands of specialists who helped build the completely new Olympic complex in the north of Munich – quite literally from the ground up – in less than five years. His job was to renovate a load-bearing pillar in which holes and cracks had been discovered. Given the Olympic construction site management's instructions forbidding repair work, the project had to be kept secret. Indeed, management had already issued orders to tear down and rebuild one faulty concrete wall. "A three-month delay and several hundred thousand marks were riding on that pillar," Kranz recalls.

SMOOTHING COMPOUNDS TO THE RESCUE

The Ardex specialist was flown in, and once on site he turned to Arducret B12, a cement-based concrete filler that he himself had helped develop at Ardex and which had been available for only a few months. The product contained

The attraction of this residential complex lies in its smaller row houses that serve as student accommodation and its stepped apartment buildings featuring large south-facing balconies.

a dispersible polymer powder made from vinyl acetate-ethylene (VAE) copolymer, which WACKER had likewise only recently begun producing.

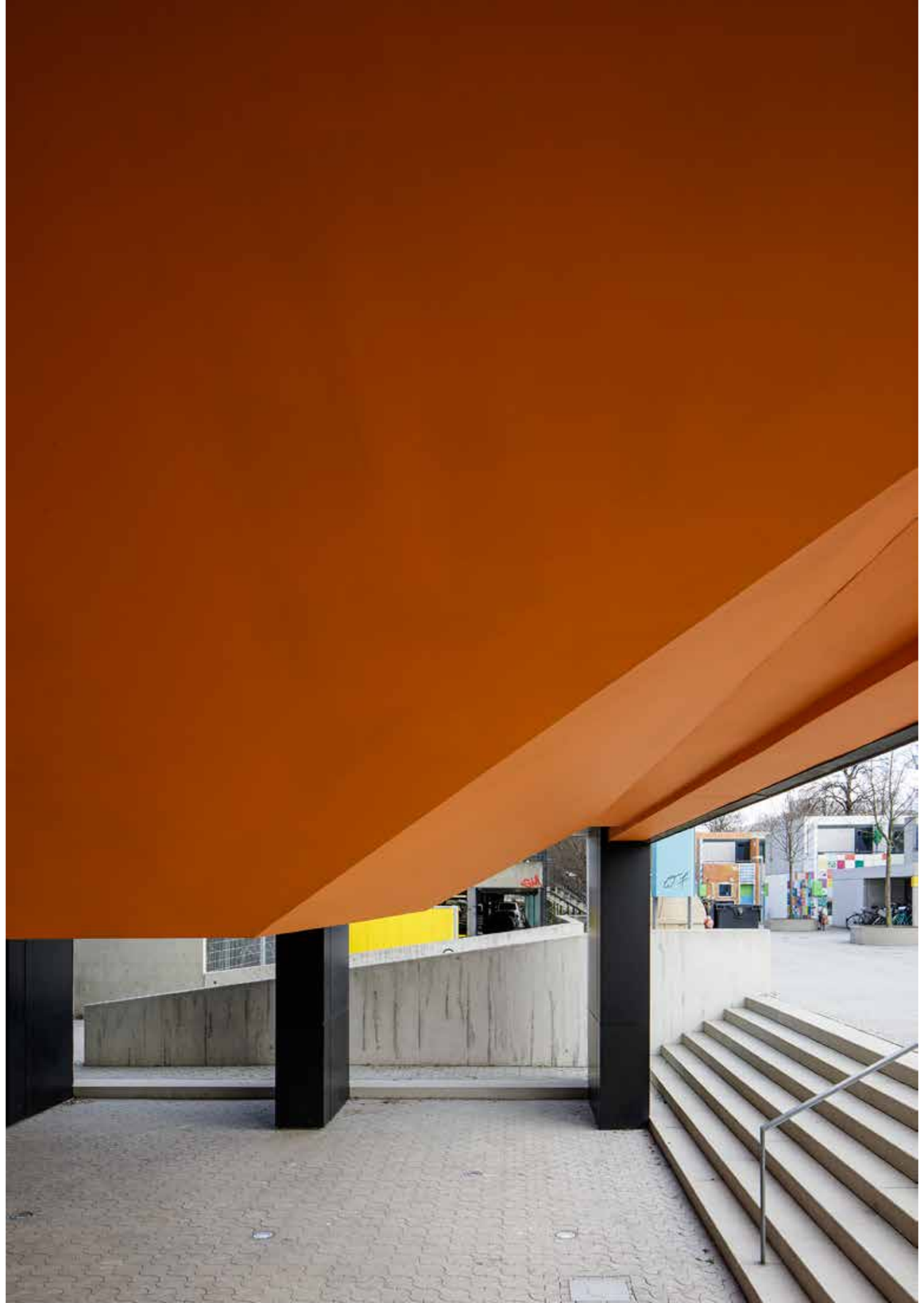
"The VAE copolymer in the mortar acts as a second, flexible binder in addition to the rigid cement," explains Dr. Peter Fritze, who heads a WACKER applications laboratory for construction polymers. It improves both the cohesion and flexibility of this specialty mortar, he notes, and the polymer modification also reduces the amount of water needed for the filler, which, in turn, reduces shrinkage. "Thanks to these improved properties, the filler is able to repair defects in the concrete permanently," the WACKER chemist stresses.

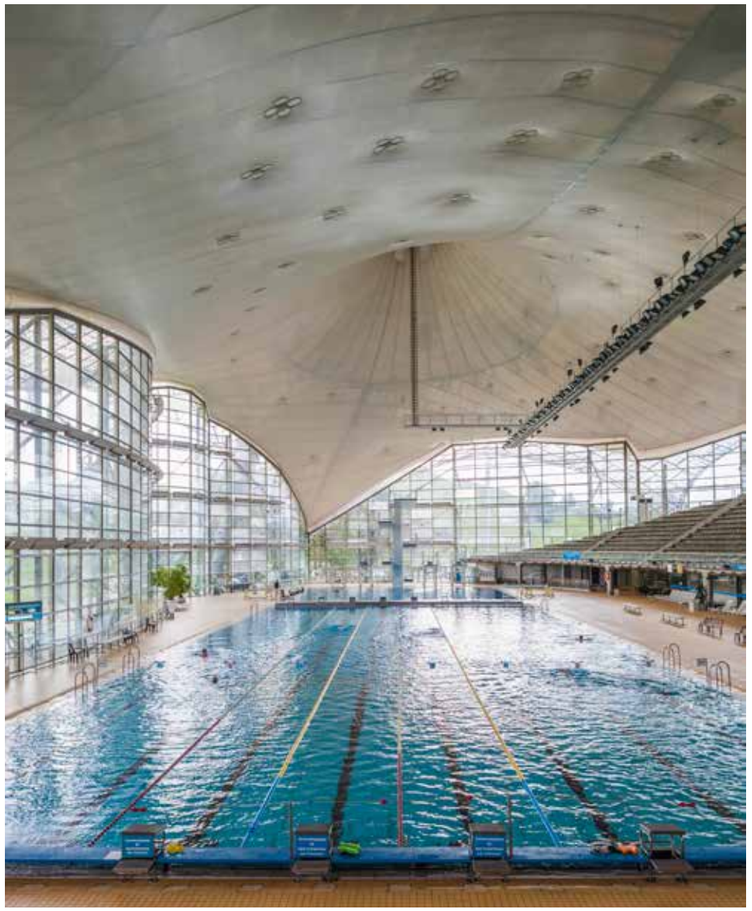
"This is so good, it's almost better than the concrete itself."

In the early 1970s, polymer-modified concrete fillers were still uncharted territory. Nevertheless, Kranz got down to work. "Even though atmospheric conditions and the sun were on my side, it was evening by the time I made it down to the support. I was just making my final pass with the trowel when someone hissed: 'Get away from the pillar – site management's coming!'"

A REVOLUTION ON THE CONSTRUCTION SITE

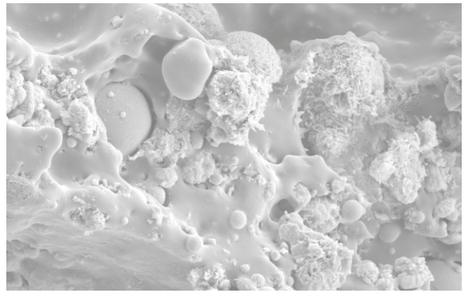
But the site management representative was not fooled. The man turned and called out to his colleagues, "They've been patching this up. But just take a look at how good it is – it's almost better than the concrete itself." Kranz sees the



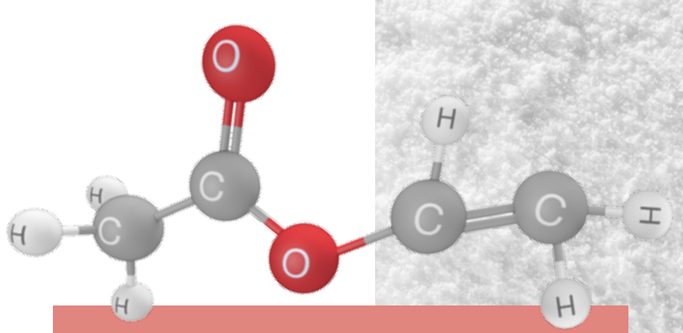


The light, airy architecture of the Olympic buildings, like the swimming pool, for example, were intended to create a pleasant atmosphere.

The color scheme for the Olympic buildings was created by the renowned Munich designer Otl Aicher, who was lead designer during the 1972 Olympics.



Polymer-modified cement mortar under a scanning electron microscope: The VAE polymers in the image have a smooth surface. They act as binders and increase the flexibility of the set mortar.



VAE

VINNAPAS® vinyl acetate-ethylene (VAE) dispersions and dispersible polymer powders are copolymers produced by emulsion polymerization of vinyl acetate (a hard polar monomer) and ethylene (a soft hydrophobic monomer). Vinyl acetate and ethylene are polymerized at high pressure in water using colloidal stabilization.

Ethylene is an ideal plasticizer for vinyl acetate, which imparts long-lasting durability to VAE polymers. As a result, vinyl acetate-ethylene doesn't need an external plasticizer.

VAE polymers have outstanding film-formation properties – no solvents are needed. This means formulators can develop and manufacture water-based products with a very low VOC content that adhere well to non-polar substances. The glass transition temperature varies from +25 to –25 °C as a function of the ethylene content.

episode as a breakthrough for Ardex concrete filler at the Olympic building site.

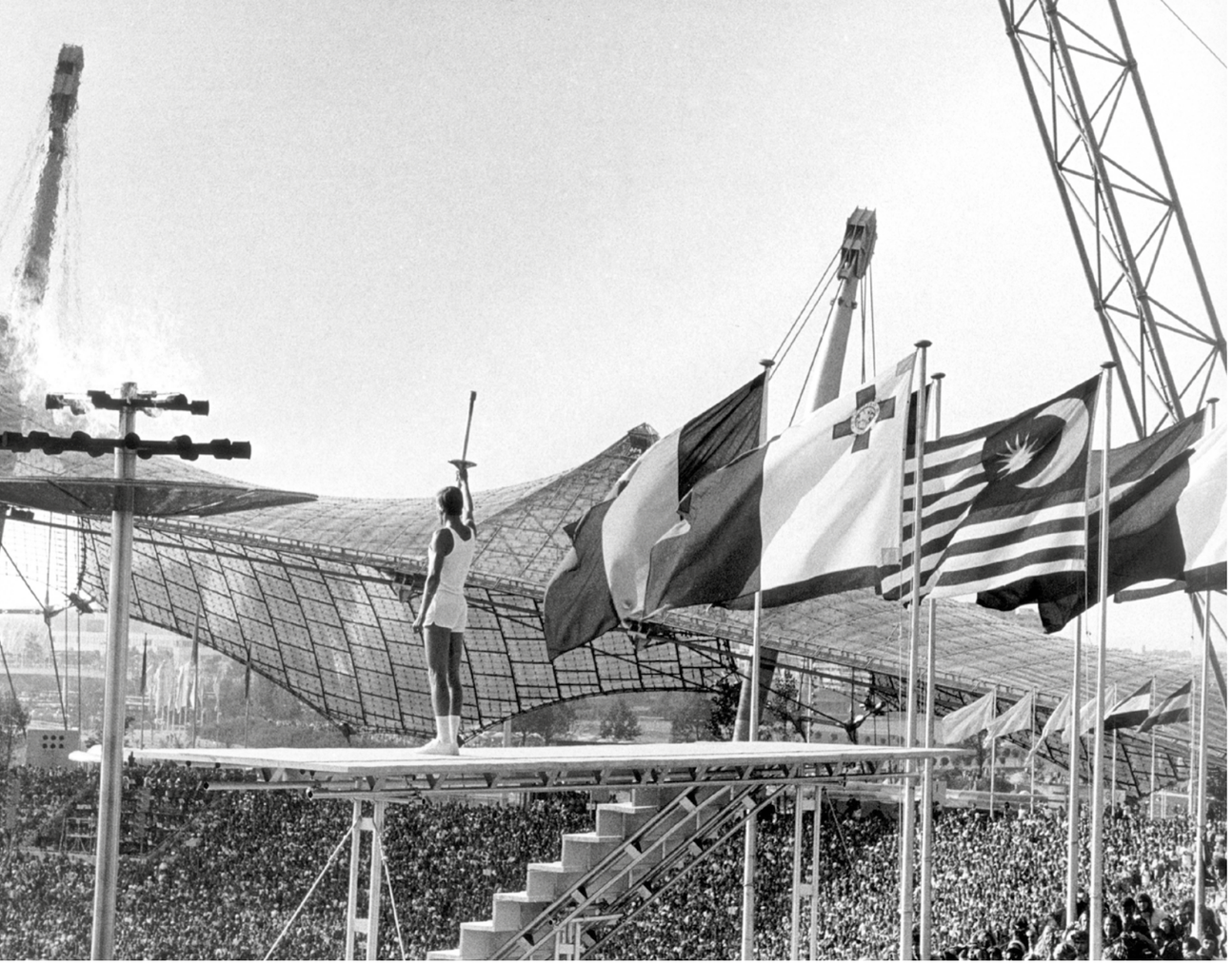
Another Ardex product used was Ardurit X7G, a tile adhesive Kranz also had a major role in developing. "The product – today we'd call it a flexible adhesive – had been considerably enriched with VAE copolymer," says Kranz.

LEAN LAYERS

Up to that point, the thick-bed technique was used for tiling all over the world: tiles were placed in a layer of mortar at least 1.5 centimeters thick, consisting almost exclusively of cement, sand and water. "That kind of slightly moist material is difficult to process and almost impossible to apply with a spatula," says Dr. Fritze from WACKER's Technical Service. Also, he notes, the mortar tends to bleed. In other words, the water content migrates to the surface of the mortar and/or is absorbed by the substrate. "That could prevent the cement from setting sufficiently, especially if the mortar layer is thin," says Fritze, adding that the adhesive mortar has to be a few centimeters thick in order to have enough water to harden sufficiently.

The thick-bed technique was both prone to error and time-consuming. "It wasn't until we had VAE polymers that we could process

The thin-bed method for laying tiles with mortar layers of less than half a centimeter has become an established standard worldwide. VAE polymers improve the adhesion of the tiles on the substrate and help dissipate any stress that might arise.



The opening ceremony of the Munich Olympic Games on August 26, 1972. The Olympic Stadium with its curved polyacrylic glass roof was revolutionary at the time.

The 72,800-square-meter canopy consists of steel cables suspended on 80-meter high pylons and a covering made of acrylic glass panels.

"VAE copolymers in the mortar act as a second flexible binder in addition to the rigid cement."

Dr. Peter Fritze, Technical Service at Construction Polymers, WACKER POLYMERS

cementitious materials into layers less than a half centimeter thick," observes Kranz. These polymers improved tile adhesion on the substrate and helped dissipate any stress that might arise. Thin-bed technology – the standard of today – was born. "The technology meant that tilers could cover larger areas in the same amount of time – a huge advantage, given rising labor costs," Fritze adds.

The rise of densely sintered porcelain stoneware tiles and their reduced porosity – and hence greater resistance to freezing – made polymer-containing tile adhesives like Ardurit X7G a necessity. Fritz and Kranz are of one opinion: "There's no way you could lay these tiles with the old thick-bed technology." The tiles would quickly detach from the floor or wall, they add, noting that polymer-modified tile adhesives are the only way to permanently bond these kinds of tiles.

"Thanks to the new technology and the new products used for the Olympic venues, my name quickly gained currency in technical circles after the games," says Kranz. That was the beginning of an exceptionally successful career: trade organizations from all over Germany invited him to speak, Ardex promoted him to the position of technical manager for the tiles and screeds business, and he earned a degree in civil engineering while continuing to work. And he has served as an expert witness ever since retiring from Ardex – a role he continues to fill to this day.

ADHESION THAT LASTS FOR DECADES

Many of the tiles laid in the early 1970s in the kitchens and bathrooms of the Olympic Village are still there – bonded in place as firmly as ever. What's more, the pillars in the Olympic Stadium have coped with the large crowds attending events such as the 1974 World Cup, Bayern Munich soccer matches (who played there for many decades), and Rolling Stones concerts (which have been held there seven times to date). ■

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KEEPING THE WHEELS ROLLING

In a large-scale company project, Deutsche Bahn (German rail) is investigating 3D printing (additive manufacturing) as a cost-effective, high-quality means of reproducing critical components. Owing to their exceptionally high durability and their broad spectrum of applications, silicone rubbers rank highly among the materials currently under consideration.

Nuremberg railroad station: Deutsche Bahn operates over 100 different types of trains of varying age. And for some of them, spare parts are not always in stock.

Silicone rubber diaphragms made with the ACEO® 3D printing process. These diaphragms are needed for train brakes.

"We're dealing with over a century of railway history that begins with roughly ten different manufacturers and ends with over 100 different trains and models."

Florens Lichte, head of Deutsche Bahn AG's 3D-printing (additive-manufacturing) project.

Germany's Deutsche Bahn AG rail operator (DB AG) runs roughly 40,000 trains a day on a rail network spanning 33,400 kilometers. Keeping that fleet moving requires a sophisticated logistics chain and a constant supply of crucial components.

The railway network itself consists of the track route, permanent way, track bed, overhead power lines and power supply. And the varied nature of the vehicle pool is no less complex, explains Florens Lichte, who leads the 3D-printing project at Deutsche Bahn: "We're dealing with over 100 years of railroad history – beginning with roughly ten different manufacturers and ending with over 100 different trains and models." The ICE high-speed train alone has been operating since 1989 and is now in its fourth generation. "One of the greatest challenges we face, especially when it comes to spare parts, is the supply of materials," Lichte points out.

INVESTIGATING ALTERNATIVES

In order to continue meeting this challenge going forward, DB AG launched a company-wide 3D-printing project in 2015. All the company's divisions are involved in the search for new ways of leveraging this innovative production method to keep the trains and their logistics systems running. This includes 3D printing with silicone rubber compounds, as offered by ACEO®, an internal WACKER startup.

The driving force behind the project is the maintenance division headed by Lichte, who carried out his first 3D project when he joined the company in 2014. Back then, he printed simple coat hooks, but the experience introduced him to the technology. Under his tutelage, those first coat hooks grew into 50 more applications in 2016 alone, for a total of 1,000 3D-printed parts. That figure doubled in 2017, and a specific goal of 15,000 items has been set for 2018.

The reason why railroad companies, of all businesses, would be eyeing 3D printing becomes clear when we take a closer look at the many ways the technology could be applied. The German rail network, for example, still has 800 entirely mechanical signal towers, and the complex process of modernizing them would simply not be worth the effort.

Both the infrastructure and the locomotive fleet require a constant supply of spare parts that, for a variety of reasons, can no longer be procured – either because production has been discontinued or because the supplier has gone bankrupt. As Lichte explains, the supply chain contains a particularly large gap: "We're always running into problems with spare parts – especially when obsolete technology is involved. The depreciation period for a train is 25 years, but its service life can often be as long as 40 to 50 years. And generally speaking, manufacturers only guarantee availability of spare parts for 15 years."

Over the course of the project, Lichte's team has to deal with a wide range of materials and production technologies, regularly screening the entire 3D-printing market to find new technologies and to determine how mature they are. Identifying parts and meeting supplier qualification requirements quickly push these mostly young companies to their limits. Parts have to comply with normative standards so that they can be used under live operating conditions. At present, Deutsche Bahn uses two material groups: metals and organic plastics.

Plastics represent the most widely used material for industrial-scale components ranging up to 60 centimeters in size. Up to now, DB AG has relied primarily on polyamides or polyether imides, often incorporating flame-resistant additives. The printed spare parts are mostly installed in non-safety-critical applications in the engine room or passenger areas; these include headrest casings, housing covers or clips for window blinds.

Silicone elastomers are an exceptionally good choice of material for applications in which plastics are subjected to significantly higher stresses. They are stable, yet elastically deformable plastics that yield to tensile and compressive forces and then return to their original shape – just like other plastics based

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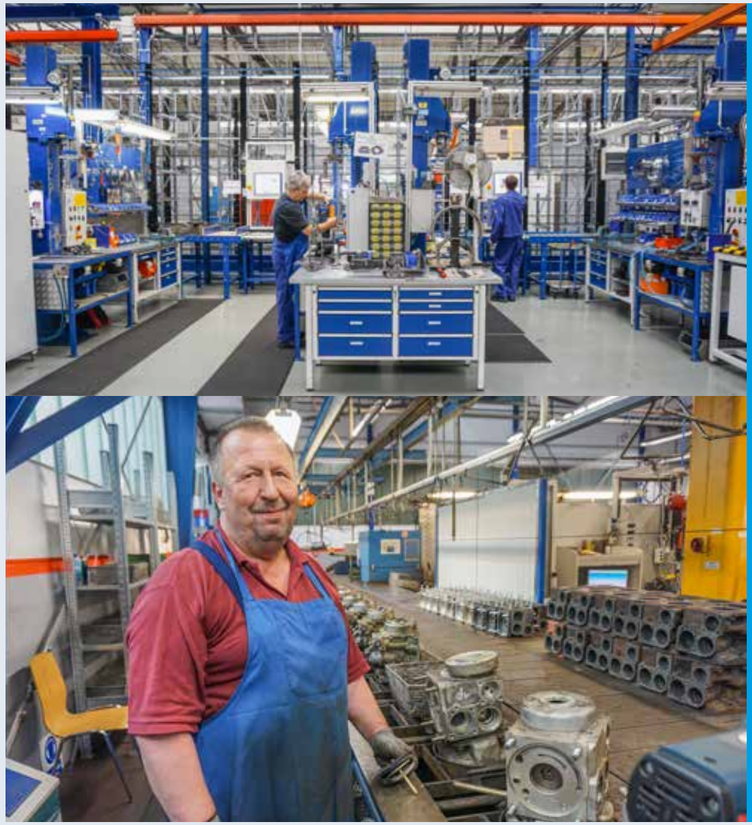
An inside view of a control center at Deutsche Bahn: the complexity of this transport system that includes not just trains, but also the routes followed by the tracks, overhead power lines, station buildings and a whole lot more, means it is ideal for individualized procurement of 3D-printed spare parts.



BRAKE COMPONENT SPECIALISTS

A view of Deutsche Bahn's maintenance facility in Fulda, Hesse (upper photo): 150 years ago, it started out as a train repair shop at Fulda main station. Today, it is a highly specialized technical center for brake components (lower photo). 584 employees inspect, repair and modernize different types of brakes that are installed for external customers at all other DB facilities across Germany and Europe. They also design and set up their own testing equipment, which can be used at other sites if required. The brake testing equipment they produce is used in a variety of countries from Algeria, Italy, Cuba and Switzerland to Russia.

on organic materials. Since silicone elastomers offer significant advantages over their organic counterparts in terms of stability and resistance to various influencing factors, DB AG is currently paying very close attention to 3D printing with this material. In addition to their remarkable resistance to thermal and thermo-oxidative stress, for instance, silicone elastomers are less sensitive to UV or electromagnetic radiation and withstand hot water and steam. These properties make them especially interesting for safety-critical applications.

"It's particularly hard to find spare parts like diaphragms for brake components," says Lichte. "We identified this as an opportunity for our project, and during the market-screening process, we came across ACEO®. They are one of the few partners offering elastomeric components we could take seriously."

IN-HOUSE GROUP STARTUP

ACEO® is an internal startup at Wacker Chemie AG specializing in 3D printing with silicone rubber compounds. Its over 3,000 standard silicone products and over 70 years of expertise in the field make WACKER not only one of the world's largest silicone manufacturers, but also a leader in important submarkets. Since 2014, the company's team of experts, led by ACEO® project manager Dr. Bernd Pachaly, has been working on more than just developing silicone elastomers for printing – they also develop the requisite hardware and software for making parts according to customers' unique specifications.

"From the very beginning, our mission was to formulate 3D-printing silicones that have the same property profiles as our elastomers and are processed using traditional methods such as injection molding," explains Dr. Pachaly. "In other words, 3D-printing silicones must be capable of withstanding pressure, heat and other stress factors, just as conventional silicones do."

> "It's particularly hard to find spare parts like diaphragms for brake components. We identified this as an opportunity for our project, and during the market-screening process, we came across ACEO®."
>
> **Florens Lichte,** head of Deutsche Bahn AG's 3D-printing (additive-manufacturing) project

The ACEO® printing process can produce samples in customized shapes, provided they remain within a certain size range.

3D PRINTING WITH SILICONES

The ACEO® production facility in Burghausen: two employees print silicone rubber products using computer-controlled printers. The equipment and software were developed specifically for ACEO®'s patented 3D-printing process.

Quality control includes taking geometric measurements of the components. ACEO® laboratory workers use a measuring microscope which captures the most intricate details.

UPLOADING CAD DESIGNS

ACEO®'s business model adopted a completely new approach, which is why the project was given the unique status of internal startup at WACKER in 2016. The first-ever online shop for 3D-printed silicones enables product designers to simply upload their CAD designs and await prompt delivery of their 3D-printed silicone part to any destination in the world. ACEO®'s Open Print Lab in Burghausen offers customers another option: they can familiarize themselves with the technology on site, and even produce test components at the end of a workshop tailored to their individual needs. "Ongoing dialogue and the resulting learning process are just as essential as a pioneering spirit when it comes to teaching our customers about the unprecedented opportunities our technology offers," Pachaly emphasizes.

Initial contact in the fall of 2017 led to a joint workshop at the DB Fahrzeuginstandhaltung GmbH facility (full-service rail-vehicle maintenance provider) in Fulda, Germany, where DB AG and ACEO® developers and engineers met to begin discussions and identify potential applications and challenges. "The chance to share our expertise with Deutsche Bahn – just two years after we launched – is another milestone for us," explains Pachaly.

As a result of this partnership, there are plans to make a brake diaphragm as an initial test part. The idea is to develop a diaphragm that can be installed as a component in the control valve of a train brake. Designed as an 11-cm-diameter, plate-shaped disk with a sealing lip, this diaphragm is relatively thin at just four millimeters, yet, as Florens Lichte stresses, it must of course meet the most demanding material requirements. "ACEO® silicones are definitely in a class by themselves," he says. "Many competing products very quickly become brittle, making them unsuitable as train components. ACEO® offers us great potential not only in this one application." Long-term testing is already in the planning stages, and both WACKER and DB are confident that they will find further areas to work on.

What ultimately matters is using innovative technologies like 3D printing to make sure the fleet keeps moving. Which is why DB AG intends to cooperate with suitable partners to create trailblazing solutions that can be integrated into day-to-day operations in the medium to long term. The project phase of the company's 3D-printing initiative is expected to last until 2019, after which the results will be transferred to production. Until that time, however, their plan is to put new 3D-printing technologies to the test.

"3D printing is perfect for producing a few individual parts or small batches that you need on short notice," explains Lichte, who studied mechanical engineering and business administration. "In other words, the higher price tag for 3D-printed parts is not an issue if it means we can keep the materials flowing."

VERSATILE APPLICATIONS

Before that can happen, however, the variety of 3D-printing applications first has to be anchored in the minds of developers within the company. Lichte has so far conducted over 40 workshops at various sites, where the project team talks with participants directly to make them aware of the possibilities the technology offers, while collecting and following up on ideas from actual operations. What can 3D printing do? What are its limitations? What direction is the technology headed? To what extent has it already been applied on an industrial scale? What ideas have already been implemented in the company? Lichte and his DB team revisit these questions each and every day. "It's easiest to just bring a sample part with me. If you want to make something tangible, nothing is more convincing than putting a printed part in someone's hand." ■

The silicone components are postcured in a vacuum postcuring oven at 200 °C. This process step enables the components to achieve their final strength and at the same time, any remaining volatile organic compounds escape.

RESTORING THE SPLENDOR OF AN IMPERIAL PAST

The Budapest Western train station is currently being lovingly restored. Now that it has been impregnated with an alpha-silane-terminated polyether, the faded terrazzo flooring is once more as radiant as in the days of the Austro-Hungarian Empire.

Lovers of revivalist architecture from the second half of the 19th century will find plenty to get excited about in Budapest, where entire streets and districts dating from the Austro-Hungarian Empire have survived fully intact and have been renovated and restored to their original style.

FUNDING FROM BRUSSELS

The architectural gems of the Austro-Hungarian Empire include Budapest's listed Western train station (Nyugati pályaudvar), which – thanks to EU funding – is being completely renovated and lovingly restored. "The aims of the restoration project included returning the terrazzo floors in some of the buildings to their original splendor," explained Udo Goedecke, the marketing manager in charge of building-protection applications at WACKER SILICONES.

TRAINSHED BY THE EIFFEL COMPANY

Officially opened in 1877, the building was largely designed by August W. de Serres, a railroad engineer, who was chief architect at the Imperial Austrian railroad company at that time. The commission for detailed planning and building execution was given to the firm of Gustave Eiffel, who later designed the famous tower named after him in Paris. The steel-girder structure above the platforms was the work of Eiffel's former partner Theophil Seyry.

As was common practice in the early days of the railroad, de Serres designed the terminus station so that trains arrived on one longitudinal site of the platform area, while passengers left on the other. The buildings at the departure end were particularly magnificent so that passengers making their way to the platforms from the adjacent forecourt were given a delightful and dignified send-off. Viewed from this forecourt, the buildings are arranged like the court of honor of a French-style Baroque palace.

BRILLIANT COPPER INLAYS

The wing on the right-hand side of this courtyard is the pavilion that used to house the station post office. Its magnificent terrazzo floor features copper inlays, while

Now restored to its original style: the right wing of the train station with the pavilion that housed the former post office.

1877

saw the dedication of Budapest's Western train station, which is known for the highly ornamental architectural style of the Austro-Hungarian Empire.

narrow strips of copper accentuate the contrasting colors of the surface design – reddish-brown/pale gray and anthracite/gray. A cement screed holds the colored natural stone grain together, which experts refer to as a cementitious or cement-bound terrazzo. Once the renovations are complete, the city of Budapest wants to use the former post office pavilion as an agency for dealing with ID and passport matters.

In general, a cementitious terrazzo floor is considered to be hard wearing and durable. When in use, however, this kind of floor is more sensitive than it looks. There are two reasons for this: first, the hardness of each terrazzo component varies. As people walk over the floor, the softer cement wears down more quickly than the harder stone aggregates. Second, the terrazzo floor has a porous surface.

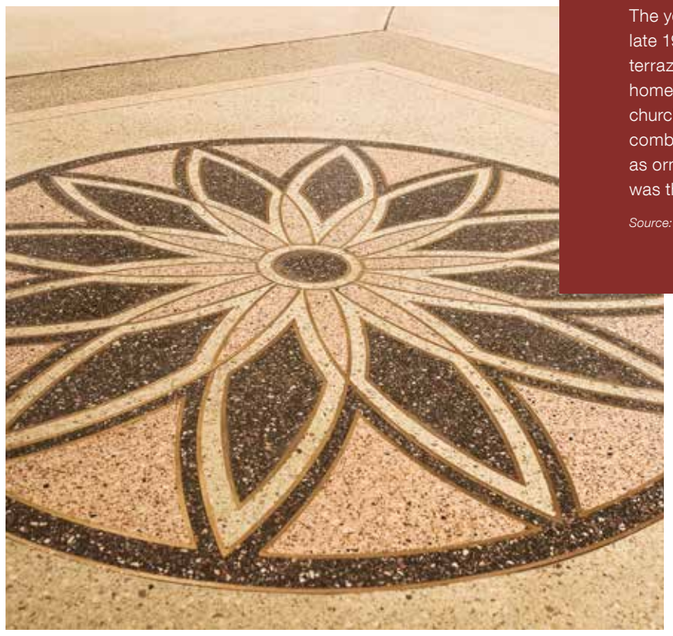
A POROUS SURFACE

"As a result of its porosity, the surface absorbs spilled drinks, oils and other liquids. This produces dirt marks that are very difficult to remove completely," explained WACKER building-protection expert Udo Goedecke. What's left are unpleasant stains and – in the case of considerable abrasion – visible traffic areas, which disfigure the floor. "So it's sensible to protect a terrazzo floor," he advises.

The planners responsible for restoring the floor in the former post office likewise had to tackle this challenge. Initially, they decided to treat the floor with a polyurethane-based product. Aesthetically speaking, their decision turned out to be the wrong one, as the treated surface looked artificial, taking on a matte and dull appearance – which satisfied neither property developer nor architect.

THE DECISION TO USE SILRES® BS 6920

The developer contacted Durostone Kft. for advice. Located in the Budapest suburb of Sóskút, this company specializes in the manufacture and restoration of industrial flooring. Durostone's development engineer, Péter Árva, recommended sanding off the polyurethane layer that had been applied to the test surface of the floor and treating it instead with an impregnation agent based on SILRES® BS 6920.



Impregnation does an especially nice job of bringing out the patina of the 140-year-old terrazzo flooring.

SILRES® BS 6920 is a new, clear liquid and low-viscosity binder that belongs to the group of alpha-silane-terminated polyethers. WACKER scientists had optimized it specifically for the impregnation of cementitious floors. In combination with an aminosilane catalyst such as WACKER's GENIOSIL® GF 9, it can be processed to one-component, solvent-free and odorless formulations. These formulations adhere well to cementitious surfaces and, when exposed to atmospheric humidity, cure quickly, forming a stable siloxane network.

BINDER FILLS PORES

The binder penetrates deep into the cementitious floor, filling the pores and curing to a hard and non-combustible material that has both water-repellent and oil-resistant properties thanks to its chemical molecular structure. "An impregnation agent based on our new binder greatly improves the floor's resistance to rub off and scratches. It also affords really good stain protection," said Dr. Udo Anders, in charge of technical support for this product group at WACKER SILICONES. "Everyday liquids – whether waterborne or oily – are no longer able to penetrate into the treated surface and can easily be wiped away using a paper towel."

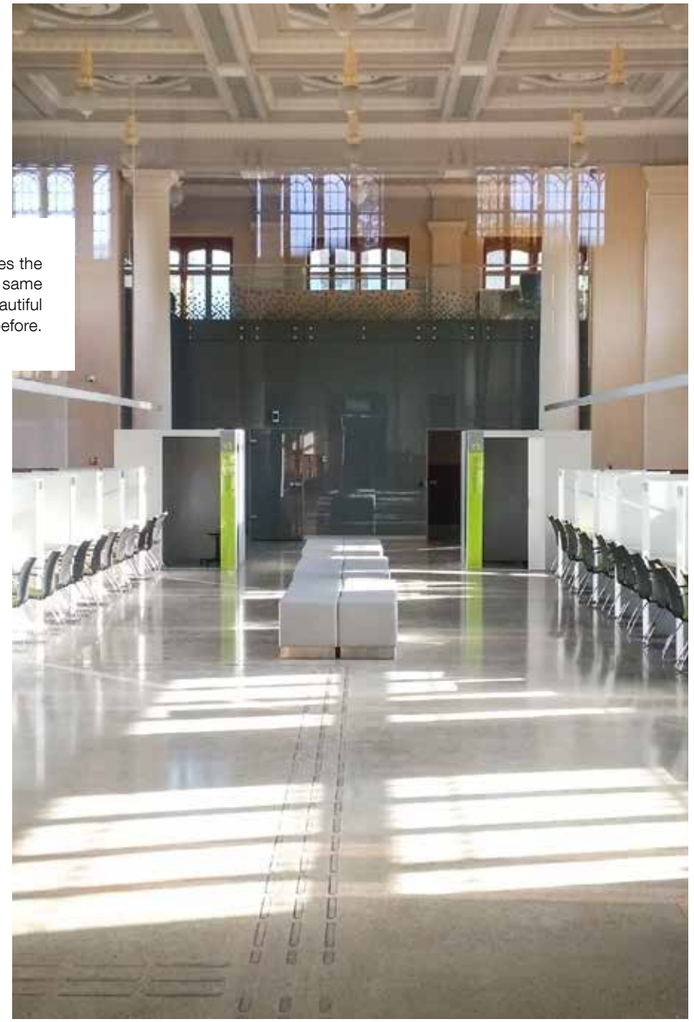
What's more, SILRES® BS 6920 improves the surface appearance, as Dr. Anders explains: "If the SILRES® BS 6920 formulation is transparent, it intensifies the surface coloring and brings out the contrasts so that the treated floor looks darker and the appearance of its aggregate is emphasized. The surface is also given a slight sheen, which emphasizes the quality of the floor. We have conducted a large number of tests in our applications lab to prove all these effects."

TERRAZZO

The term 'terrazzo' describes a type of flooring known since antiquity in which a decorative and often colorful aggregate is applied directly to a cement-bound screed bed to form a single material. After drying, the surface of the terrazzo is ground and polished to its final gloss. Aggregates used as far back as the Roman times include marble, limestone and dolomite, as well as harder materials such as granite gravel and moraine or river pebbles, in order to make the floor more resistant to wear.

The years of the Austro-Hungarian Empire, from the late 19th to the early 20th centuries, were when terrazzo flooring was used most widely, and not just in homes – it was also common in public buildings such as churches and train stations. These floors often featured combinations of surfaces in different colors, as well as ornaments or inscriptions made of mosaic tiles, as was the case in Budapest's Western train station.

Source: Wikipedia



Impregnation gives the terrazzo floor the same splendor and beautiful patina as before.

IMMEDIATELY READY TO USE

It is precisely this property profile that motivated Durostone development engineer Péter Árva to process the new binder into a ready-to-use impregnation agent (Durosmart Floorprotect S). This agent was ultimately used to treat the approximately 300 square meters of terrazzo flooring in July 2017.

"The sanded-down floor was in an excellent state," recalled Goedecke, who went on to say: "On our advice, the applicator team decided to apply two coats and to dilute the Durostone impregnation agent intended for the first coat with 10% SILRES® BS 1701 reactive thinner." In this way, about 50 grams of the diluted formulation were to be applied as an initial coat and then as a second coat to each square meter of the terrazzo floor.

THE VISCOSITY OF WATER

The reactive thinner makes it possible to adjust the formulation's viscosity to almost match that of water. As a result, the agent can be spread over the surface particularly well. In addition, the greatly diluted agent remains workable for a lot longer. The applicator therefore has enough time to process the material properly.

The odorless SILRES® BS 1701 reactive thinner is a low-viscosity silane incorporated into the resultant siloxane network during curing. "A diluted impregnation agent makes the initial coat particularly effective," says Goedecke. "The applicators can stir the thinner into the impregnation agent on site."

In many cases, a second coat is needed to ensure that the surface looks even, the reason being that the porous floor absorbs a large amount of the impregnation agent applied as an initial coat. Some spots absorb a considerable amount of agent, while others absorb much less. This is why the surface often looks stained or uneven after application of the first coat. That changes with the second coat, which forms a thin, slightly glossy film.

TEST SAMPLE

SILRES® BS 6920 is brushed onto a test sample made of cement and aggregate stones.

CONTAMINATION

A technician then drips contaminants such as engine oil onto the impregnated (left) and non-impregnated surfaces.

JUST WIPE

The protective effect of the impregnation becomes apparent when the contaminants are wiped away.

"The once faded terrazzo looks natural and fresh once again, while the high contrast between its coloring and ornamental features has been shown to advantage."

Zoltán-Gábriel Géza, sales manager for WACKER Hungary

After application of two coats, everyone is happy with the result: the surface was completely even, with a high-class finish, according to Zoltán-Gábriel Géza, sales manager at WACKER Hungary. "The once faded terrazzo now looks natural and fresh once again, while the high contrast between its coloring and ornamental features has been shown to advantage."

A NATURAL, HIGH-QUALITY FINISH

Durostone's flooring expert was delighted. Árva explained: "It's exactly this natural and high-quality finish that influenced me to choose the new SILRES® BS 6920 binder straight away. Another factor in its favor was that it is extremely simple to process so as to obtain a ready-to-use product: all the components – including the thinner – needed for production are simplicity itself to mix. So, I can very quickly supply a customer with a tailored floor anti-stain impregnation."

The comments of the applicators were positive, too. They were impressed that both processing and the look of the floor produced excellent results in spite of the very small amount of agent applied. They also mentioned how easy it was to apply the low-viscosity agent, and were full of praise for its lack of odor. Finally, Árva was not just appreciative of the quality of the product itself: "Because WACKER had provided us with extensive technical support beforehand, there were no doubts whatsoever about using the impregnation agent on such an architectural jewel." ■

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WWW 1.18 ▸ SOLUTIONS ▸ **E-MOBILITY**

AN ENERGIZING LEAD

WACKER is supporting the German automotive industry's move toward the new era of electromobility with a portfolio of custom-made silicone products: gap fillers and heat-dissipating adhesives ensure safe heat management in electric motors, batteries and power electronics. Encapsulants protect inductive charging systems and sensors for driver-assistance systems.

"Our objective is to have the necessary silicone products available in time for when the large-scale production of electric vehicles begins."

Dr. Klaus Angermaier, Global Business Development, WACKER SILICONES

0.7%

of all new vehicles in Germany were sold in 2017 with a fully electric drive. 0.85% were plug-in hybrids, combining a combustion engine with an electric drive.

Source: European Alternative Fuels Observatory (EAFO)

New vehicles waiting for delivery: not even 1% of new vehicles sold in Germany in 2017 were electrically operated.

Around 17 percent of worldwide carbon dioxide emissions are due solely to road traffic. One solution for traffic-related emission problems is promised by e-mobility (see box on page 46). Governments, city councils and non-government organizations see this mobility form as a way to meet the obligations agreed to in the 2015 Paris Climate Agreement on reducing greenhouse gas emissions. They are therefore supporting entry into the e-mobility market with generous financial assistance, expansion of the charging infrastructure, and preferential licensing. Cities are also increasingly taking drastic measures – all the way up to driving bans – to accelerate this change.

Many car buyers in smog-choked Chinese mega-cities such as Shanghai and Beijing are already choosing to buy electric vehicles because they would otherwise have to wait for years to get permission, if they are lucky, for gasoline and diesel cars. China will likewise be introducing production and sales quotas for electric vehicles as of next year. Air is running out for gasoline and diesel vehicles in Europe, too: Paris, for example, aims to ban all combustion-engine vehicles from the city by 2030.

The German automotive industry, which has long had a wait-and-see attitude to the topic of electromobility, is now advancing the development of electrically powered vehicles at top speed: VW has an e-Golf, while its subsidiary Audi will be marketing its first, fully electrically powered SUV – the e-tron – at the end of the year. BMW has been a pioneer in the German market with their i3 since 2013 – the Munich company is now one of the world's largest manufacturers of electric vehicles.

From a customer perspective, there are three decisive weak points that make many car drivers hesitate about changing over to an electric vehicle: the significantly higher price, the sparse charging infrastructure and the fear of being stranded on the road during long journeys. The charging infrastructure issue should be resolved over the coming years through initiatives by the automotive companies and government incentive programs. Range is also being targeted: Opel's Ampera-e is currently the leader on the German market with a standard range of 520 kilometers on one charge.

Nevertheless, the dissemination of electric vehicles is still highly dependent on the underlying conditions that governments set: through restrictions as in China or more commonly in Europe through financial support. In Norway, where the state subsidizes electric vehicles by not applying VAT, import or vehicle taxes, and where plenty of hydroelectric power is available, electric vehicles are often less expensive than their combustion-engine counterparts. Almost 40 percent of all those who bought new cars in Norway last year chose an electric vehicle. The market share of electric vehicles in 2017 in the major car nations, such as Germany, Japan, France and the USA, was in contrast just 1 percent or less, or between 1 and 1.6 percent if plug-in hybrids are included – but these figures are showing a significant upward trend.

The third disadvantage for a buyer – the relatively high price compared to a conventional vehicle – is due to the high additional costs for the battery, which cannot be fully compensated for by the removal of other components, such as the transmission. "The industry, how-

A Volvo hybrid bus operated by the Hamburger Hochbahn public transport company (HHA) at a charging station: HHA wants to convert its entire fleet of approximately 1,000 vehicles from diesel to electric drive over the next few years.

ever, expects these additional costs to cancel out within a few years – and this is confirmed by cost developments over the past years," said Dr. Klaus Angermaier. The chemist is responsible at WACKER SILICONES for the development of new business areas – including electromobility.

The falling prices forecast for batteries should rapidly promote the large-scale production of electric vehicles. All major manufacturers are aiming to produce electric vehicles on the same industrial scale as conventionally powered vehicles within a few years. To achieve this objective, the automotive sector is working hand in hand with the chemical industry, which will be providing the innovative materials for the new challenges posed by electromobility.

ELECTROMOBILITY

Many newspaper reports place electromobility on an equal footing with the utilization of electric vehicles. But electromobility is a whole lot more. It is based on a concept that goes far beyond just vehicles: this new form of mobility links the transport system with the energy transition, viewing electric vehicles as one component of a comprehensive and fully digitally networked mobility offering. A person favoring electromobility does not therefore simply use their own electric vehicle, but will, as a matter of course, also use car-sharing options or public transport.

Changes in attitude toward transport networks and energy must work hand in hand so that electromobility can help significantly reduce environmentally harmful emissions. If an electric vehicle is driven using coal-generated power, exhaust gases would not be produced locally, i.e. by the vehicle, but greenhouse gases would still be generated at the power station.

"Such demanding tasks include dissipating the heat generated in a vehicle's electrical components during driving or charging", said Dr. Angermaier. Another challenge is building up the infrastructure for charging the traction battery. Angermaier said, "Methods for inductive charging are currently of great interest."

TWO TO THREE KILOGRAMS OF SILICONE

A project group headed by Angermaier is looking very closely into which silicone materials will be required for this new form of mobility. Around two to three kilograms of silicone can be found in a midsize car's combustion engine today. For example, silicone rubbers are used in turbocharger hoses, protective jackets for spark plug connectors and ignition cables, vibration dampers and various gaskets and sealing mats. In addition, the electronics used in the vehicle control units are protected by dispensable silicone sealing adhesives or encapsulants. Even the functional safety of an airbag significantly profits from a silicone coating, since it makes this technical textile permanently flexible and resistant to temperature, aging and wear.

Some of these silicone applications will not be required in a fully electrically powered vehicle, but other new applications will be. "Electric cars are another vehicle category where silicone materials are essential," emphasized Angermaier. "Our objective is to have the necessary silicone products available in time for the start of industrial-scale production of electric vehicles."

The drive train of a fully electric vehicle has three key components: the electric motor, traction battery and power electronics. The combustion engine and transmission are omitted or can be of a simpler design. The compact, but powerful electric motor provides the necessary torque for the drive in electric vehicles. The rechargeable battery – lithium-ion batteries are currently state of the art – serves as the energy storage device. The power electronics have the task of supplying electrical energy in the required form and voltage

Using a charging cable instead of a gas-pump nozzle: a BMW i3 with 125 kW electric motor being charged at a public charging station.

levels, and of controlling the energy flows. They are located in power conversion units.

The electric motor, traction battery and power electronics work with high electrical outputs and generate heat during operation. If they overheat, this can lead to the aging and premature failure of the components, some of which are very expensive. The released heat must be rapidly and effectively dissipated to prevent this.

Heat management is particularly important for lithium-ion batteries (see article on page 58), explains Dr. Philipp Müller, head of an applications laboratory at WACKER SILICONES' Industrial Solutions business unit. "The lithium-ion batteries only reach their full performance capability between 20 and 35 degrees Celsius and must therefore be temperature-controlled, i.e. kept within that range," he emphasized. The traction batteries are usually installed below the passenger compartment, where they take up most of the area, and have a modular structure: several battery cells are combined into modules. Several modules are then combined to form a complete battery with an electronic battery management system, temperature-control system and a housing.

Not even the smallest air gap can be present between the assembled components so that the heat can be transported rapidly and effectively from the battery modules to the temperature-control system – or in the other direction when heating is needed. The reason is that air is a very poor heat conductor and would hinder heat transfer. The gap is therefore completely filled with a thermally conductive material called a gap filler. This forms a thermal bond between the parts being joined.

PASTES

WACKER is offering new silicone-based gap fillers with their SEMICOSIL® 96x TC series, ideal for the thermal bonding of the battery modules with the temperature-control system. These pastes rapidly cure at room temperature with a platinum-catalyzed addition reaction. They achieve the thermal conductivity levels required in practice with values of 2 to 4 Watt per meter and Kelvin. The starting point of this development was based on products that have been used successfully for years for heat management in power electronic modules.

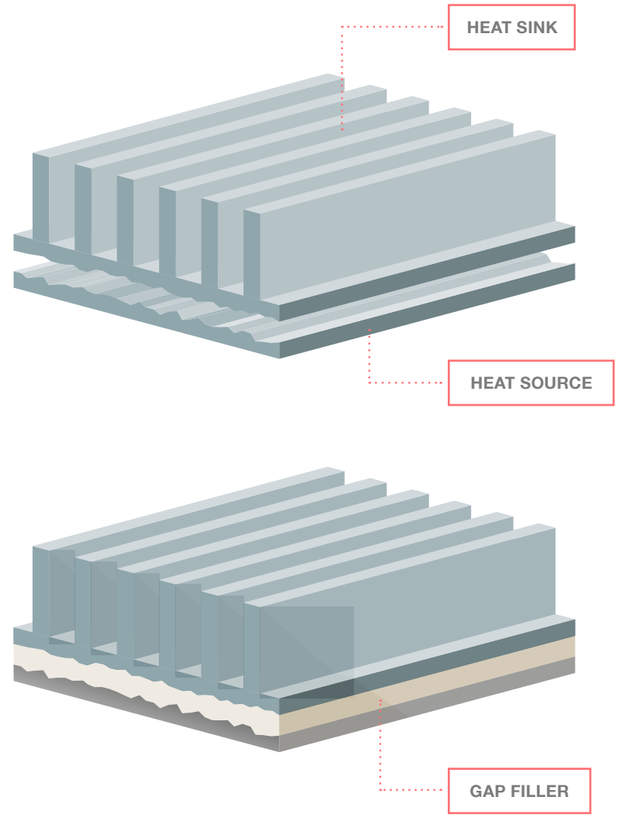
Like conventional products, the SEMICOSIL® 96x TC series grades form elastically deformable silicone pads in the gaps. Closely following the contours of both surfaces, these pads perfectly fill even the slightest roughness and unevenness in the millimeter range.

As silicone products, such gap fillers have major advantages over products based on organic polymers. Because they do not age, they permanently ensure good heat transfer and thereby contribute significantly to the required service life and stability of charge-discharge cycles in expensive traction batteries. As they are virtually non-flammable, they also contribute to battery safety.

The processing properties are just as important for the automotive industry. "Thanks to a new formulation concept, we managed to match the flow properties of the gap fillers to the manufacturing processes of the automobile manufacturers," explained Dr. Müller. These paste-like materials are a solid when at rest, but can be applied rapidly and accurately to large surfaces, enabling automated assembly. A single dispenser can be used to apply up to six kilograms of paste per minute. Such high application rates were previously unthinkable for gap fillers, but will be necessary for the planned large-scale production of batteries required in the automotive industry.

Dispensing is used to apply a long, wavy bead of gap filler to the heat sink of a power electronics module. A paste-like thermal interface material, SEMICOSIL® 961 TC is applied directly onto the heat sink. The electronic circuit is then placed on top of it and pressed down. During subsequent curing, the gap filler forms a soft, vibration-damping silicone cushion that optimally conducts heat to the heat sink.

APPLICATION OF A SILICONE-BASED GAP FILLER



Optimized heat transfer: thermal interface materials are used to replace the air – a poor heat conductor – in the gap between the heat source and heat sink, creating a thermally conductive connection. The pastes are applied by dispensing. Silicone-based thermal interface materials are ideal for filling in minute surface roughnesses and unevennesses in the millimeter range.

> "Lithium-ion batteries only reach their full performance capability between about 20 and 35 degrees Celsius and must therefore be temperature-controlled."
>
> **Dr. Philipp Müller,** laboratory manager, Industrial Solutions business unit, WACKER SILICONES

NO SPECIAL CONTAINERS REQUIRED

The new thermally conductive materials also exhibit considerably higher sedimentation stability than conventional products and can be supplied in 200-L containers – another prerequisite for use in industrial-scale production. The solid filler usually sediments and cakes together rapidly in conventional gap fillers. Once a filler has formed a sediment, it can no longer be remixed or only with great difficulty. Many conventional silicone gap fillers can therefore only be supplied in special small containers such as cartridges with stirring options. This problem has been solved by the newly formulated gap fillers from WACKER SILICONES.

Another heat source in electric vehicles comes from the power electronics installed in the power conversion unit: their active components, known as insulated-gate bipolar transistors (IGBTs), can become very hot during operation. Depending on the specific grade, IGBT operating temperatures can often reach well over 100 °C.

Overheating can damage the sensitive semiconductor structures of the IGBT and so lead to aging and eventually to component failure. Such failures can be prevented by actively cooling the printed circuit board (pcb) and IGBT assembly. It is necessary here to thermally couple the pcb to the cooling plate. If operating temperatures lie above 150 °C, a silicone-based thermally conductive material is the preferred choice – thermally conductive materials based on organic polymers cannot withstand this temperature load.

According to Dr. Markus Jandke, who, like his colleague Philipp Müller, heads an applications laboratory at WACKER SILICONES' Industrial Solutions team: "The gap fillers in the SEMICOSIL® 96x TC series have proven to be optimal in numerous cases." He emphasized that "Even non-curing silicone pastes such as SEMICOSIL® Paste 40 TC, which retains its consistency within the gap, or thermally conductive silicone adhesives such as SEMICOSIL® 9712 TC or 9754 TC can be used."

Where it's sensible to wear a face mask: practically no other metropolis is so badly affected by smog as Beijing. Inhabitants wear these masks in an attempt to protect themselves against fine dust particles and pollutants.

The choice of material depends on how the pcb is connected to the cooling plate. This means that gap fillers and silicone pastes are predestined for such structures where heat sinks and heat sources, when in use, are screwed together or are otherwise securely connected by mechanical means and squeezed together. Thermally conductive silicone adhesives, in contrast, bond the two adherends through their adhesive strength so that additional mechanical fastening is not required in many cases.

Even an electric motor (see article on page 56) generates heat during operation – despite a high degree of efficiency, which is generally over 90 percent. In comparison, combustion engines reach an efficiency of around 30 to 45 percent. Most of the heat is released in the stator, the stationary component of the electric motor. Various automobile manufacturers have decided to produce stator coil windings for future motor generations by using hairpin technology as this unconventional technology permits faster large-scale production.

There are two reasons why efficient heat dissipation is necessary in electric motors as well: firstly, the wire enamels used to coat the stator windings can age due to the heat. This must be prevented as the electrical insulation effect of the enamel is essential for problem-free motor operation. Secondly, permanently excited synchronous motors – a frequently used motor type – use magnetic materials derived from rare earth metals and some of these materials can lose their magnetic properties at temperatures above 130 °C. In addition, the heat dissipated from the electric motor can be very readily deployed elsewhere, for instance to heat the passenger compartment and the windshield. This protects the battery and increases the range. Dr. Christian Ochs, another applications laboratory head at WACKER SILICONES, commented: "In this respect, it is also important

Kilometer-long traffic jams every day: Thailand's capital, Bangkok, suffers from bumper-to-bumper traffic and exhaust fumes. Thailand has started a program to promote electromobility in order to reduce pollution.

17%

of worldwide carbon dioxide emissions are caused by road traffic alone.

"Short production times are possible when our silicone products are used to manufacture electronic components."

Dr. Klaus Angermaier, Global Business Development, WACKER SILICONES

to note that significantly less waste heat is normally generated in an electric vehicle. Intelligent systems for waste-heat utilization and insulation will therefore be used."

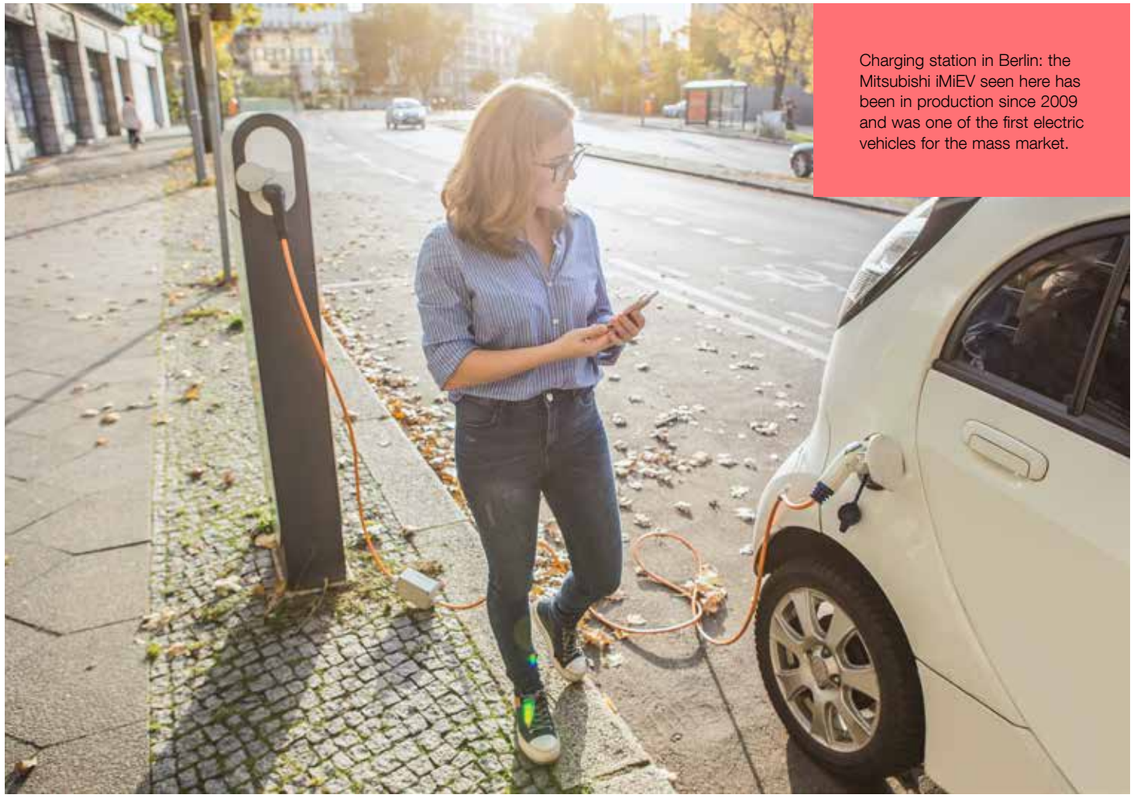
Electric motor manufacturers are currently investigating various approaches to heat dissipation. "It is still unclear which one will prevail. But it is clear that thermally conductive silicone products can play an important role here," said Dr. Ochs.

One such approach proposes transferring the waste heat from the stator via the laminated core (armature) – an important component in the stator – to the motor housing with the aid of a thermally conductive silicone resin. WACKER has developed the SILRES® H 68 TC silicone resin precisely for this purpose. The resin is so viscous at 60 °C that it can be easily trickled into the small gap between the copper hairpin and the stator sheets.

Another approach to heat transfer uses the route along the copper hairpin toward the winding heads lying on the front of the stator. WACKER has an appropriate product for this application, too, as explained by Dr. Ochs: "In this case, a thermally conductive elastic silicone encapsulant such as ELASTOSIL® RT 744 TC can effectively support heat transfer."

A peek into the engine compartment of a Renault Fluence: this vehicle was equipped with a traction battery that could be replaced at special stations. Time-consuming charging was therefore no longer necessary. The thick orange high-voltage cables are clearly visible under the engine hood.

A rapid-charging Tesla station, or supercharger, at the Austro-Italian border: these superchargers can only be used by Tesla vehicles, however.



Charging station in Berlin: the Mitsubishi iMiEV seen here has been in production since 2009 and was one of the first electric vehicles for the mass market.

Other discussions involve whether the laminated core of the stator should feature small channels that coolant medium can pass through. The medium in this case could be a heat-resistant silicone fluid, such as POWERSIL® Fluid TR 50, which has been used for many years now to cool transformers. In comparison to water-glycol mixtures used for cooling in modern combustion engines, silicone fluids have the advantages of not being electrically conductive and of remaining free-flowing right down to -50 °C. Optimal cooling would therefore be ensured even during a cold start in the depths of Nordic winters.

An electric motor maintains a high torque across the entire speed range. The maximum torque is already available at speed zero in contrast to conventionally operated vehicles with transmission where torque increases up to a specific speed. Even with a comparably moderate motor performance, the electric vehicle achieves enormous acceleration from a stationary position, while the driver of a diesel or gasoline vehicle has to tediously shift gears – electric vehicles mean more driving fun, but also more frustration at gas stations. Even with a Tesla DC charger, also known as a supercharger, drivers need to wait 30 to 40 minutes until the battery is 80 percent charged.

PROTECTING AGAINST THE ELEMENTS

Automotive manufacturers and their suppliers are hoping that electric vehicles will gain in appeal once the principle of inductive charging becomes more widespread. Charging is far more convenient with this wireless technology: drivers simply position their vehicles over a charging panel set into the ground. Although charging takes longer in this case, the process can be implemented with standard AC voltage systems. As soon as the vehicle is correctly positioned with the help of an electronic driver assistant, charging starts automatically. Such charging panels can be installed not only in garages, but also in customer parking lots.

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What's more, visionary concepts envisage these installations at traffic lights, railroad crossing barriers or along traffic routes in general so that even fairly short stopping times could be used for charging.

This charging technology uses the principle of magnetic induction: high-frequency alternating current flows through a coil in the charging panel. The current is generated from a stationary AC voltage network by means of power electronic components. A second coil is located under the vehicle floor. Once both coils lie on top of one another, an alternating voltage is generated in the second coil. This is rectified by the vehicle's on-board power electronics to charge the traction battery. The base plate and vehicle also contain electronic components that are networked via WLAN and which control the entire charging procedure. The efficiency of this contactless charging is today almost as good as charging with a cable.

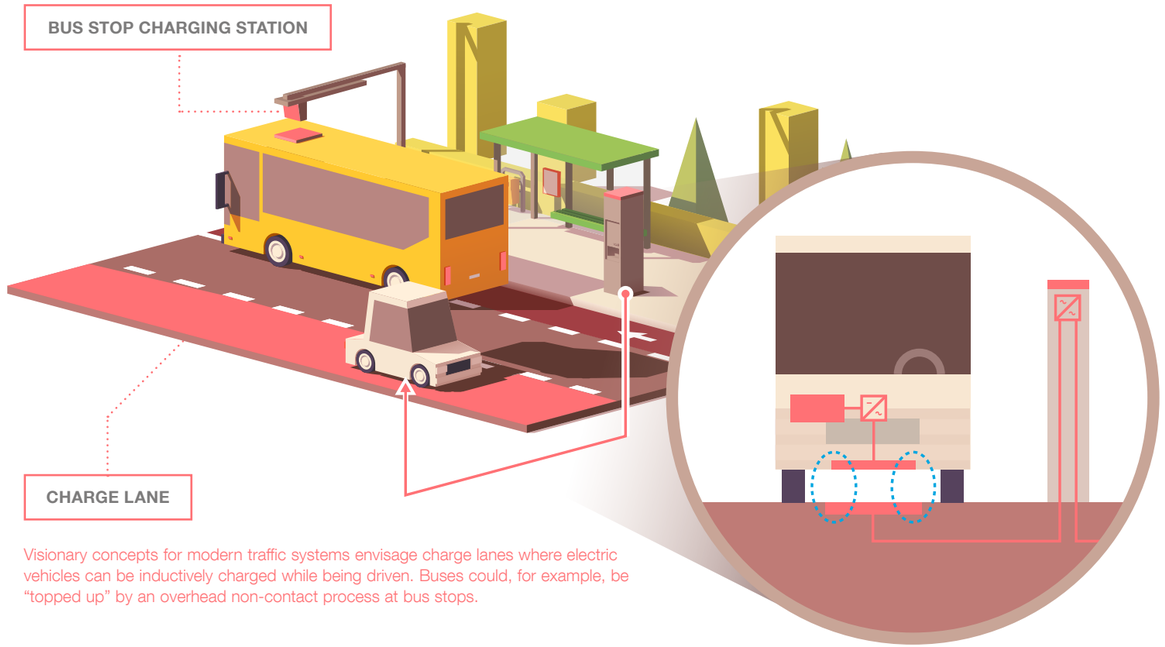
The charging electronics are encapsulated to protect them against weather conditions and mechanical stress. WACKER offers a comprehensive range of encapsulants, sealants and adhesives for this purpose. These either rapidly cure at room temperature or at moderate temperatures or form bonds with the substrates involved – extremely interesting and important for innovative industrial-scale production. "Short production times are possible when our silicone products are used to manufacture electronic components. And the electronics are perfectly protected for many years under such rough operating conditions," underlined Klaus Angermaier. Automotive companies are currently working intensively on the enhancement of inductive charging systems.

Wireless charger for a smartphone: electric vehicles may be able to "top up" on electricity using the same principle in the future.

Entering the electromobility age means that the automobile industry is undergoing an upheaval affecting the whole supply chain and supplier relationships. A great many automotive manufacturers are, for example, intending to set up their own battery and motor production lines and will then purchase the necessary raw materials directly from the suppliers. This means that WACKER will continue to deliver silicone products – such as the thermally conductive gap fillers required for effective heat management – not only to automotive suppliers, but also directly to automotive manufacturers. In this regard, WACKER is working to obtain certification for the relevant production areas in compliance with the IATF 16949 standard which is applicable to all automotive suppliers (see interview on page 61).

Ultimate technical solutions have not yet been established with regards to the technical design of individual electric-vehicle components and charging-infrastructure details. "We do, however, clearly see today that silicones will play an important role in electromobility. Above all, they will help to ensure that key technical components function over the long term," summed up Angermaier. ■

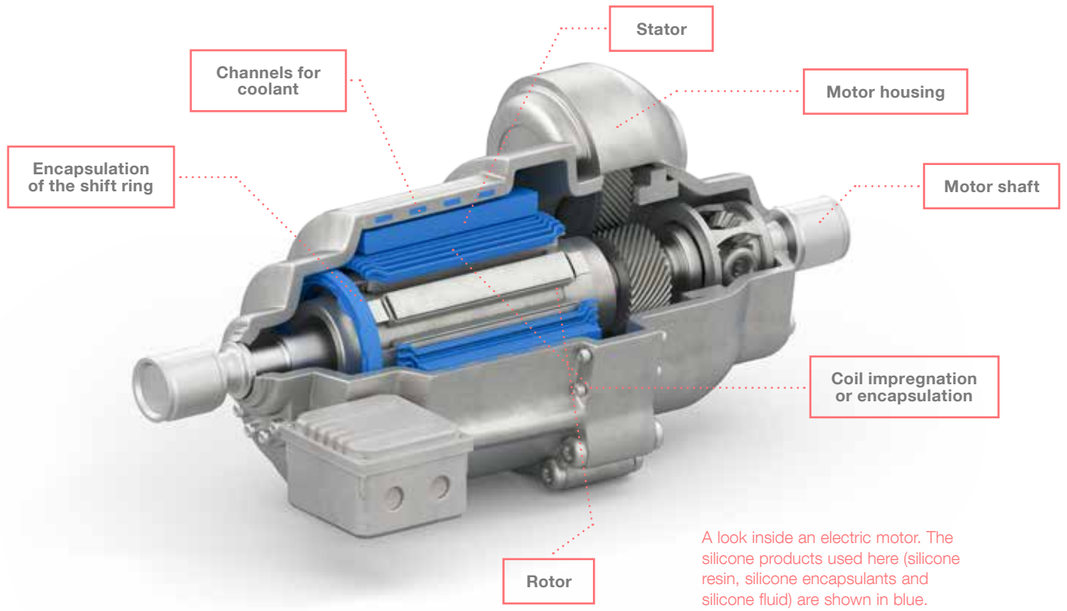
CHARGING WHILE DRIVING – WITH INDUCTION



Visionary concepts for modern traffic systems envisage charge lanes where electric vehicles can be inductively charged while being driven. Buses could, for example, be "topped up" by an overhead non-contact process at bus stops.

Principle of inductive charging

KEY COMPONENT
ELECTRIC MOTOR



A look inside an electric motor. The silicone products used here (silicone resin, silicone encapsulants and silicone fluid) are shown in blue.

Automotive manufacturers are using three-phase current motors in electric vehicles, primarily as permanently excited synchronous motors. Such motors achieve high performances, despite their compact size and low weight. These are almost always so-called internal rotors: located on a shaft, the rotor rotates inside the stator, which is designed as a hollow body. The stator (i.e. stationary part) is fixed to the motor housing, whereas the rotor is mounted such as to rotate inside the housing. The housing is usually actively cooled.

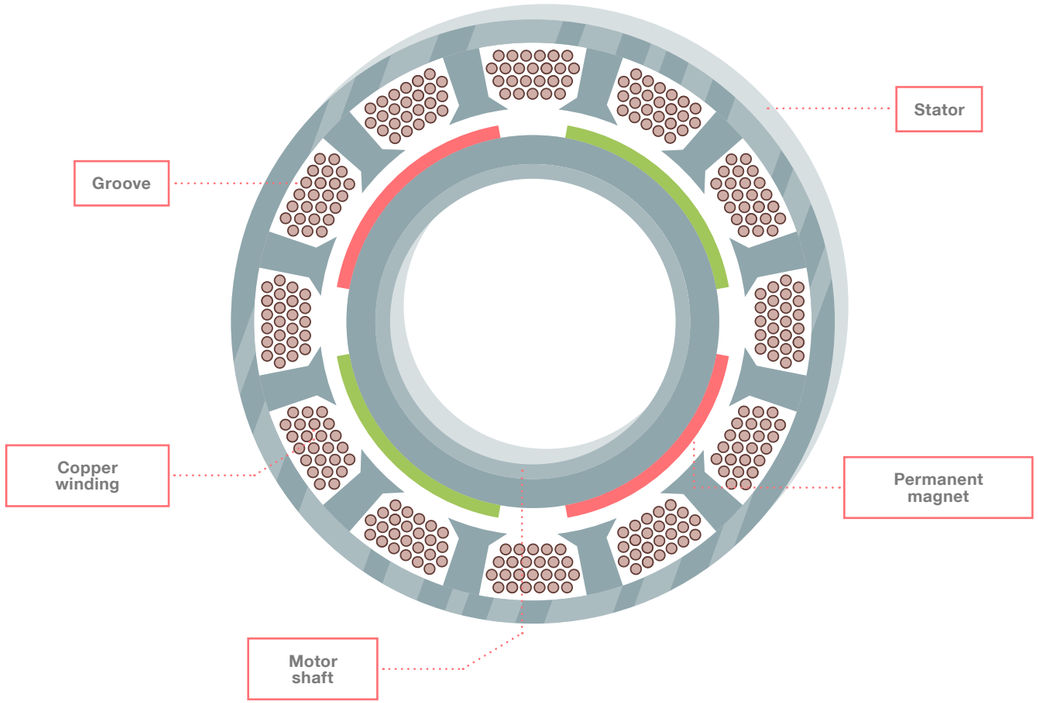
The main stator components are the laminated core or armature – a stack of annular, punched iron plates with grooved inner rims – and a system of coils whose windings lie in the grooves. These coils, known as windings in motor technology, are supplied with three-phase current. They are designed for the three-phase current to generate a magnetic field whose direction constantly changes within the stator – the magnetic field spins around its axis. The rotor's permanent magnets generate a permanent magnetic field, which follows the rotary field of the stator so that the rotor and motor shaft also rotate. The speed is determined by the frequency and the amount of torque by the amplitude of the three-phase current.

The windings can be designed in various ways. The traditional method is coil winding using a copper round wire – a complicated production method. The trend is currently moving towards hairpin technology, which involves forming coils from thin copper wire segments with a rectangular cross section. The segments are bent into hairpin shapes – hence the name – and inserted into the grooves made for this purpose in the laminated core, then bonded according to a certain pattern by soldering. Hairpin technology is suitable for the creation of fast, industrial-scale production.

Heat is generated in the windings and the laminated core of the stator during operation and this must be transported to the heat exchanger. A thermally conductive silicone resin or silicone encapsulant can help in the transfer of heat.

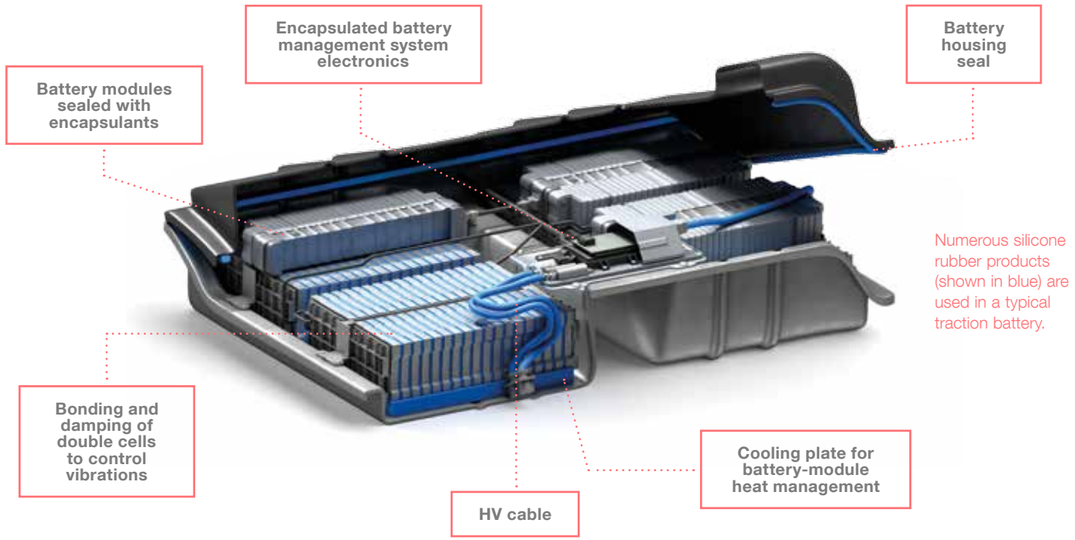
In contrast to combustion engines, three-phase motors supply a constant torque over the entire speed range used and do not therefore need complicated gearing. This kind of motor is also capable of recuperating energy, as it acts as a generator during braking, converting the majority of the kinetic energy into electricity. This recovered electric energy is fed into the traction battery.

PERMANENTLY EXCITED SYNCHRONOUS MOTOR



Schematic cross section of a permanently excited synchronous motor designed as an internal rotor: the rotor is positioned on the motor shaft and is located inside the stator, which is connected to the housing. The color of the permanent magnets indicate which magnetic pole is pointing to the stator (red: north pole, green: south pole). The stator windings are switched in turn so that their magnetic field makes the rotor rotate.

KEY COMPONENT
LITHIUM-ION BATTERY



Numerous silicone rubber products (shown in blue) are used in a typical traction battery.

Lithium-ion batteries are rechargeable battery systems that use lithium ions as mobile positive charge carriers in their cells. The cells contain two electrodes that can reversibly store the lithium ions and an electrolyte in which the lithium ions can be transported between the electrodes. A thin membrane, known as a separator, is positioned between the electrodes. This membrane is an electrical insulator, but is permeable to lithium ions. Chemical reactions take place in both electrode materials – spatially separated from each other – and this generates an electric voltage between the electrodes.

Current traction-battery production often uses cells with graphite anodes and a lithium-nickel-manganese-cobalt oxide (abbreviated to NMC) for the cathodes. The electrode materials are present as thin layers on metal foils which act as current collectors, transferring electrons that are flowing in or out. The electrolyte is a solution of a conducting salt that contains lithium ions (lithium hexafluorophosphate) in a mixture of organic carbonates.

Such NMC-graphite battery cells achieve both a high specific energy and a high power density, and can therefore store large amounts of energy per kilogram and rapidly release the stored energy. Specific energies of up to 260 Watt hours per kilogram for these battery cells are technically feasible, but not yet common in the industry.

If an electric consumer is connected to the charged cell, the anode donates electrons to its current collector, releasing the stored lithium ions. The electrons flow through the external consumer circuit, where they do their work, before flowing on to the cathode, which accepts the electrons via its current collector. At the same time, the lithium ions released from the anode's graphite material move through the electrolyte to the cathode and are stored there. The entire procedure occurs in reverse when the battery is being charged.

A certain amount of electrolyte decomposes on the anode surface during the very first charge that takes place when the battery is being manufactured. The decomposition products, which contain lithium, form a solid film on the anode. This surface film, known as SEI (solid electrolyte interphase), is permeable to lithium ions and protects the anode from further decomposition. Parts of the SEI can be damaged due to various battery cell issues such as deep discharging or even high temperatures. Although the SEI is formed again during the next charge, the damage leads to battery-capacity reduction because of the irreversible loss of lithium ions in the electrolyte: the battery can no longer store as much charge as before.

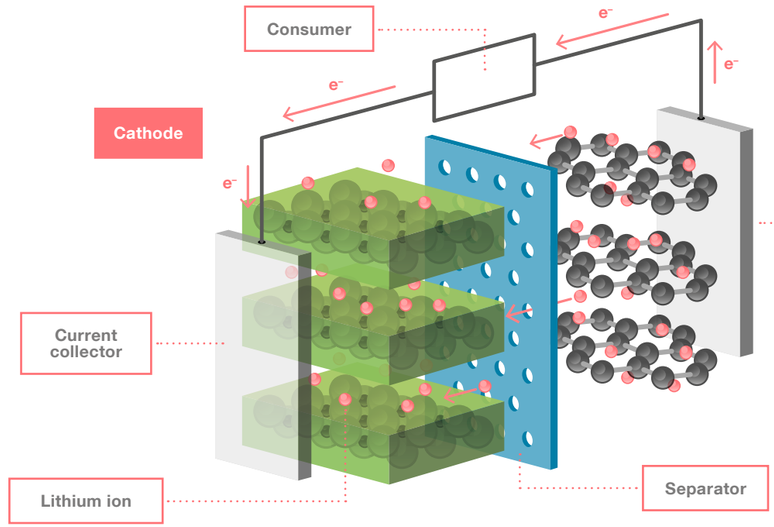
Overcharging the battery is also damaging, as it can cause the release of so many lithium ions from the cathode material that its structure is damaged. There is also the danger of metallic lithium being deposited on the anode in the form of pointed, branched crystals, known as dendrites. These electrically conductive lithium dendrites can penetrate the separator and cause an internal short circuit.

The colder the battery is, the more viscous the electrolyte becomes and this increasingly hinders the movement of lithium ions. At low temperatures, there is a danger of overpotential during charging causing lithium to be deposited in metallic form instead of being stored in the graphite.

High temperatures accelerate chemical reactions. This is particularly noticeable as undesirable aging and degradation processes in lithium-ion batteries. Temperatures above 45 °C can cause a lithium-ion battery to age rapidly, while the conducting salt reaches its thermal stability limit at 60 °C. The optimum temperature is 25 °C.

The battery therefore needs to be temperature controlled – it must not get too hot or too cold during operation. In practice, the traction battery is maintained at operating temperatures between 0 and 45 °C. The newly developed silicone gap fillers from WACKER support heat transfer between the battery modules and the temperature-control system, for instance in the cooling plate located in the lower housing shell and through which coolant flows.

CONFIGURATION OF A LITHIUM-ION BATTERY AND HOW IT WORKS



The anode material releases stored lithium ions when the cell is discharged, donating electrons (e^-) to the current collector. The released lithium ions move through the electrolyte to the cathode, pass through the separator and are stored in the cathode material. In the cell, the anode forms the negative terminal and the cathode the positive terminal.

HV cables and plug connectors: the silicone cable sheaths and silicone coating of the plug connector are orange – characteristic of the high-voltage on-board power supply.

SILICONES FOR HV CABLES

In addition to their normal 12 V network, electric vehicles have a second electrical on-board power supply with a voltage level between about 400 and 600 Volt. This high-voltage (HV) network transports electrical power between the traction battery, power modules and electric motor. Special cables and plug connectors are used.

Special cables and plug connectors transport electrical power in the high-voltage on-board power supply of electric vehicles. These HV cables are significantly thicker and heavier than the cables used in the 12 V network. Their bold orange color is a warning about the high voltage level – around 400 V direct voltage in the battery circuit and 600 V alternating voltage in the motor circuit. The automotive industry decided on these voltage levels as the power losses generated when electrical energy is converted to heat consequently remain low. The power cables used must have reliable electrical insulation – permanently and under all operating conditions, climatic zones and weather conditions – to guarantee functionality and safety of the high-voltage network over the entire service life of the vehicle.

Reliability and safety are dependent to a high degree on the cable sheath. Many cable manufacturers use silicone rubbers to sheath high-voltage cables – i.e. silicones that cure to form silicone elastomers during processing. The main reasons for choosing these materials are their excellent electrical insulation capacity, high resistance to aging and heat, and low-temperature flexibility. Silicone elastomers are also a preferred material for plug connectors: the specific design determines whether these connectors are sheathed in silicone or come with a housing fitted with silicone single-wire seals.

WACKER has put together a portfolio of ideal solid and liquid silicone rubbers for use in the high-voltage on-board power supply. They include grades providing cable sheaths with high flexibility and high tear strength. Various silicone rubbers are available for the production of single-wire seals. For example, self-lubricating silicones and silicones with low-friction surfaces are available. Seals made with such silicone grades make it easier to feed through the cable cores during the production and assembly of cables and plug connectors. WACKER also supplies self-adhesive silicones, making rapid production of two-component wire seals possible.

“EXCEPTIONAL REQUIREMENTS”

Dr. Thorsten Schneppensieper is a quality manager at WACKER. Here, he discusses the IATF 16949 standard and its significance for the production of silicone thermal interface materials.

WWW: WACKER is known to its customers for the consistently high quality of its products. Does the automotive sector need special treatment?

Dr. Thorsten Schneppensieper: The automotive industry has exceptionally high requirements that relate to the sector’s typical supply chain. Suppliers are responsible for at least three-quarters of the entire value creation inherent in the production of a vehicle. Carmakers process the supplied parts and materials using fast and highly-automated manufacturing processes. High costs would result if faulty components or materials cause their assembly lines to stand still. Automotive manufacturers expect a zero-error strategy from their suppliers so that value creation functions. The IATF 16949 standard, issued by the International Automotive Task Force, is intended to ensure freedom from faults along the entire supply chain. A supplier not certified to this standard has almost no chance of working directly with the car industry.

What are the main specifications in IATF 16949?

Error avoidance, risk management and reliability are the core of IATF 16949. The notion of error avoidance is particularly important: instead of reacting to malfunctions and correcting errors, such errors should not even arise. This minimizes the failure risk for automotive manufacturers and the liability risk for suppliers. The standard not only states what needs to be done, but also specifies how this should be done, i.e. what quality-assurance measures need to be undertaken in particular. It also entails meeting every single customer-specific requirement in full.

How would WACKER benefit from meeting these criteria and obtaining IATF 16949 certification?

We would be able to create robust, i.e. failure-proof, transparent and traceable processes, have our liability risk under firm control, stabilize our existing business and open up new markets in the world of automotive manufacturing. In many regards, we have already been working along these lines for a long time. But now that the era of electromobility is dawning in the automotive industry, the right time has come to actively seek certification. We have decided to certify that section of production which also includes thermal interface materials because we see great market potential for our gap fillers in electric vehicles.

What progress have we made in obtaining certification?

The first steps have been taken. We have already installed the first system improvements for error avoidance in the production of thermal interface materials. The idea is to make it practically impossible for anyone operating the production equipment to do something wrong. Our goal: we want to achieve certification within two years.

MOLDED INTO SHAPE

The colors, raw materials and other ingredients in chewing gum are always changing – but the actual shape of the gum has so far been limited. CAPIVA® C 03 from WACKER is coming to the rescue, as it allows manufacturers to deposit chewing gum into a variety of different molds.

WWW 1.18 ▸ INNOVATIONS ▸ **CHEWING GUM**

"Retooling the system in this way lets us make chewing gum in any shape we want on the same equipment we'd use for normal candy production."

Patrick Knoll, Bosch Makat Candy Technology GmbH

The rheology and viscosity of a mixture can be adjusted so as to prevent undesirable phenomena such as a stringy consistency or entrapped air.

Statistically speaking, 13.5 pieces of chewing gum a year go into the mouths of every human being on earth – a number derived by taking the volume of chewing gum sold in 2017 according to the Euromonitor market database (700,000 metric tons) and dividing that figure by the global population. The phenomenon is not new: humans have been chewing rubbery substances for thousands of years. Whereas northern Europeans chewed birch tar, the Romans preferred mastic, a resin obtained from the mastic tree. The Maya and Aztecs, on the other hand, consumed chicle, the latex of the sapodilla or naseberry tree. Chewing gum has continued to develop over the centuries, and now generally begins with a gum base that serves as a carrier for sugar, polyols or other sweeteners and flavorings.

New flavors have continued to pour in over the years, and the purpose of chewing gum has changed as well. No longer consumed just for enjoyment, chewing gum is now used as an oral-care product and as a means of delivering medications.

SHAPE LIMITATIONS

While the composition and taste of chewing gum may be quite diverse, the shapes it can take have been limited up to now. The reason for this lies with the raw materials, which must be mixed while warm – whereas candies suitable for molding into any shape can be cooked. Chewing gum traditionally consists of a gum base, powdered sugar or polyols and concentrated flavorings. The mixture takes on a tough, sticky consistency at around 60 °C and has to be processed by special, high-performance equipment, after which it is forced through an extruder. The extruded material can then be cut into pellets (tabs) or sticks of various sizes, or it can be shaped into gumballs.

WACKER, one of the leading manufacturers of polyvinyl acetate solid resins for chewing gum, is introducing CAPIVA® C 03, a copolymer-resin-containing composition that opens up the door to entirely new shapes. Insoluble in water, this premix can be completely melted, allowing it to be blended uniformly into a sugar compound. "In other words, we're producing a raw material that lets you cook chewing-gum-like candy and shape it however you want instead of going through an elaborate mixing process," explains Dr. Thomas Wimmer, head of the chewing-gum lab run by the WACKER BIOSOLUTIONS division.

Dr. Thomas Wimmer working in his laboratory to create the perfect formulation.

RUNNING TESTS IN A PILOT PLANT

The process also works on an industrial scale, as demonstrated by a pilot project carried out by a team from Bosch Makat Candy Technology GmbH, a subsidiary of Bosch Packaging Technology near Cologne, Germany, that manufactures specialty equipment for the confectionery industry. "Thanks to CAPIVA® C 03, we had to spend very little on additional plant components. So producing a huge variety of shapes is no problem on our existing mogul line," says Patrick Knoll of Bosch Makat Candy, who worked on process-engineering issues with Dr. Alessandro Capuani, a business development manager in the Gum department of WACKER BIOSOLUTIONS.

Bosch Confectionery Technology specializes in developing and constructing what are known as mogul lines for large-scale manufacturing of gummy bears, jelly candies, etc. Through the introduction of heat, a continuous cooker upstream from these lines produces a homogeneous, crystal-free mixture that is then brought to the required molding temperature under vacuum, thus minimizing the water content of the mixture. Further

WWW 1.18 ▸ INNOVATIONS ▸ **CHEWING GUM**

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this topic, please contact:

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ingredients such as colorings, flavorings or acid are then added.

LITTLE INVESTMENT REQUIRED

The next step is where CAPIVA® C 03 comes into play. CAPIVA® C 03 can be melted in a bulk melter at 100–115 °C and pumped into the hot sugar solution through special dosing and mixing equipment. "Retooling the system in this way lets us make chewing gum in any shape we want on the same equipment we'd use for normal candy production," Knoll explains. Stirring produces a homogeneous mixture that is immediately ready for molding via what is known as the mogul process, which involves depositing the mixture into prepared starch molds.

"The advantages of using starch molds are that you can create any shape you can think of and you can change molds quickly," Knoll points out. The mogul process is suitable for a wide range of confectionery products, such as jellies, gummy candies, marshmallow candies, soft candies and fondants – and now for chewing gum too. Chewing gum made from CAPIVA® C 03 can easily be deposited, shaped and dried in silicone molds as well.

"We can adjust and optimize the formulation to meet the customer's technical specifications so that the production systems will run as smoothly as possible," explains Dr. Capuani. Working in Dr. Wimmer's laboratory, Capuani collaborates with customers to work out the most suitable formulation for them. Changing the composition allows researchers to alter the rheology and viscosity of the mixture to create a depositable material that molds well and is easy to process, thus preventing undesirable phenomena such as a stringy consistency or entrapped air. "CAPIVA® C 03 allows us to offer formulations that don't become stringy or that gum up the equipment – thus reducing the time spent on cleaning and the amount of material consumed," Dr. Capuani adds by way of explanation. Chewing-gum ingredients formulated with CAPIVA® C 03 can be easily cleaned from equipment using hot water or common industrial detergents.

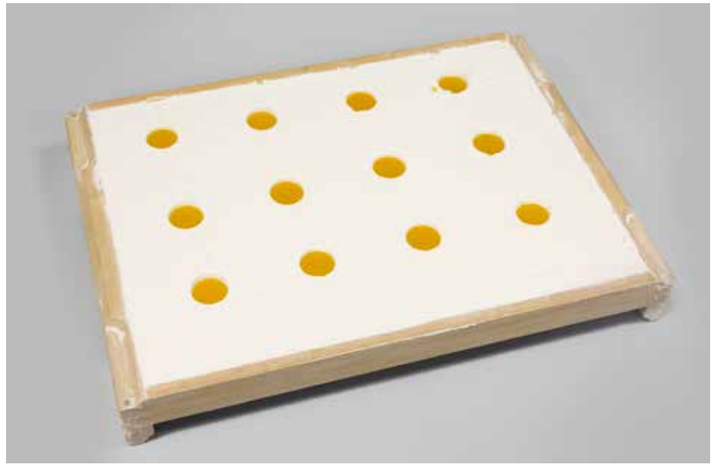
A FLEXIBLE FORMULATION

As with other confectionery products, the ability of molded chewing gum to retain its shape depends on the precise formulation and the ingredients used. "We can vary the formulation and the process parameters to make the product harder or softer. But CAPIVA® C 03 gives us greater versatility when it comes to the formulation," says Dr. Wimmer. Another advantage is that the cooking process allows formulators to use a number of liquid ingredients that could not be used in the conventional process.

WACKER developers are convinced that CAPIVA® C 03 will open up many new opportunities. "By offering new moldable chewing-gum products, we hope to encourage our customers to bring more variety to the candy aisle without having to neglect classic chewing gum," Capuani explains. ■

Dr. Alessandro Capuani depositing the warm chewing-gum base into mogul molds. CAPIVA® C 03 makes it possible to customize the shape of the mixture.

Bosch engineers used their equipment to test WACKER's new formulation. The result is a mixture that is easy to use in conventional industrial confectionery-manufacturing equipment.



Chewing-gum ingredients formulated with CAPIVA® C 03 can be used to mold chewing gum in every shape imaginable.

COPIES FROM THE HAND OF A MASTER

One of the best in his profession, Arnaud Briand has a contract with the French association of national museums to create plaster copies of the most important sculptures in art history. And for his reproductions of originals he uses silicone elastomers from WACKER.

Modern public housing, a dozen construction sites surrounded by cranes, and plots overrun with weeds – this is what the neighborhood looks like around the "Ateliers de moulage." This studio, which belongs to the national museums of France and where replicas of the most significant sculptures from antiquity to modern times are made directly from the originals, is housed in an unprepossessing, functional metal building from the 1990s in Saint-Denis, Paris – just a few hundred meters from the well-known soccer stadium. While this suburban location may jar with the images we commonly associate with stately French museums, the disconnect quickly fades as soon as you walk through the doors of the studio.

Inside, immediately next to the breaker box and the fire extinguisher, suggestive necklines lure visitors over to three red-white-and-blue sculptures of Marianne, the national symbol of France. In the spacious lobby, which serves as both an office and a reception area, well over 250 busts and miniatures are stacked up to the ceiling on simple wooden shelves. Eyes gazing into the distance, hands folded gracefully, muscular bodies outstretched. A desk with a computer is all but

"Now, when I organize my 'ingredients' for making an impression of a piece, I follow the same strategy I used for managing deliveries in the kitchen. You have to be really well prepared."

Arnaud Briand

invisible behind a monumental statue of a reclining three-meter-long Greek goddess. The head of a Madonna serves as a bookend on the back shelf; boxes of index cards form the foreground to an ancient Roman relief; and immediately next to that, the tender face of a child shares the cramped shelf space with a used coffee cup.

"There are a lot of amusing coincidences around here. Entirely unrelated objects end up sharing the same space," says Arnaud Briand with a laugh. The 43-year-old Frenchman is a moulleur statuaire – a moldmaker and plaster-caster, in other words – and has been authorized to refer to himself as a Meilleur ouvrier de France since 2015. This prestigious, lifetime title – MOF for short – is an honor bestowed in France on unusually gifted artisans who have undergone an exacting test and are esteemed master craftsmen. "The title is something of a holy grail," explains Briand, who took the challenge in the "Decorative Plaster Sculptures" category and succeeded. "There are only four or five MOFs in France with this particular area of specialization. And here in the studio, I'm the only one."

Below The foyer to the master copier's kingdom: visitors are greeted by over 250 busts, some of them over 200 years old.

Right Arnaud Briand in his studio

Above The master craftsman, who bears the title of Meilleur ouvrier de France, blends the silicone. He knows the formulation by heart and adjusts it to suit the current room temperature and humidity.

Right The first step in making an impression is to coat the original sculpture with a layer of polyvinyl alcohol to protect it from being damaged during the process. You always get the best mold from the original, says Briand.

INTUITION REQUIRED

Briand began working in Saint-Denis in 2009 when the renowned studio operated by the Louvre and the French association of national museums (RMN) was contracted to replace the sculptures in the gardens of Versailles with more weather-resistant cast-resin copies. "I had worked with a lot of casting resins for my previous employer, so I had a fair bit of experience with the material," explains the Parisian, who took a non-traditional path to his profession, discovering his passion for casting only at the age of 30. Prior to that, he had spent ten highly successful years in catering. When his then boss was forced to close his restaurant, Briand had to make a choice: either open his own bar or change careers. A three-month internship eased the decision for him. "My years in catering help me in my work today too," says the master craftsman. "Now, when I organize my 'ingredients' for making an impression of a piece, I follow the same strategy I used when managing deliveries in the kitchen. You have to be really well prepared."

And that preparation shows: Briand's work bench has everything on it he needs, all carefully laid out and waiting to be used. Kitchen utensils such as pastry scrapers, knives and ladles are positioned next to numerous spatulas, a wire brush, scissors, emery paper and an electronic scale. Large tools like saws and electric drills hang on the wall where they are readily accessible. The windowsill is strewn with plastic containers full of brushes in all shapes and sizes. An old olive jar is filled with mineral spirit. "This spirit is exceptionally compatible with silicone. Just the thing for cleaning brushes."

THE ORIGINAL ENSURES THE BEST QUALITY

Briand reaches for a pack of blue disposable gloves and begins working on an 18th-century bust about 30 centimeters high. "You always get the best mold from the original. But we have plaster molds here that are nearly 200 years old and, in some cases, are in better shape than the original sculpture," he explains as he brushes a protective coat of polyvinyl alcohol onto the bust.

While that layer dries, Briand blends the silicone for the first coat. He places a bucket on the scale and uses a plastic cup to measure out the ingredients – which he appears to do just by feel. The muscular Parisian then stirs the mixture with a pastry scraper, constantly checking its texture. "While I do have a book with all the formulations, what I've learned from experience is even more important," says Briand. "Because many factors can play a role, like room temperature. It's a little cool in the studio today, for example. I have to take that into account."

When he uses brand-new products, Briand initially sticks to the recommended proportions provided with the product. After that, however, he feels it is his job to perfect the formulation. "Trial and error is the only way to bring out the best in a product. I'm really curious, and I like experimenting, because it shows me the limitations of a product and indicates what will work and what won't." And afterward, he's happy to share his experience with the manufacturers. He also tells them what he'd like.

Right now Briand is trying out WACKER's new curing agent for its ELASTOSIL® M silicone rubber compounds, which are distributed in France by ABYLA (Gazechim Group). NEO is a catalyst containing no organotin com-

> "While I do have a book with all the formulations, what I've learned from experience is even more important."
>
> **Arnaud Briand**

WWW 1.18 ▸ APPLICATIONS ▸ **MOLDMAKING COMPOUNDS**

Above When using a casting process to make a mold, the individual parts first need to be securely bolted together before casting can begin. Shown here is a small-scale copy of a bestseller: the Nike of Samothrace.

Right A finished mold: a number of layers combine to form a solid casing. In the center, you can see a negative impression of the back of a sculpture.

pounds, and the corresponding NEO booster makes it possible to cure relatively thick layers of material – together with silicone rubber, an excellent combination for making a mold quickly.

"I see this product as a major advance," Briand says. After all, when he and his colleagues worked on their contract in Versailles, they processed 120 kilograms of silicone in just one-and-a-half weeks. And even in the case of a small bust like the 18th-century head he's currently working on, he still uses two to three kilos, because he will apply up to four layers of material to the sculpture.

In each new layer of silicone, the master moldmaker slightly modifies the texture and composition, adding a few drops of a catalyst or a thickener here and there. "You get a better result if you work with a really thin silicone for the first two layers and with thicker material after that."

Silicone is now dripping continuously onto the work bench. Again and again, Briand uses scissors to cut off the drops and carefully pats the surface with his little finger to monitor the drying progress. He allows about a half hour to elapse between each layer. The final layer is applied along with a glass fiber mesh, which partially envelops the previous layer.

For difficult spots around the eyes, mouth, ears and nose of the sculpture, Briand uses a syringe to apply a rather viscous silicone, which he has optimized with a thickening agent. This smooths out irregularities to produce a homogeneous surface he then carefully blots with a damp sponge. "That destroys the air bubbles that form when I apply the silicone." The back of the sculpture has already been sufficiently reinforced with a final layer of silicone rubber. For this last layer, he has to stay focused and work fast – it hardens in just five minutes.

> "You can't make any mistakes while casting because you can't go back and fix anything."
>
> **Arnaud Briand**

Briand primarily uses two grades of silicone: ELASTOSIL® M 4514 is his choice for preparing skin molds, as they are known. By adjusting the concentration of the curing agent or by adding

Preparing and organizing your tools well is an indispensable step in creating copies if the process is to go smoothly.

a thickener, he can also use this compound for controlled, vertical molding processes. And for casting what are known as block molds, he uses ELASTOSIL® M 4630 A/B.

Using a casting process to create silicone molds is technically very demanding. "You can't make any mistakes during casting because you can't go back and fix anything," he stresses. That's what, in his opinion, makes ELASTOSIL® M 4630 A/B so suitable: it does not exhibit any chemical shrinkage, and so does not contract. The result and the quality of the work are not visible until the model is removed from the mold, however. "Cast models generally last longer and retain their quality better than copies made vertically," the Frenchman explains, running his hand through his close-cropped hair after finishing the job.

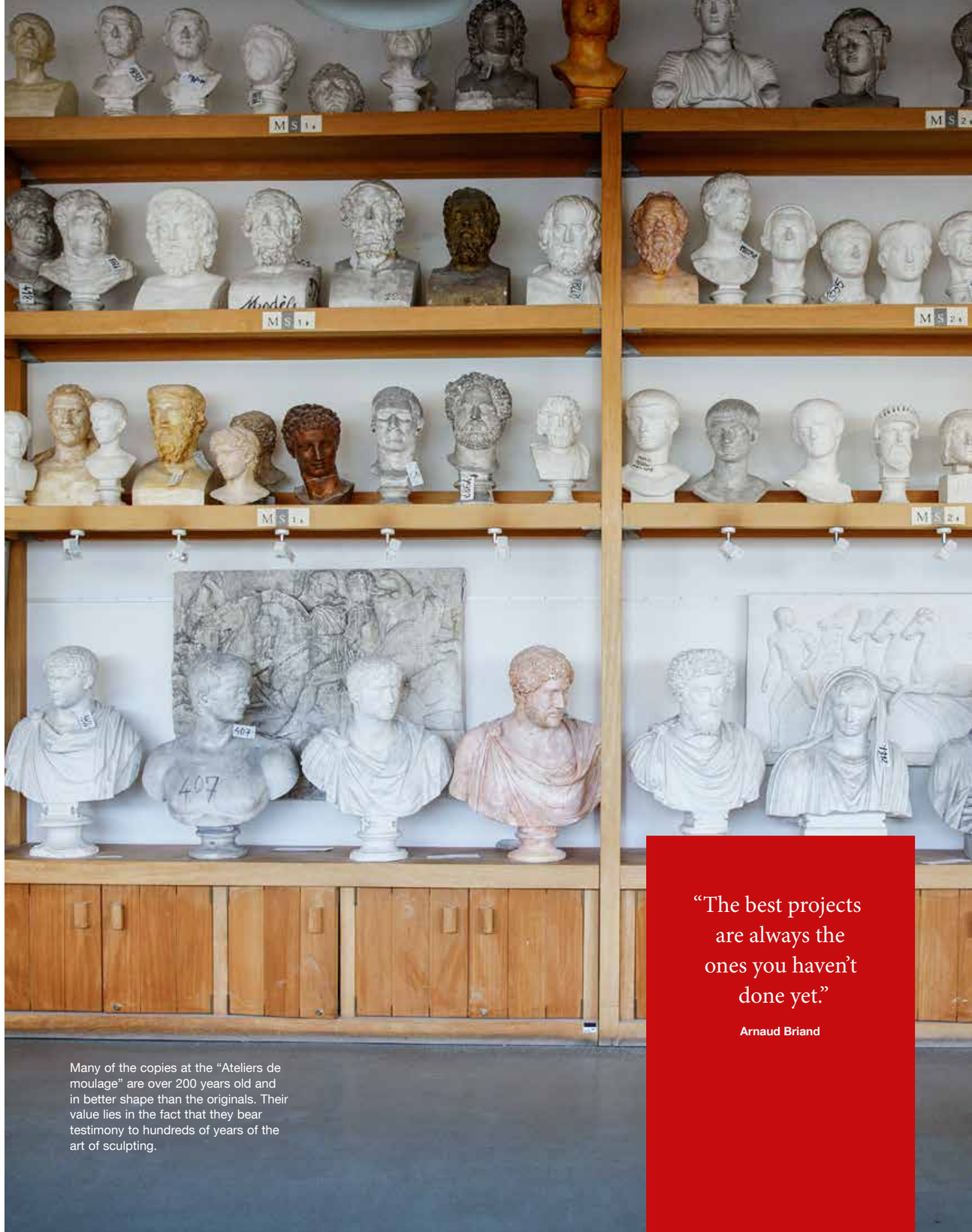
DOZENS OF COPIES POSSIBLE

If it never comes into contact with water, a plaster cast can last for up to 1,000 years, Briand explains. And a silicone model? "We can't say for sure, since we've only been using the material for 50 years." It also depends on how often a copy is cast from the mold. "We've used a lot of our molds here 30 to 40 times. Others we've only used once."

The greatest demand, he says, is for sculptures of Molière and Voltaire, and the bust of Louis XIV by sculptor Gian Lorenzo Bernini. "Bernini is one of my favorite artists. He was a contemporary of Michelangelo, but in my opinion, Bernini's work is even greater than Michelangelo's. His sculptures display extraordinary finesse."

At the end of his workday at the "Ateliers de moulage," Briand is covered head to toe in white flecks of plaster, silicone and resin droplets. The floor, work benches, tools – simply everything in his studio – is spattered with spots. Only the sculptures gleam in flawless white.

Does he have a project that he dreams of doing? The father of two does not hesitate for long: "The best projects are always the ones you haven't done yet," he says as he leaves, closing the studio door behind him. Its silent residents, the hundreds of busts and sculptures, now wait for their latest companion – created today by Arnaud Briand's hands – to leave the drying chamber and join them on the shelf. ■



Many of the copies at the "Ateliers de moulage" are over 200 years old and in better shape than the originals. Their value lies in the fact that they bear testimony to hundreds of years of the art of sculpting.

"The best projects are always the ones you haven't done yet."

Arnaud Briand

A BROAD FIELD

Nature harbors millions of mushroom species. Most remain shrouded in mystery. Bremen-based preparator Klaus Wechsler has developed a process using WACKER silicone moldmaking compounds to preserve them for posterity.

Dozens of angel wing (Pleurocybella porrigens) thrive on a rotting tree trunk; the octopus stinkhorn's fiery red tentacles reach toward the sky while the golden-capped larch bolete glistens brightly. Over 1,000 mushrooms – from the delicious chanterelle to the giant puffball – are causing a stir at an exhibition currently running in Wiesbaden. Visitors gain a fascinating insight into the enormous biodiversity of these organisms – which occupy a class all of their own, belonging to neither the plant nor the animal kingdom. To date, there are an estimated four to five million largely unresearched species. A mere 130,000 species are known and have been classified.

The specimens at the "Fungi – Food, Poison and Mythology" exhibition are not, however, living organisms. These delicate models are the work of Klaus and Lilo Wechsler. The trained biologist preparator and his wife make a silicone rubber negative mold of an actual fungus. They use this mold to produce a colored synthetic cast, the intricate details of which extend to a depth of five micrometers. Klaus and Lilo Wechsler, who reside in an almost rural part of Bremen called Ellener Feld, developed their enthusiasm for the world of mushrooms back in the 1970s. "But we're not interested in mushrooms as food," says Klaus Wechsler. They hope to raise awareness for the beauty of nature with their astonishingly lifelike mushroom replicas. "I want to rekindle the forgotten art of observing," he notes. His advice is to walk through woodland with your eyes wide open.

Mycologists (scientists who study fungi) are full of praise for Wechsler's work. His replica mushrooms recreate nature far more accurately than a painting, photo or dried original. "In terms of size, shape and color, Klaus Wechsler's works are a perfect reproduction of nature," says Meike Piepenbring from the University of Frankfurt. And she should know: she is a professor of mycology and the scientific consultant for the Wiesbaden exhibition. She especially admires the almost translucent replica of the toothed jelly fungus flourishing on dead wood or the long spiny form of the milky-white bearded hedgehog mushroom. "All that's missing is odor and texture." But this would be asking too much of these intricately prepared models that stand the test of time.

NO NEED FOR FAR-FLUNG DESTINATIONS

Even though the mushrooms have exotic names ranging from crimson waxy cap, turkey tail or

Three of the delicate silicone replicas that Klaus and Lilo Wechsler made from the original fungi and then painted by hand. Left-hand page: octopus stinkhorn (Clathrus archeri); below: larch bolete (Suillus grevillei). On the right: toothed jelly fungus (Pseudohydnum gelatinosum)

Klaus Wechsler and the preparation he made of a morel (Morchella esculenta).

scarlet caterpillar club (Cordyceps militaris), the Wechlers did not have to travel to far-flung destinations to find these treasures. Observant walks along wetlands in Bavaria or Denmark yielded astonishing finds. These areas have been left relatively unscathed by agricultural or industrial pollutants, but finding fungi is still a question of luck to an extent. Even if a mycelium's delicate threads (hyphae) are capable of weaving a carpet spanning a few hectares of forest floor, the fruiting bodies they form are not visible every year, as mushroom collectors will testify. "Friends often bring amazing specimens by," says Klaus Wechsler.

> "My approach evolved slowly. Each specimen is unique and has to be treated accordingly."
>
> **Klaus Wechsler**, biological preparator

A replica of a bearded hedgehog mushroom (Hericium erinaceus): this rare fungus is a parasite that grows from the wounds of older deciduous trees, usually oak and beech.

Once he gets his hands on the mushrooms ensconced in peat moss, he has to act swiftly. Years of experience have taught him that the coloring of fungi, in particular, rapidly changes. Wechsler inspects the specimens, which he has spiked on a thin wire. His trained eye notes the base shade and the mottled coloring on the stalk and cap. He compares each shade with a palette in his practical, albeit well-worn book that lists over 1,000 color nuances. He accurately notes the color codes he will later use as a basis for painting the models. "The process evolved slowly," says the mushroom enthusiast. "This is not a standard procedure. Every specimen is unique and has to be treated accordingly."

The next step is to conserve all the intricate structures of the fruiting body – its micrometer-sized hairs, gills and grooves – with a moldmaking compound: Wechsler dips the mushroom, which is fitted on a wire and securely affixed to it, into a white, low-viscosity rubber compound: WACKER's two-component silicone rubber ELASTOSIL® M. This compound penetrates every tube and every gill, cleaving perfectly to the mushroom's anatomy.

INCREDIBLY FINE STRUCTURES

"Silicones can only replicate such intricately detailed structures if they have outstanding flowability properties and can cover long flow distances," says Hans-Rudolf Pfeffer, who is in charge of technical support for silicone moldmaking compounds at WACKER.

MUSEUM WIESBADEN

The "Fungi Food, Poison and Mythology" exhibition showcases over 1,000 fungi, from the giant puffball to the scarlet caterpillar club. These fungi are impressive examples of state-of-the-art replicas created by Lilo and Klaus Wechsler. The exhibition runs until August 5, 2018.
museum-wiesbaden.de/en/exhibitions/pilze/619

Fungi exhibition at Museum Wiesbaden. Klaus Wechsler created the replica fungi on show in the exhibition's 17 biotope display cases, but not the giant models.

Above left: part of a silicone elastomer negative mold of a Lake's bolete (Suillus lakei)

Above right: a three-part negative mold and a block mold of a Lake's bolete

Opposite page, bottom right: model of a white saddle (Helvella crispa)

Ramaria flavescens is a coral fungus featured on several European countries' Red List of threatened species.

Available in dozens of grades, ELASTOSIL® M is used in the ceramics, jewelry and food industries. Prototypes of household appliances, for example, are also made with silicone moldmaking compounds. Even after some 39 years in the business, Pfeffer never fails to be impressed by the detailed accuracy these plastics achieve. "And Klaus Wechsler's mushroom replicas with their delicate, richly detailed structures are in a league of their own," he says.

The flexible silicone rubber compound cures completely within 24 hours and stabilizes the mushrooms, recreating the original like no other process. Then what's needed is patience. Usually, he very carefully cuts the white silicone rubber compound into three sections: the cap and the two halves of the stalk. He stores these fragments for up to a year. This gives the mushroom time to rot, allowing residues to be washed out easily and – importantly – without causing any damage.

Once the mold is clean, he wets it with a mixture of mineral spirit (paint thinner) and petroleum jelly. A thin film forms on the structures and the mold can be filled with epoxy resin. For larger varieties of mushroom such as a giant puffball with a diameter of over 50 cm, Wechsler designed a special rotating mount so that the epoxy resin flows evenly into the mold and the heat is released optimally during curing. After each casting, the preparator waits at least a day before carefully removing the mushroom replica from the flexible silicone rubber compound.

UP TO 30 COATS OF PAINT

Wechsler then reaches for his notebook with the color codes he wrote down the previous year. Transparent, semi-coverage, full coverage – the sequence of the painting process is crucial. "I use oil paints thinned with turpentine which are color fast for a very long time," he explains. Depending on the color, he applies ten to 30 coats of paint to the mushroom molded with epoxy resin. He waits a day for each layer to dry before applying the next. It can take weeks to complete the work of art. "Some 100 hours of painting went into one of my larger works," says Wechsler. And that's not counting drying time.

Wechsler has produced over 1,700 exhibits with methods he has developed and refined over time. Due to their impressive quality, they are considered to be unique worldwide. As currently evident in Wiesbaden (https://museum-wiesbaden.de/en/exhibitions/pilze/619), they are very popular at mushroom exhibitions, delighting both the general public and experts. Wechsler will be more than content if his work makes a small contribution toward raising awareness for nature. "Because we can only protect what we know," he says.

Wechsler is now enjoying retirement, which will give him and his wife plenty of opportunity to discover, assess and make true-to-nature models of many more mushrooms. It is highly likely that he will continue to fascinate a great many more people with the vast and varied world of fungi. It would certainly suit Meike Piepenbring if his replicas inspired future mycologists: "Because mycology is a very broad field that is still in a pioneering phase in many areas." ■

ELASTOSIL® M

ELASTOSIL® M moldmaking materials are room-temperature-curing, two-part (RTV-2) silicone rubber compounds known for their excellent reproduction accuracy. They are ideal for making replicas, irrespective of their complexity, and for all kinds of casting material, from wax to plaster, concrete and casting resins to low-melting metal alloys. Thanks to their high elasticity and outstanding release properties, cured ELASTOSIL® M grades separate very easily from the model. Their high resistance to the reproduction material means they can be used over and over again.

ELASTOSIL® M moldmaking materials are available as pourable, paintable, non-sag spreadable and kneadable systems. The flow characteristics of the different types is described in terms of viscosity: non-sag spreadable types do not flow as well as spreadable products. Up to a maximum film thickness (mostly up to 10 mm), they neither flow down vertical or inclined surfaces nor do they sag, despite the pull of gravity.

All these processing properties make ELASTOSIL® M indispensable to moldmaking and ideal for numerous fields of application in skilled crafts and trades, and the industrial sector. The food industry uses them in chocolate production; the automotive industry deploys them for dashboard prototypes, for example, and the cosmetics industry utilizes negative molds to manufacture lipsticks.

Laboratory tests have shown that VINNAPAS® 4240 N (left) provides better tensile adhesive strength and stripping resistance than traditional products (right) – even after one day. This ensures a very strong adhesive bond between an EPS panel and masonry in external thermal insulation composite systems (ETICS/EIFS).

EXTRAORDINARY BALANCE BETWEEN TENSILE ADHESIVE STRENGTH AND FLEXIBILITY

Dispersible polymer powders are suitable for applications on walls and for finishing plasters.

At Paint Istanbul 2018 (March 22 – 24), WACKER unveiled its flexible VINNAPAS® 4240 N dispersible polymer powder, which offers an extraordinarily good balance between flexibility and tensile adhesive strength. The powder, which is based on vinyl acetate-ethylene (VAE), is ideal for various wall applications such as adhesive and embedding mortars in external thermal insulation composite systems (ETICS/EIFS) and for finishing plasters.

The high proportion of ethylene in the polymer chain means that VINNAPAS® 4240 N has a low glass transition temperature and therefore displays good crack-bridging properties and improves the flexibility of mineral mortars. As a result, the product does an excellent job of compensating for the stresses that arise due to temperature fluctuations, weathering, material shrinkage and vibrations. The dispersible polymer powder also features particularly good resistance towards severe impacts, which plays a major role in finishing plasters and in the embedding mortars used in ETICS/EIFS.

In addition, VINNAPAS® 4240 N positively affects the cohesion of the end product, thereby improving adhesion to inorganic and organic surfaces. This means that, when used for adhesive and embedding mortars in ETICS/EIFS, an extremely strong adhesive bond can be formed between EPS panels and masonry.

VINNAPAS® 4240 N can also be readily combined with other polymeric binders. When used in the dry component alongside VINNAPAS® 760 ED (a soft dispersion for two-part waterproofing membranes), VINNAPAS® 4240 N achieves a very high tensile adhesive strength in the end product without impacting the system's crack-bridging properties.

WACKER IN FIGURES

Polymeric binders based on vinyl acetate-ethylene copolymers (VAE) help improve the performance, efficiency and sustainability of a large number of products. WACKER is the world's number one producer of VAE dispersions and dispersible polymer powders. These binders are used in applications such as paints and coatings, tile adhesives, external thermal insulation composite systems (ETICS/EIFS), self-leveling flooring compounds, interior plasterwork, paper coatings and adhesives.

Over 800,000 metric tons

of WACKER POLYMERS dispersions and dispersible polymer powders were sold worldwide in 2017.

52%

is WACKER's share of the global market for dispersible polymer powders.

39%

represents WACKER's share of the global market for polymeric binders based on VAE.

Roughly 80%

of the dry-mix mortars used throughout the world are not polymer-modified – that represents enormous potential for growth at WACKER POLYMERS.

50

innovation projects

are currently underway at WACKER POLYMERS.

15

WACKER technical centers for polymeric dispersions and dispersible polymer powders are in operation around the globe.

A POWERFUL BOND

Around 3,500 years ago, adhesives were being produced in Egypt from tendons, cartilage and other animal parts for use with veneers – a fact evident in archaeological finds from the final resting place of the Pharaoh Tutankhamun. Carpenters still worked with such pastes, made from waste skin, leather or bones, up until the 1920s, when synthetic adhesives gradually became available in the market. Based on WACKER's polyvinyl acetates, these adhesives enabled substantially more hygienic processes. Also known as "white glue," they require utmost precision, as they remain white when they dry out, making any excess clearly visible. What is more, they are not waterproof. Modern adhesives using WACKER's VINNAPAS® dispersions are opaque once dry, are waterproof and weather-resistant depending on their grade, and adhere optimally to nearly all wooden substrates and wood-based materials.

WACKER

VINNAPAS® binders for wood applications are available in D2, D3 and D4 classifications of water resistance, as specified in the EN 204 standard. Where necessary, they can also be modified to exhibit low viscosity, very low sedimentation, excellent plasticizer compatibility, non-discoloration and longer open time.