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WACKER

K SPECIAL

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"SILICONES ARE A CORE TECHNOLOGY"

Dear Reader,

The goal we set – "Creating tomorrow's solutions" – highlights the crucial role innovation has always had for our business. WACKER supplies global markets and almost every key industry with precursors and intermediates, products that have become indispensable for our customers' applications.

This is especially true of silicone rubber. Its highly diverse, customizable, such as its heat and UV resistance, continuously open up new applications – in the car and electrical industries, in medical technology, in construction and in many other sectors.

In 1950, WACKER started producing silicones at Burghausen – as Europe's very first silicones manufacturer. Through team spirit, perseverance and determination, we have steadily strengthened and diversified our portfolio. Today, it contains about 3,000 silicone products.

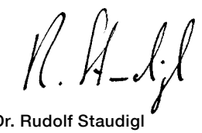
In this issue, we will show you the strength of our innovation pipeline. We will be presenting our latest solutions and products at K 2019 in Düsseldorf, the world's leading plastics and rubber tradeshow.

Making screens in cars even safer and easier to use, our new silicone laminates act as virtual buttons for screens, but are also suitable for sensor applications. These wear-free, compact and energy-saving laminates create additional opportunities through their potential as sensors. Alongside sensor technology, other promising innovative applications range from medical technology and robotics, through to the auto industry, where laminates could control the orientation of headlamps and mirrors, for example.

Our innovations in liquid silicone rubber show that we have done a great deal to meet the needs of processors and end customers for sustainably manufactured products. Indeed, we have oriented our entire LSR portfolio toward low-level volatiles. The future clearly lies with such silicone rubber grades, where even postcuring (thermal post-treatment) is unnecessary.

At K 2019, WACKER – as the world's second-largest silicone manufacturer – will again be setting new industry standards with its low-volatile initiative and other innovations, highlighting that organosilicon plastics have clearly become a core technology in numerous sectors.

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

"Our low-volatile initiative for liquid silicone rubber is setting new industry standards."

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K SPECIAL

LIQUID SILICONE RUBBER

Up to now, silicone products often required postcuring, i.e. subsequent heat treatment, to achieve the desired properties. This was particularly true of sensitive applications such as baby products. As a result, WACKER has launched a low-volatiles initiative and considerably reduced the residual volatile substances in its liquid silicone rubber products.

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NEWS

APPLICATIONS

K SPECIAL

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WACKER WORLDWIDE

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 PHILADELPHIA

WACKER, other companies, academic institutions, researchers, authorities and investors attended an annual exchange at the Biotech International Convention. This year saw a new record with 17,307 visitors from 65 countries. With more than 48,500 partner meetings at Convention 2019, the participants even broke last year's Guinness World Record for "The Largest Business Partnering Event." Biotechnology is an inter-disciplinary science that combines enzymes, cells and whole organisms with technical applications to develop entirely new medicines, make food healthier, protect the environment and more. The service portfolio of full-service contract manufacturer Wacker Biotech ranges from molecular biology, analytical services and process development, through production of clinical test samples and actives, live microbial products and vaccines, to commercial market supply.

2 NOORDWIJK

At the beginning of April, Dutch company Avery Dennison honored WACKER with its "Supplier Distinction Award." Avery Dennison is one of the world's leading manufacturers of self-adhesive materials for retail packaging, display graphics, logistics, clothing, industry and the healthcare sector. Its award recognizes suppliers for outstanding services in four categories: sustainability, quality, service and growth. WACKER began collaborating with Avery Dennison over 25 years ago in the Netherlands. Today, the company is WACKER's biggest global customer for DEHESIVE® products.

3 HOLLA

Wacker Chemicals Norway AS (WCN) was the first company to be voted "The Apprentice Company" of the year by the county of Trøndelagin. WCN regularly hires apprentices and supports young people on their journey through secondary school. The company currently has 18–19 apprentices doing training courses in various fields including chemistry and process technology, logistics, electronics and automation, industrial mechanics, office work and administration, laboratory control and production engineering. In-house educational facilities and a program enabling students to have a stay abroad were among the factors that swayed the judges' decision in favor of WACKER.

4 HAMBURG

ArcelorMittal, the world's largest steel manufacturer, wants to make steel production in Hamburg greener with wind power and hydrogen. Managing Director Dr. Uwe Braun is planning the world's first almost CO_2-free steel works on the Elbe River. The project involves using hydrogen recovered with wind power as fuel for furnaces which produce only steam after combustion. Three wind turbines on the premises of the Hamburg-based steel manufacturer have supplied some 23 gigawatt hours of electricity per year for production since 2017. The new hydrogen plant, which is set to revolutionize steel production, will go into operation in about three and a half years' time. 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.

5 KOLKATA

In April, around 200 guests attended the 20th anniversary celebrations of the Indian joint venture between WACKER and Metroark. Guests included Executive Board members Dr. Christian Hartel and Auguste Willems, and Dr. Robert Gnann, president of WACKER SILICONES. Apart from a plant tour and dinner, there was a rich cultural program featuring art shows, traditional Indian dance and vocal performances by employees. Metroark was founded by Swaraj Ranjan Mukherjee in November 1947. Metroark and WACKER formed a business relationship in the mid-1970s, which led to their joint venture in 1998, with WACKER owning a 51% share. Since February 1999, the business has been operating under the name Wacker Metroark Chemicals. Today, Wacker Metroark is the number-one provider of silicones in India and neighboring countries.

GROUP UPDATE

TECHNICAL CENTER LAUNCHED IN INDIA

The demand for customized tile adhesive solutions is on the rise in India

WACKER has strengthened its presence in India by opening a technical center in Bengaluru. “The Bengaluru technical center is another important milestone in our growth strategy for India,” said Andreas Collignon, head of Construction Polymers at WACKER. He added that the objective was to meet the individual needs of customers locally – especially in South India – and to support and test new applications. “Our technical center sets new standards for service, consulting and knowledge transfer, enabling us to offer our customers and partners considerable added value,” explained the head of WACKER India, Anand Gopaladesikan, during the official opening ceremony. “Our goal is to contribute to the accelerated development of the tile adhesives market in India.”

A recent study forecasts that India is set to become the world’s third largest construction market by 2025. Some 11.5 million houses will be built there every year. Demand for construction products and applications catering to the Indian market is rising at a correspondingly fast rate.

Adhesive strength and flexibility are vital for tile-adhesive formulations. WACKER’s polymeric binders improve how tiles adhere to the substrate, make the adhesive highly water-resistant and extremely easy to process, while permitting flexibility within the adhesive – an effective way of preventing cracks and fractures. What is more, formulations containing WACKER dispersible polymer permit the use of special installation techniques, known as thin-bed technology. This makes significant savings possible in terms of raw materials, such as cement or sand.

The new technical center in Bengaluru is WACKER’s third such facility in India, after Mumbai and Kolkata. Like its counterpart in Mumbai, the new technical center in Bengaluru adjoins a WACKER ACADEMY training center, the purpose of which is to intensify knowledge transfer in the local market. WACKER ACADEMY courses cater to the specific needs of India’s construction-chemicals industry.

The technical center in Bengaluru specializes in the development of customized tile-adhesive applications.

An engineer monitors production in the control room.

NEW SPRAY DRYER FOR MANUFACTURING DISPERSIBLE POLYMER POWDERS

WACKER invests €65 million in a VAE plant in South Korea

Following a construction phase lasting 20 months, WACKER brought a new spray dryer for the production of dispersible polymer powders on stream in Ulsan, South Korea at the beginning of September. The plant is part of an ongoing site expansion aimed at boosting the company’s production capacity for dispersions and dispersible polymer powders in Asia.

WACKER already produces vinyl acetate-ethylene copolymer (VAE) dispersions in Ulsan. The new spray dryer converts liquid dispersions into dispersible polymer powder by feeding them through an atomizer into a stream of hot gas, which dries them extremely quickly to yield a fine powder. The new plant has a total capacity of 80,000 metric tons per year. Now complete, the spray dryer is one of the two largest of this kind in the world. The second plant with this capacity is located at WACKER’s Burghausen site. The new spray dryer has created some 50 new jobs in Ulsan.

Construction is also underway in Ulsan on a further reactor for VAE dispersions, the feedstock for dispersible polymer powders. The reactor is scheduled for start-up in the first quarter of 2020. Overall capital expenditure on the plant complex, spanning the full production chain from VAE dispersions through to dispersible polymer powders, amounts to some €65 million.

“Our binders not only enhance the properties of building materials but also make construction activities more resource-efficient,” says Peter Summo, head of the WACKER POLYMERS division. “The new plant in Ulsan will help us serve the growing market in Asia and additionally shorten our delivery routes and times.”

The new spray dryer will be used to produce VINNAPAS® 5010 N and VINNAPAS® 5044 N binders, for instance. They are needed in the construction industry to formulate high-quality tile adhesives, mineral plasters, self-leveling flooring compounds, EIFS/ETICS, construction adhesives, smoothing compounds and joint fillers, for example.

“By expanding our production capacity, we are ensuring that we will remain the first point of contact for regional manufacturers of building materials seeking to optimize their products with dispersible polymer powders,” says Dal-Ho Cho, head of the Wacker Chemicals Korea subsidiary.

A look inside the new food-applications lab in Shanghai.

NEW LAB FOR FOOD APPLICATIONS IN SHANGHAI

WACKER strengthens its position as a partner to the Chinese food industry

This spring, the WACKER Group opened a new lab for food applications in Shanghai to support customers in Asia even better with the development of innovative, tailored products in the burgeoning food market. “With our new range of services in Shanghai, we are strengthening our position as an innovative partner to the food sector on the Chinese market,” said Dr. Gerhard Schmid, president of WACKER BIOSOLUTIONS.

WACKER already operates three specialized food laboratories in Burghausen (Germany), Adrian (USA) and, since 2016, Singapore (Southeast Asia). With the new 150-square-meter laboratory for food applications in Shanghai, the Group is now also expanding its range of services across the growing market in China.

“China is already the biggest market in the world for food and beverages. And its growth continues to be strong. With our new lab for food applications, we are able to accommodate our local customers’ needs even better,” said Paul Lindblad, president of WACKER Greater China. “We offer support in developing innovative solutions that satisfy consumer tastes and expectations.”

The new laboratory, which covers an area of some 150 square meters, focuses primarily on applications involving cyclodextrins, cyclodextrin complexes and cysteine, as well as chewing-gum applications.

Cyclodextrins are ring-shaped sugar molecules, which WACKER bioengineers from plant-based raw materials such as corn or potatoes. They can selectively replace specific ingredients in foodstuffs and thus make it possible to produce baked goods, desserts and sauces that are free from animal-based emulsifiers, cholesterol and solid fats. What is more, cyclodextrins protect sensitive ingredients such as vitamins and coenzymes from harmful influences, for example oxygen or light, and they increase the bioavailability of hydrophobic substances like the natural antioxidant curcumin.

WACKER AT TRADESHOWS

K 2019
Düsseldorf, Germany
October 16 – 23, 2019
www.k-online.de

CPhI
Frankfurt am Main, Germany
November 5 – 7, 2019
www.cphi.com/europe

COMPAMED
Düsseldorf, Germany
November 18 – 21, 2019
www.compamed-tradefair.com

Formnext
Frankfurt am Main, Germany
November 19 – 22, 2019
formnext.mesago.com

Middle East Coatings Show
Dubai, UAE
March 9 – 12, 2020
www.coatings-group.com/mecs/dubai

PAINTINDIA
Mumbai, India
March 12 – 14, 2020
www.paintindia.in

American Coatings Show
Indianapolis, IN, USA
March 29 – April 1, 2020
american-coatings-show.comi

in-cosmetics Global
Barcelona, Spain
March 31 – April 2, 2020
www.in-cosmetics.com/global

WACKER HONORED FOR AI IMPLEMENTATION

RWTH Aachen honors initiatives within the Group, and especially the Research department

WACKER received the Successful Practice 2019 award from the renowned RWTH Aachen University’s Machine Tool Laboratory and Complexity Management Academy GmbH for outstanding performance in implementing artificial intelligence (AI).

For over 100 years, the Technical University’s Machine Tool Laboratory has stood for future-oriented research in the field of production technology worldwide. The award is based on the results of an international benchmarking study on Artificial Intelligence in R&D. The aim was to identify especially successful methods, structures and processes in the systematic implementation of artificial intelligence in Research and Development.

“Most of the participants are in the planning phase of AI projects,” says Prof. Günther Schuh, director of the Machine Tool Laboratory. “WACKER, on the other hand, was able to show that AI is already being used in Research and Development, for example, in NMR spectroscopy. With initiatives like WACKER Digital, the Group is also establishing the organizational prerequisites for using AI applications.”

Over 200 international companies took part in the study. The Technical University and a prestigious consortium comprising 24 leading industrial corporations selected the five top companies. Apart from WACKER, 3M, Dürr Systems, ABB and Airbus also received the award.

“By implementing artificial Intelligence, we want to analyze and use complex data in a more targeted manner,” says Dr. Thomas Renner, head of the WACKER Consortium. “In Research and Development, for example, we will be able to develop materials and products more quickly. The award shows that we are on the right track with our projects. It also increases our visibility, enabling us to further expand our network to solve this challenging task.”

Dr. Thomas Renner, head of the Consortium, (left) accepted the award for WACKER from Director of Studies Jan Koch (center) and Prof. Günther Schuh (right) at the final Benchmarking Conference at Eurogress in Aachen.

PYROGENIC SILICA NOW MARKETED ONLINE

WACKER now also supplies HDK® on the CheMondis and PINPOOLS marketplaces

WACKER now offers HDK® pyrogenic silica on CheMondis and PINPOOLS, two online marketplaces for selling chemical raw materials and specialty products. By using internet platforms like these, WACKER hopes to gain experience with digital B2B trading venues and, over the long term, acquire new customers and open up additional marketing channels for its product portfolio.

Industrial customers will be able to use the platforms to order a total of nine HDK® grades with an extremely wide range of surface and rheological characteristics. HDK® N20 Nutrition and HDK® T40 Nutrition, two products developed especially for the food and animal-feed industries, are available only on PINPOOLS.

"By deciding to sell our pyrogenic silica online now, we hope to take advantage of the opportunities afforded by digitalization while raising the profile of a product that can be used as an additive in so many different applications," said Maria-Anna Biebl, director of the HDK® business team at WACKER SILICONES.

The decision to sell products on CheMondis and PINPOOLS was the result of an intense selection process. "We were especially looking for platforms that would complement our existing sales activities as effectively as possible and would help us reach out to new customers and markets," said Axel Schmidt, chief digital officer for customers, whose responsibilities include developing digital business models at WACKER.

The startup CheMondis (www.chemondis.com) founded by specialty chemicals group Lanxess and the online platform PINPOOLS (www.pinpools.com), launched in 2016, are two of the leading marketplaces for chemicals in Europe. The online platform CheMondis is now used by 650 companies across Europe to sell more than 7,500 products.

"WACKER's listing on CheModis is another powerful signal that customer-friendly technology is going to succeed on the market," says CheMondis Managing Director Sebastian Brenner. "We're looking forward to collaborating and to growing our existing network even further with WACKER."

Over 500 active buyers and suppliers are currently using PINPOOLS, which offers more than 5,000 products, especially for the paint and coatings, construction and food and animal-feed industries. PINPOOLS Managing Director Alexander Lakemeyer: "We're very happy that with our marketplace, we're able to provide a prestigious company like WACKER with direct access to new customers."

Pallet with HDK® bags

The WACKER Group's new competence center for cement and concrete in Shanghai. Its focus is on novel silicone-based products and solutions which improve the durability and sustainability of cement and concrete.

NEW COMPETENCE CENTER FOR CEMENT AND CONCRETE APPLICATIONS OPENS IN SHANGHAI

Silicone additives are to provide even more effective protection against environmental influences

WACKER has opened a new competence center for cement and concrete applications in Shanghai. The laboratory will develop silicone products that will improve the properties and durability of cement and concrete in the long term. Its specific focus is on performance-enhancing silicone additives.

According to current market studies, China is the world's largest producer and consumer of cement and concrete. But the country faces a number of challenges due to the high energy consumption of cement manufacturing and rising demand for sustainable products, carbon dioxide reduction and more durable, corrosion-resistant cement and concrete construction materials.

"The new competence center in Shanghai will give our customers the support they need to cope with these challenges and to seize the opportunities which have opened up," says Paul Lindblad, president of WACKER Greater China. "As a regional innovation platform for cement and concrete applications, our lab will cooperate with the country's leading universities, research institutions and industrial customers. The goal is to develop innovative products and solutions that contribute toward the sustainable growth of the Chinese construction materials industry."

The new competence center will focus on investigating how silicone products can protect cement and concrete against environmental influences more efficiently for longer periods of time. Waterproofing technologies are currently trending in science and industry.

Silicones are known for their ability to provide protection against alkali-silica reactions, efflorescence, graffiti and corrosion. Yet surface treatment also has its limitations. "One of our lab's goals is to develop silicone-based products that not only offer excellent dampproofing and increase the durability of cement, but also address other unresolved problems," says Dr. Peter Jerschow, head of Product Development for the Construction Silicones business unit in the WACKER SILICONES division.

"Silicones can be used to manufacture cement. With a new silicone additive developed by our competence center in India, customers have been able to produce several thousand metric tonnes of cement," adds Jerschow. "Shanghai is the first WACKER competence center to deal exclusively with silicone-based cement and concrete admixtures. It will leverage the Group's worldwide resources and make a valuable contribution toward sustainable development of China's cement and concrete industry."

MATTE OR GLOSSY – WITH SILICONE RESINS ANYTHING IS POSSIBLE

Matte surfaces are produced wherever one of the ingredients in the preparation creates a light-scattering surface, i.e. reflects light in different directions. Conversely, a homogeneous, smooth surface with a high refractive index produces specular reflections, and therefore appears shiny.

Many women currently prefer matte surfaces with a natural look, while others want to set a different accent with shiny finishes. With its two new silicone resins BELSIL® B 110 and BELSIL® R 220, WACKER is tapping into current trends for controlling the reflective properties of skin or hair.

FINE-TUNING THE SHINE WITH SILICONE RESINS

In day creams and foundations, the spherical particles of the new BELSIL® B 110 silicone resin fill out wrinkles or skin imperfections, creating an even skin appearance. At the same time, they scatter light falling on the skin, giving its surface a matte finish and smoothing over wrinkles.

Another new product is BELSIL® R 220. This film-forming silicone resin was designed for use in nail varnishes. It has a high refractive index resulting in a high-gloss, water-resistant surface.

At this year's in-cosmetics, WACKER is showcasing new silicone fluids in the BELSIL® eco product line, which are produced using biomethanol from renewable resources.

EXPANDING THE BELSIL® ECO PRODUCT RANGE

Biomethanol made from renewable raw materials improves the eco-balance of cosmetics

At the beginning of April, WACKER showcased several new products for the cosmetics industry, including three new silicone fluids, a silicone resin and a gum blend, at in-cosmetics global in Paris, the leading tradeshow for the international cosmetics industry. The products are part of the biomethanol-based product line BELSIL® eco. In addition, two new silicone resins in the standard BELSIL® range were presented. One enables the manufacturing of foundations and day creams for matte, natural-looking skin. The other imparts an especially deep shine to nail polishes.

BELSIL® eco was originally unveiled at in-cosmetics 2018. So far, the product line has comprised six linear dimethicones with viscosities ranging between 5 and 60,000 centistokes (mm^2/s). WACKER uses biomethanol from renewable raw materials to manufacture these products. BELSIL® eco silicones therefore have a much more favorable carbon footprint than conventional products. WACKER is currently the only company to offer such products for cosmetic applications.

Now, the chemical company has expanded its BELSIL® eco line with three further low-viscosity silicone fluids: BELSIL® eco DM 0 65, BELSIL® eco DM 50 and BELSIL® eco DM 1000. BELSIL® eco DM 50 and BELSIL® eco DM 1000 are linear dimethicones. BELSIL® eco DM 0 65 is a so-called disiloxane. They are all are colorless, non-polar liquids characterized by very low surface tension and good spreading properties.

The addition of these three grades means the cosmetics industry now has biobased silicone fluids with viscosities of 0.65, 50 and 1,000 centistokes at its disposal. The products can be used as liquid carriers in many cosmetic preparations. BELSIL® eco DM 0 65 vaporizes rapidly and completely. Thanks to its low heat of vaporization, it evaporates without perceptibly cooling the skin.

BIOBASED GUM BLEND FOR STRESSED HAIR

The new gum blend BELSIL® eco GB 1020 and the silicone resin BELSIL® eco TMS 803 are based on biomethanol. BELSIL® eco GB 1020 acts as a conditioning agent in fluids to combat split ends, in hair masks and conditioners, and as a softening agent in skin-care creams and lotions. The silicone resin BELSIL® eco TMS 803 forms a gas-permeable, water-resistant film which ensures long-lasting effects. Thanks to its good solubility in cosmetic oils and alcohols, this free-flowing white powder is easy to process.

A VISUAL TREAT

With his imaginatively molded 3D desserts, Belgian pastry chef Carlos Deleye has worked his way into the ranks of the top suppliers to the gourmet foods industry. He owes his success to a grade of WACKER silicone rubber approved for food production.

The Deleye employee needs barely 30 seconds to fill the silicone molds with the mascarpone mixture.

The tall, silver, stainless-steel pot of freshly mixed panna cotta cream is ready, as is the twelve-cavity silicone baking mold. Dressed in his white uniform, the pastry chef swings into action: he dips a big ladle into the viscous mixture one, two, three times and then pours the sweet contents onto the flat template. He jiggles the mold with his right hand, and the light-yellow cream automatically distributes into the round cavities. In his left hand, he holds a long icing knife and helps the process along with smooth spreading motions. In less than thirty seconds, the delicious treat has spread into the mold's nooks and crannies. He finishes with a few more forceful shakes to burst any air bubbles and to fill in the last remaining open spaces. Then, with a practiced hand, he brushes a spatula across the top to remove any residual batter from the mold. All done.

The twelve identical white circles now make a decorative contrast to the terracotta-colored baking mold, and their next stop is the freezer. "We freeze the panna cotta rings at minus 35 to 40 degrees Celsius," explains Carlos Deleye, CEO of the company he founded. A tall Belgian with short hair and bright blue eyes, Deleye employs around 40 people at his site in Mouscron in the Wallonia region of Belgium, which is near the French border and only about 20 km from the city of Lille in northern France. The factory, a quite imposing facility covering 6,000 square meters, produces desserts and small, bite-sized appetizers known as amuse-gueules. The Deleye company offers some 120 different frozen foods, which it sells through wholesalers to numerous restaurants and catering businesses throughout Europe and, more recently, to buyers as far away as Australia and Canada. Its customers even include a few Michelin star chefs, who of course wish to remain

You need plenty of practice before you can push out the frozen mascarpone rings. You have to gently bend the edges of the silicone mold so as not to break the ring.

anonymous. As Deleye points out, "Let's not kid ourselves: with the exception of fruit flans and tarts, nearly every pastry in today's modern restaurants comes from the freezer. Even in the most famous establishments."

"Silicone is no problem to cool and it's easy to clean, and that means you can refill it faster."

Carlos Deleye, pastry chef

STARTING OVER WITH FROZEN FOODS

A pastry chef by training, Deleye single-handedly set up his successful dessert business, which continues to grow steadily. As he explains, "At first, all I had was a little bakery where I sold bread and cakes. I supplied these cakes to the restaurants on the square – Sundays and holidays too. The restaurant owners usually showed up before the store opened." Business was good, but it was also very stressful: Deleye worked through the weekends and had problems finding good employees. After three successful years, he took a leap of faith and started over with frozen foods in 1993 – with two employees and 200 square meters of space in a former textile factory. "At that time, our selection consisted of 13 cake rolls, which we later followed with tartlets. Both were frozen. It was quite a novelty at the time."

With that product line, the entrepreneur was able to make his startup profitable. But the resourceful pâtissier wanted to expand more and was looking for new ideas. "I wanted

to give my cakes new forms. After all, we are serving up a visual treat. Tasting good isn't the only concern – it has to look good too."

Deleye dreamed of 3D shapes – edible decorative balls, for example – that he could use to adorn traditional cakes in entirely new ways. But how could he produce them? He started out using thermoplastic molds. "But getting the cakes out of the mold was too hard. You had to wrap the tart in plastic film and then carefully remove it from its shell by pulling on the film. The plastic was also very stiff and often tore as it cooled."

> "I wanted to give my cakes new forms. After all, we are serving up a visual treat."
>
> **Carlos Deleye,** pastry chef

TRYING OUT FOUR BLENDS

He discussed the problem with his friend Roger Van Damme, a well-known Michelin star chef from Belgium, who prompted Deleye to give silicone a try. "I didn't really have much of a feel for the material, but I knew it could be used with food."

Online research led Deleye to Tony Roex of the MCtechnics company, a distributor of raw materials for the composites industry, including silicones. One call was all it took to pique Roex's interest. The silicone expert immediately traveled to Mouscron, taking various WACKER components with him. As Roex recalls, "We tried out four silicone blends. Some of the components we stirred in with egg beaters. I'd brought a vacuum pump with me just in case."

It took a full year and a half to find the perfect silicone rubber compound. "A lot of our attempts failed or weren't satisfactory. First it was too elastic, then it was too tough." In the end, the ideal formulation for dessert production turned out to be ELASTOSIL® M 4601, a two-part, room-temperature-curing silicone rubber compound in which the A and B components are blended in a 9-to-1 ratio.

Deleye makes the dessert and baking molds in his factory himself by preparing a thermoplastic prototype on a 3D printer. He then uses the prototype to make a negative impression in the silicone. The company consumes some 600 kg of the elastic material each year and, for

Even if the production line looks fairly industrial at first sight, all the desserts are still made by hand. Miniature tiramisus are being prepared here.

“Elements” – sweet spherical decorations – are among Deleye’s bestsellers. These miniature decorative balls are made in silicone molds and packaged by being lined up on square plastic pallets. The desserts shown here are made of mango and passion fruit.

some time now, its founder has been thinking about installing various machines as a way of reducing the manual processes.

He’s hesitant about making the investment, but at the same time he’s also planning on expanding his wealth of molds even further over the coming years. “When I started out with silicone in 2014, I was a pioneer. But just three years later, Instagram and Pinterest were full of pictures of these desserts. If I’m going to defend my position as a trailblazer, I have to keep coming up with new ideas.” He’s constantly thinking up new designs, such as entrées in the shape of asparagus or mushrooms, or desserts shaped like keys. The father of two finds many of his ideas in toy stores or simply outdoors. To illustrate this point, he goes to his office and retrieves plastic and wooden toy vegetables from a grocery store play set for children. He also turns over a large, rough-edged stone in his powerful hand in an almost loving way. “I found this one when I was out for a walk and made a silicone cast from it. It was an experiment, and I’m not satisfied with the result yet.” His perfectionism is also what ensures his success: “A lot of restaurants have tried to make our molds themselves. But since they can’t match our quality, they’re still our customers.”

CONTACT

For more information on this topic, please contact

Andrea Bogner
Marketing Manager,
Industrial Solutions
WACKER SILICONES
Tel.: +49 89 6279-1375
andrea.bogner@wacker.com

He currently uses eight different models to shape 40 different appetizers and desserts, most of which he still fashions in traditional 3D shapes like eggs, rings and various sizes of spherical decorations. “You can make about 100,000 decorative balls for desserts from a single silicone mold. The molds have a very long service life if you’re careful with them,” he explains with evident satisfaction. You have to be particularly cautious when removing frozen treats from them, he says. Gentle pressure quite literally pops the balls from their silicone envelopes, while carefully, skillfully bending the elastic mold at the edges and in the center releases the rings, which are then stacked in their packaging by hand. Of course, you need a certain amount of practice, explains Deleye, adding with pride: “My employees have that.”

SILICONE BOOSTS EXPANSION

The 52-year-old Flemish pastry chef is generally satisfied with his selection of materials in other ways as well. As he himself has stated, they have really helped his company grow – and won him quite a few innovation awards: “Silicone is no problem to cool and it’s easy to clean, and that means you can refill it faster. Even the cost of acquisition and production is significantly below that of other baking molds.” Certain grades also meet the standards of the US Food and Drug Administration (FDA) and Germany’s Federal Institute for Risk Assessment (BfR), making them suitable for food contact. Are there really no disadvantages at all? “You have to look out for cracks. The desserts run out when that happens.”

Despite the fairly industrial atmosphere in the production halls at Mouscron, all of the desserts are still made by hand the old-fashioned way. The boss develops the recipes himself, while the six pâtissiers he employs oversee preparation. Only the finest ingredients are good enough. “We use nothing but Belgian chocolate from Callebaut, for example. That’s the very best chocolate there is. Our mascarpone comes straight from Italy, and our fruit, vegetables and herbs are completely fresh – we couldn’t get away with anything less today.” The company’s best sellers include “Elements,” which are spherical decorations flavored with caramel, mango/passion fruit, yuzu or basil and which range in diameter between 1 and 2.5 cm, and “Quenelles,” oval-shaped confections roughly 5 cm long and made of various types of chocolate and fruit. Also very well received are the company’s “Amelioras” – little round flavored decorations made of herbs and flowers, such as hibiscus, turmeric, basil or lemon grass, and used for appetizers and salads. As Deleye notes, “You couldn’t have made any of these products in the past, but they’ve made my company a top player and earned us awards. As far as I’m concerned, the future of gastronomy lies in the use of silicone.”

The innovative desserts that company founder Carlos Deleye creates have already won him several awards. What’s more, he is always on the lookout for new shapes.

SILICONES THAT ENSURE SOFT-TOUCH SURFACES

Consumers are increasingly expecting plastic surfaces to feel silky-soft and retain a high-quality appearance even after intensive use. Thanks to a new silicone-based additive, compounders can easily reduce the hardness of thermoplastic elastomers and ensure pleasant tactile properties.

Cellphone covers and watch straps are typical consumer articles that must withstand a lot, but should still feel good and last for a long time.

Thermoplastic elastomers (TPEs) are known for their good mechanical properties, their wear resistance and low-temperature flexibility. They can be found in many items used in sports and leisure, as well as in microelectronics, machinery manufacturing, automotive and electrical engineering, and medical technology.

Standard thermoplastic polyurethane (TPU) elastomer grades produced and processed in large quantities are generally relatively hard – typically with Shore hardness values ranging from around 80 A to 45 D. Components made from such grades often feel a bit rubbery and dull. However, good tactile properties are an important quality characteristic for items that consumers touch frequently or wear directly on their bodies.

"There are nevertheless only a small number of soft TPU grades on the market," says Dr. Peter Randel of WACKER SILICONES' Technical Marketing for Plastics & Coatings. "They are difficult to manufacture. In many cases, they contain plasticizers that can migrate out of the plastic and contaminate other objects."

Plastics manufacturers and compounders are thus looking for ways of making TPU softer and of giving TUP precisely those tactile properties that consumers expect without noticeably diminishing other properties of the plastic. The ultimate goal is to open up new application areas for the material. An easy way of doing this comes in the form of WACKER's new silicone-based additive GENIOPLAST® Pellet 345, which is being unveiled to a broad audience of experts for the first time at K 2019, the International Trade Fair for Plastics and Rubber.

SILKY-SOFT AND DRY

When consumers choose a product, its appearance and tactile properties are often the deciding factor. "Soft-touch surfaces are currently popular," explains Randel. "These are surfaces that feel silky-soft and dry and are pleasant to touch." Soft-touch surfaces are not just in demand for plastics in automotive interiors. Consumers are looking for this silky-soft feel more and more in other applications, too, e.g. for smartphone covers and wearables. Wearables are microcomputers worn on the body that are linked to other devices, such as smartphones, and record, assimilate and evaluate data on the user's activities. Examples include activity trackers, fitness wristbands and smart watches.

These kinds of microcomputers are worn as an accessory on the arm. Not only must the casing and wristband of a wearable be sufficiently robust and elastic to protect the expensive device, but it must also look fashionable and be soft enough to satisfy the high demands in terms of how they should feel.

INCREASED ELASTICITY

Prompted by requests from the plastics industry, WACKER decided to develop a silicone-based additive that primarily reduces the hardness, as well as the surface friction, of thermoplastic polyurethane elastomers (TPUs) and increases their elasticity. The aim was to allow TPUs to be modified in such a way that the functional and tactile properties even satisfy high consumer expectations.

Silicone additives are known for their friction-lowering effect and have been employed by the plastics industry since the 1970s. It is, however, difficult to use a conventional silicone as an additive for TPEs in large quantities.

"Silicones are generally non-polar, while polyurethanes are polar," explains Dr. Oliver Schäfer, head of an applications laboratory at WACKER SILICONES in Burghausen. The two materials are thus incompatible. When a silicone is mixed in with a polyurethane, you get a two-phase polymer mixture. The silicone forms soft islands, which are dispersed throughout the hard polyurethane matrix. Due to this incompatibility, it is not at all easy to incorporate a conventional silicone into a polyurethane

GENIOPLAST® Pellet 345 alters key properties of thermoplastic elastomers. It makes these plastic grades softer and more elastic and lessens abrasion.

matrix – a difficult hurdle to overcome for an application as an additive.

That's why researchers at WACKER pursued the idea of enhancing the compatibility of silicone with polyurethane by incorporating polar groups. Their approach was based on the assumption that silicone modified in this way should be able to interact more strongly with polyurethanes, produce better dispersion in the polyurethane matrix and stabilize the bond between the silicone and polyurethane.

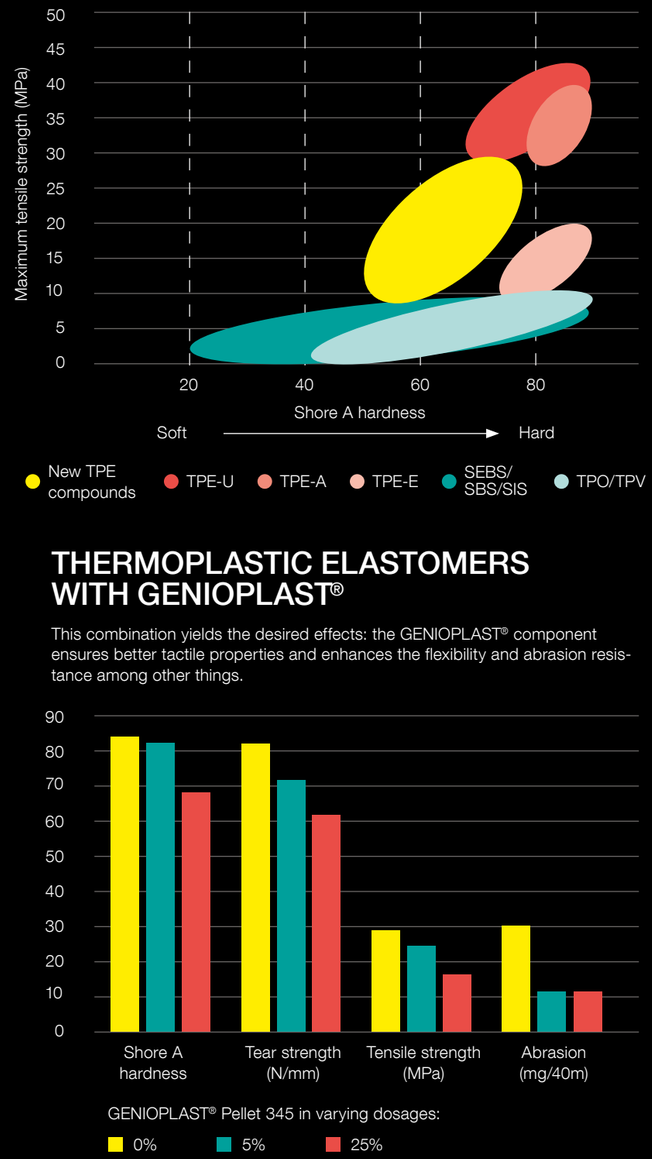
SILICONE COPOLYMER

Development work yielded a polar-modified silicone copolymer, made up of elastic, soft silicone segments and functional, polar organic polymer segments. The amount and molecular weight of the copolymer segments were optimized to achieve the properties sought for in the end product, while ensuring that the silicone copolymer is readily processed. The result was the new additive GENIOPLAST® Pellet 345. With this product, Wacker Chemie AG complements its range of silicone-based performance additives used in the plastics industry for compounding thermoplastics.

"Unlike conventional silicone elastomers, our new modified silicone is not crosslinked chemically, but physically," emphasizes Schäfer. Non-covalent bonds form between individual segments of this silicone copolymer's molecules which come into contact with each other. It is these bonds that hold the molecules firmly together. This type of bonding, though, is weaker than that of chemical crosslinking. The bonds involved can therefore be systematically broken by heat, but reform on cooling. The new additive can thus be processed thermoplastically. The additive was tested extensively

COMBINATION OF BOTH WORLDS WANTED

The market is demanding a softer thermoplastic elastomer with sufficiently high tensile strength. Plastics available on the market to date either feature limited mechanical properties or considerably higher Shore hardness values. A combination of the two properties has so far not been available in this way.



THERMOPLASTIC ELASTOMERS WITH GENIOPLAST®

This combination yields the desired effects: the GENIOPLAST® component ensures better tactile properties and enhances the flexibility and abrasion resistance among other things.

at Dr. Schäfer's applications laboratory. Testing focused not only on the additive's processing properties, but also on its effects. Does it modify the plastics' technical properties in the desired way? How does it affect the tactile properties? What side effects can be expected? The results confirm the viability of the researchers' approach.

Transmission electron microscopy images show that the new additive is dispersed not just evenly, but also very finely, throughout the polyurethane matrix – an indication of the silicone's improved compatibility with the matrix. The additive's particle size in the matrix ranges from 200 to 400 nanometers. If a conventional silicone was incorporated into a thermoplastic polyurethane elastomer (TPU), the silicone domains formed would be considerably bigger.

"Since GENIOPLAST® Pellet 345 is fairly compatible with the polar TPU matrix and exhibits thermoplastic properties, it can be processed easily with hardly any effort involved," explains Schäfer. Both the additive and the TPU are supplied in pellet form and can be melted together in conventional twin-screw extruders typically used for compounding thermoplastics. Contrary to competing modification technologies based on conventional silicones, neither specialty equipment nor particular process-engineering measures are required to incorporate the silicone product into the polyurethane matrix.

POLYURETHANE TEST PIECES

In order to test the new additive's effects, WACKER technicians made test pieces of TPEs to which they had added varying dosages of GENIOPLAST® Pellet 345. The polyurethanes used were commercial TPU grades with hardness values ranging from 70 to 90 Shore A and tensile strengths of 25 to 50 megapascal.

The tests revealed that the dosage of the new additive very strongly influences the effects. In low amounts – up to around 10 percent – the additive predominantly affects the surface properties and only has a minor effect on hardness, strength and elasticity of the plastic. A low additive dosage lowers the coefficient of dynamic friction (DCoF value) and improves the abrasion and scratch resistance, for example. When 5 percent GENIOPLAST® Pellet 345 was added, the amount of abraded material was reduced by an average of around 60 percent in an abrasion test as per ISO 4649 A.

The feel and abrasion resistance of consumer articles worn on the body – such as this plastic smart-watch strap – benefit from the plastic being modified with GENIOPLAST® Pellet 345.

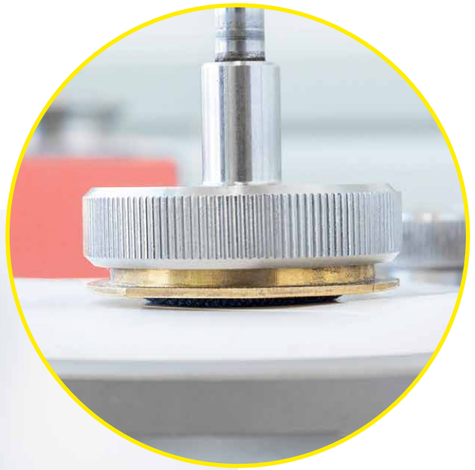
60 %

less abrasion when only 5% GENIOPLAST® Pellet 345 is added to the elastomer, according to testing as per ISO 4649.

These enhanced surface properties have a positive effect on smartphone covers, for instance. Many users carry their phone in their pocket and pull it out dozens of times every day. The surface of a particularly abrasion- and scratch-resistant protective cover looks good for longer. What is more, lower surface friction helps to remove the surface's rubber-like nature and give the cover a pleasant feel. With the addition of around 10 percent and more, the mechanical properties and hardness of the plastic change noticeably. The more GENIOPLAST® Pellet 345 is incorporated into the TPU, the softer the plastic. The hardness decreases in almost linear fashion with the amount added. As a rule of thumb, Dr. Schäfer's lab team found that an addition of 10 percent reduces the hardness of the thermoplastic by around five points on the Shore-A scale.

Elongation at break increases with the addition of additive and generally reaches its maximum at a dosage of 10 to 20 percent. The increased extensibility reflects a higher elasticity, representing a desired effect. A smartphone cover must, for example, be elastic enough to reliably protect the delicate phone against impacts.

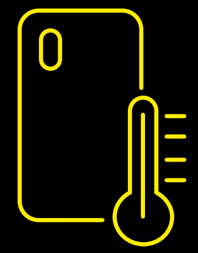
However, the applications engineers also observed that the plastic's strength lessens at dosages over 10 percent – an undesired side effect that cannot be avoided and also occurs with competing technologies. If the amount of GENIOPLAST® Pellet 345 used is increased from 10 to 30 percent, the tensile strength may be halved, for instance. Compounders can compensate for the reduced tensile strength by using a suitably tear-resistant TPU grade as the matrix. Benchmarking of soft TPU compounds of the same hardness showed that the reduction in strength is comparatively low with the new



A laboratory assistant at an applications laboratory in Burghausen performs the Martindale abrasion test. WACKER uses this test to determine mechanical wear and, in particular, discoloration when a piece of jeans fabric is rubbed against a test piece made of polyurethane elastomer and GENIOPLAST® Pellet 345.

STAIN-PROTECTED

SCRATCH- AND ABRASION-RESISTANT



HEAT-RESISTANT

additive. "In any case, the strength values of compounds made with GENIOPLAST® Pellet 345 were considerably better than those of tested reference products," says Schäfer. In terms of the visual appearance of a plastic item, the tendency to stain plays a key role alongside the scratch and abrasion resistance. It's precisely smartphones, wearables and other mobile consumer electronics devices – together with their cables – that often come into contact, during use, with substances that can discolor the surface. Mustard and the indigo dye used in jeans can produce particularly strong and stubborn stains.

Major consumer electronics companies have compiled lists of substances whose discoloring effect is checked in staining tests. WACKER's applications engineers carried out the stipulated tests with the listed substances and found that the new additive lessens the undesired color changes in TPEs.

The new additive does not alter properties specified by the polyurethane matrix. The TPU thus retains its naturally good bonding properties on numerous polar thermoplastics. The additive does not influence chemical or thermal stability either.

As adhesion remains good, a blend of TPU and GENIOPLAST® Pellet 345 can be used as a soft component for hard/soft combinations, as found, for example, in toothbrush handles. "Such articles can be produced cost-effectively by two-component injection molding, with a polar, hard thermoplastic serving as the hard component," explains Randel, who is responsible for the marketing of the new additive.

PERMANENTLY ATTRACTIVE APPEARANCE

With GENIOPLAST® Pellet 345, manufacturers of TPEs can strengthen their position on the fast-growing market of mobile consumer electronics and microelectronics. "These kinds of compounds can find use in all items that consumers expect to have a soft-touch surface and permanently attractive appearance," he added. Sheathing for headphone or charging cables, casings of laptops, tablet computers and gaming consoles, tool and tennis racket handles, and handle sections of ski poles all offer a wide range of applications. As GENIOPLAST® Pellet 345 is bonded well to the polyurethane matrix, it cannot migrate out of the plastic either. In Europe, it has already obtained approval for food-contact applications.

According to WACKER researchers and applications engineers, GENIOPLAST® Pellet 345 can, in principle, also be used to modify thermoplastic polyamide elastomers (TPAs) and thermoplastic copolyester elastomers (TPCs). Respective tests are currently being conducted at WACKER's applications labs. "Initial results are promising," explains Schäfer. ■

CONTACT

For more information on this topic, please contact:

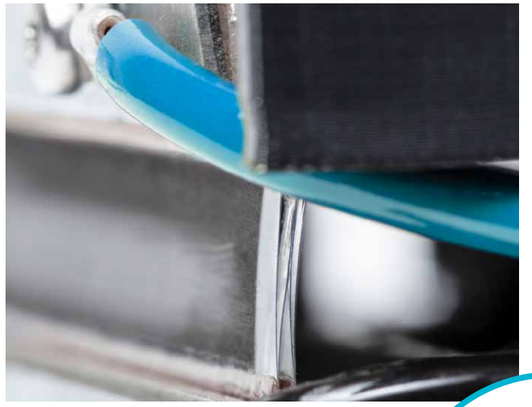
Dr. Oliver Schäfer
Head of Technical Marketing for Plastics
WACKER SILICONES
Tel.: +49 8677 83-2436
oliver.schaefer@wacker.com

SMART SILICONE SANDWICHES

Thanks to their electroactive properties, laminates that comprise electrodes and ultrathin silicone films can measure movement. They can also be made to expand and contract on demand. In the future, WACKER will be producing such prefabricated electronics components for sensors and actuators that will only require customers to fit the necessary electrical connections.

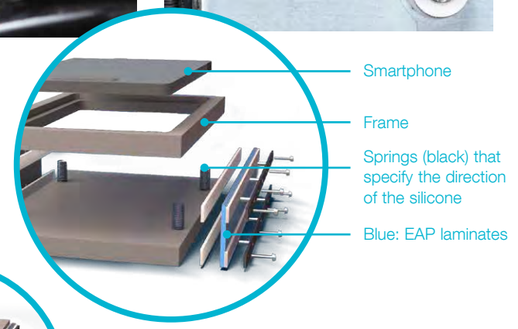
A smartphone with its well-known smooth surface. Even so, buttons can be felt as soon as appropriate fields are touched – the reason being that the integrated EAP laminates enable the entire smartphone to move. If only inactive areas of the phone are being touched, the phone keeps its normal smooth appearance.

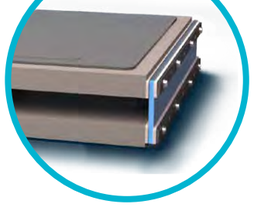
The images show a side elevation and a front view of a four-layer EAP laminate (gray surface, bottom left). The silicone films are transparent, while the electrode material is black. A voltage is applied to the laminate, which is assembled within a mount.



HAPTIC FEEDBACK FROM EAP LAMINATES

This smartphone demonstrates a possible layout.





Once the laminate is formed, the end user sees only the flat display, which rises and falls or begins to vibrate whenever pressure is applied to the appropriate areas. As a result, the display gives users the impression that they can actually feel the virtual keys.

They adjust headlamps, position side mirrors correctly and regulate the radio volume: in cars, some 300 actuators carry out a wide range of functions – from the drive train to the central locking system. The units convert electrical pulses into movement. Actuators play a key role not just in automotive engineering, but in robotics, electrical engineering and medical technology, too. Novel varieties based on electroactive polymers, in particular, are gaining in popularity in these sectors due to their positive properties.

In its ultrathin high-precision silicone film – already available on the market as ELASTOSIL® Film since 2013 – WACKER has created a powerful material with great potential. "We are now transforming this technology into specific products and are thus making it more readily available for the market," says Renate Glowacki, who is responsible for the worldwide marketing of the silicone films at WACKER SILICONES' Global Business Development.

VERTICAL INTEGRATION

By manufacturing laminates, WACKER is implementing vertical integration and is thus moving one step further along the supply chain toward industrial application. An exhibit that was developed in collaboration with the University of Saarland will allow visitors of the K 2019 plastics tradeshow (October 16 to 23 in Düsseldorf) to try out the laminates' sensor-actuator functions themselves.

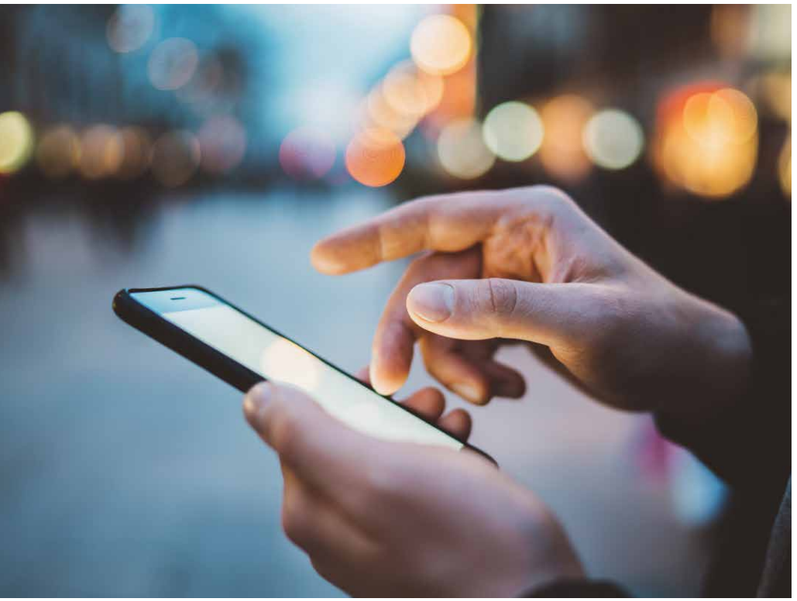
On account of their dielectric properties, silicone elastomers are categorized as electroactive polymers (EAPs). "When there is a single thin film embedded between each pair of electrodes, you get a laminate – layers bonded together on top of each other," says Dr. Andreas Köllnberger, who played a key role in the development of these silicone films at WACKER. If an electric voltage is applied to this sandwich, a flexible capacitor is created. "Due to their opposite charges, the electrodes attract each other electrostatically and deform the silicone film between them, making it thinner, but at the same time longer and wider," reports the WACKER chemist. "Its volume thus stays the same." Overall, the capacitor ends up thinner, but also larger in area. When the capacitor is discharged, the elasticity of the laminate causes it to return to its original shape.

The entire process is silent and can be repeated millions of times. "Since this deformation can be selectively controlled, these EAP laminates – marketed under the NEXIPAL® trademark – are suitable as actuators that convert electric voltage into mechanical movement. Conversely, EAP laminates can use mechanical movement – such as finger pressure – to produce changes in capacitance, and can thus be used as sensors. Even novel generators are possible," adds Dr. Johannes Neuwirth, who is a technical design expert and responsible for forward integration at WACKER SILICONES' Global Business Development unit.

At K 2019, WACKER is presenting an exhibit that illustrates the combination of sensor and actuator: a smartphone mounted on a structure with EAP elements. They cause the phone to vibrate slightly at high frequency , as the fingers, gliding over the display surface, touch certain areas. This gives the impression of a rippled surface or even keys, which are not really there.

THE BENEFITS OF EAP LAMINATES

The exhibit not only demonstrates the function of the laminates and the integrated electroactive polymers, it also reveals the potential of such haptic feedback for various applications. Motorists, for instance, can find controls in the center console more easily by touch – entirely without eye contact. What is more, the actuator elements make for greater freedom of design. In other words, it is possible to create designs that are thinner or narrower than solenoid valves. Freedom of design extends to the sur-



You can use a smartphone fitted with electroactive polymer laminates almost without having to look at it. The various applications can be felt – even though the surface of the display remains “smooth.”

faces, too – in this particular case, the buttons. They can be designed to be angular or circular or given any other shape, the actual design being determined by the algorithm underlying a particular program.

EAP actuators made of silicone laminates are compact and thus save space. They require up to 30 percent less space and are up to 40 percent lighter than conventional components, depending on configuration and design. The energy needs of EAP actuators are also low. They require less than 10 percent of the overall electrical energy needed by conventional actuators. Hence, EAP actuators are extremely energy-efficient and sustainable. This and their silent mode of action make the innovative laminate an ideal component not only in electric vehicles.

WACKER manufactures high-precision silicone films that are between 20 and 400 micrometers thick, with the thickness deviating by less than five percent over the entire width. This homogeneity is crucial for a uniform electric field, which is necessary to ensure that the NEXIPAL® laminates will later function optimally and reliably.

The high-precision films are made entirely of addition-curing silicone rubber. To exclude contamination, they are produced in cleanrooms. Like all silicone rubber compounds, the films are heat- and UV-resistant, flexible at low temperatures and chemically inert. Additionally, they are extremely elastic and do not wear out. “Our tests show that ELASTOSIL® Film can survive over ten million load cycles without displaying fatigue,” emphasizes Dr. Köllnberger.

FIRST THERE WAS SILICONE FILM, THEN NEXIPAL®

When WACKER started producing silicone films in 2013, it, in a way, entered unchartered territory. Until then, the chemical company had confined itself to bringing silicone rubber compounds onto the market as uncured raw materials.

In the case of silicone films, however, many customers quickly wanted the option of obtaining a processed semi-finished product – an EAP laminate. That’s why the Group decided to close this gap in the processing chain itself.

By now, WACKER experts have extensively familiarized themselves with the technical requirements demanded of EAP components, for example by mechatronic systems, and built up a wealth of relevant expertise. A production plant for EAP laminates is currently under construction. These are prefabricated EAP components that will only require customers to fit the necessary electrical connection. The first of these components, which will be marketed under the

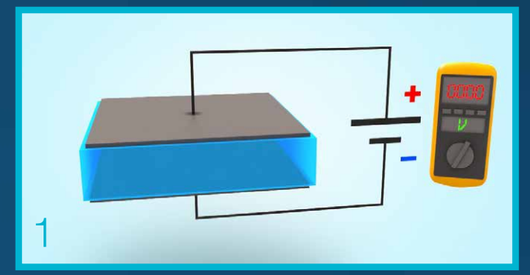
CONTACT

For more information on this topic, please contact:

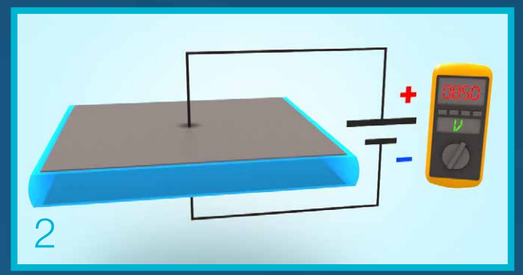
Renate Glowacki
Business Development Manager
Engineering Silicones
Tel.: +49 89 6279-1813
renate.glowacki@wacker.com
Or email
nexipal@wacker.com

HOW AN ACTUATOR AND SENSOR COMPRISING NEXIPAL® LAMINATE WORKS

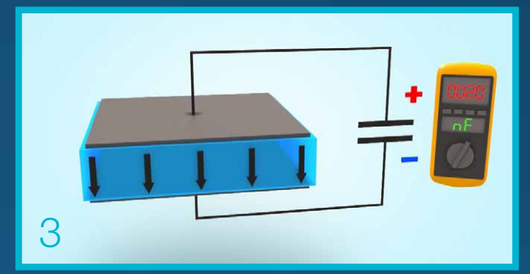
The electroactive properties of silicone film laminates mean they can be used as actuators or sensors. Actuators are drive system components that convert an electrical signal emitted by control electronics into mechanical movement. Sensors work along similar lines. Capacitive sensors measure mechanical movements.



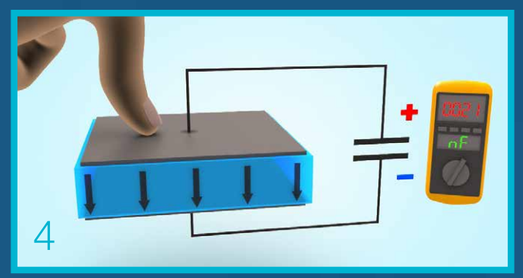
A voltage source is applied to the NEXIPAL® laminate, which comprises at least one ultrathin film and at least two electrodes, to ensure the laminate can operate as an actuator.



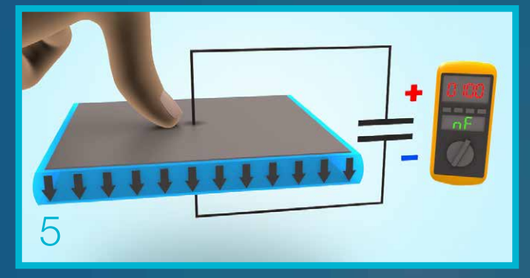
Turning on a voltage source charges one electrode positively and the other negatively. The electrodes attract one another and deform the silicone film. This makes the film thinner, yet wider so that the volume stays the same. The actuator moves. If the voltage is turned off, the silicone film returns to its original state, thereby pushing the electrodes apart again.



An EAP sensor works along similar lines. A measuring instrument is connected to the NEXIPAL® laminate to measure the capacitance.



The NEXIPAL® laminate can then be deformed by compressive or tensile movements. The electrostatic field between the electrodes changes depending on how far apart the electrodes are.



Since hardly any force is needed to deform the silicone film, it is enough to apply a slight pressure with your finger to bring the electrodes closer together. The distance between them changes and so does the capacitance, which is shown on the instrument. As soon as you remove your finger, the silicone film pushes the electrodes back into their original state.

PRODUCTION PROCESS FOR NEXIPAL® EAP LAMINATES

NEXIPAL® brand, are expected to roll off the production line in mid-2020.

In the manufacture of these laminates, the existing silicone film will be coated with a special conductive material, which serves as the electrode. The new plant will be able to produce several of these layers.The size and shape of the laminate are flexible, and customer-specific electrode designs can be ordered, too.

EAP components can also be produced as strips. Customers can subsequently transform these into rolled actuators, for example.

"Several challenges had to be overcome in developing the production process," reports Dr. Neuwirth. For example, there must be no air trapped between the individual layers of an EAP sandwich. "The handling of the ultrathin films in the coating process was a complex undertaking, too," he continues. The extent to which EAP actuators can contract, and the displacement they undergo in the process, depend on several factors. The driving voltage that is applied to the EAP component plays a key role here. For this reason, the silicone films must be as thin as possible. "The thinner the film, the lower the applied voltage necessary to achieve the desired movement effect," reports Dr. Köllnberger. "That's why we are working on further reducing the film thickness."

INTELLIGENT DESIGN

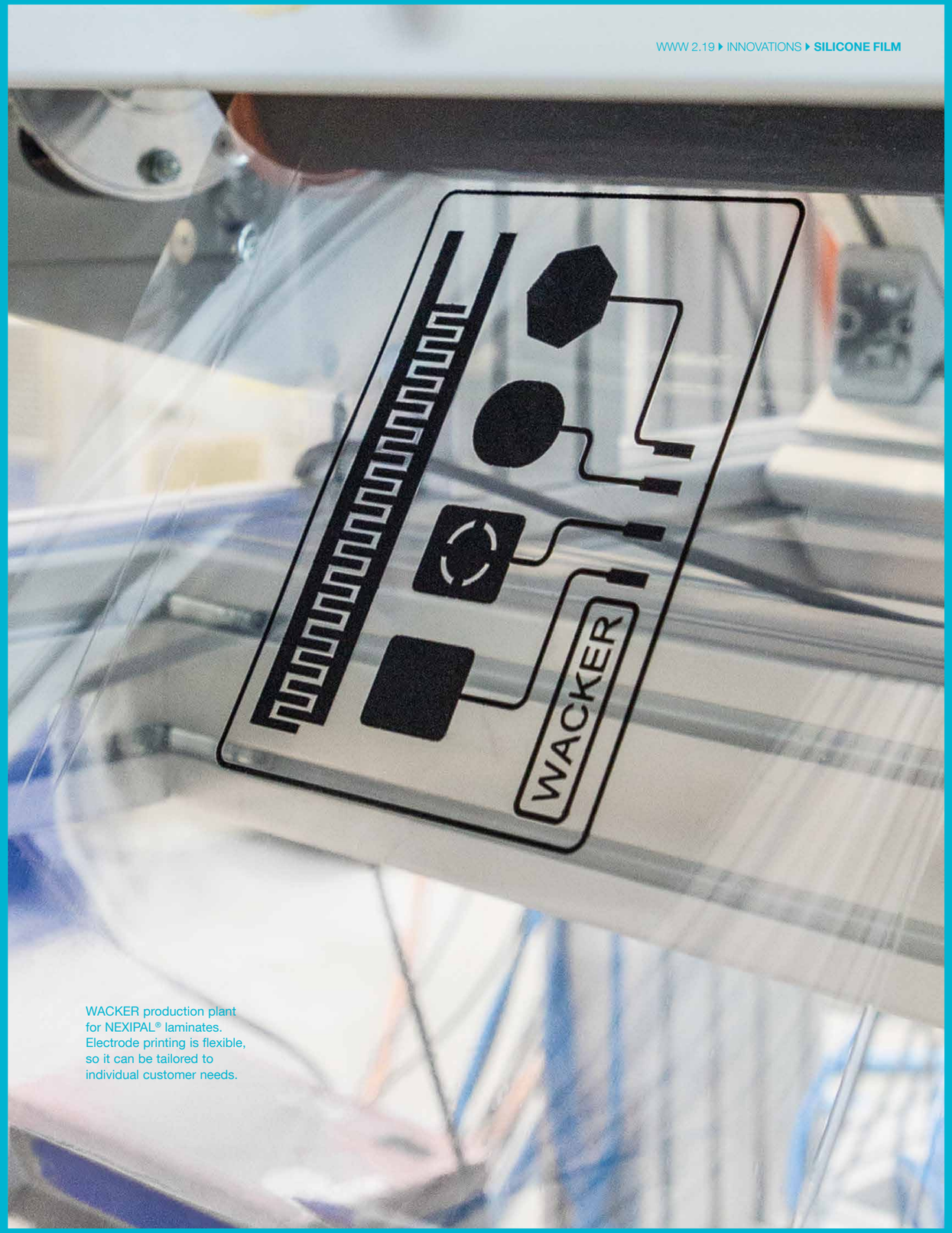
The use of high-quality electrodes and an intelligent EAP component design can also reduce the required voltage. Another option for reducing the voltage is to increase the permittivity of silicone films, for instance by doping them with special particles. In addition, a spring design can be used to produce components that achieve considerable displacement.

Alongside the advantages already mentioned, EAP actuators offer a further benefit: they can be used as artificial muscles that, unlike solenoid valves, can execute fluid, i.e. flowing movements.

This property makes silicone laminates interesting not only for the automotive and electronics industries, but also in medical technology, sensor technology and robotics. The silicone sandwiches even find use in printed electronics.

"Whether as a component of biomimetic robots, portable medical technology or instruments for human-machine communication: electroactive silicone laminates are conceivable in many promising applications," says Glowacki. ■

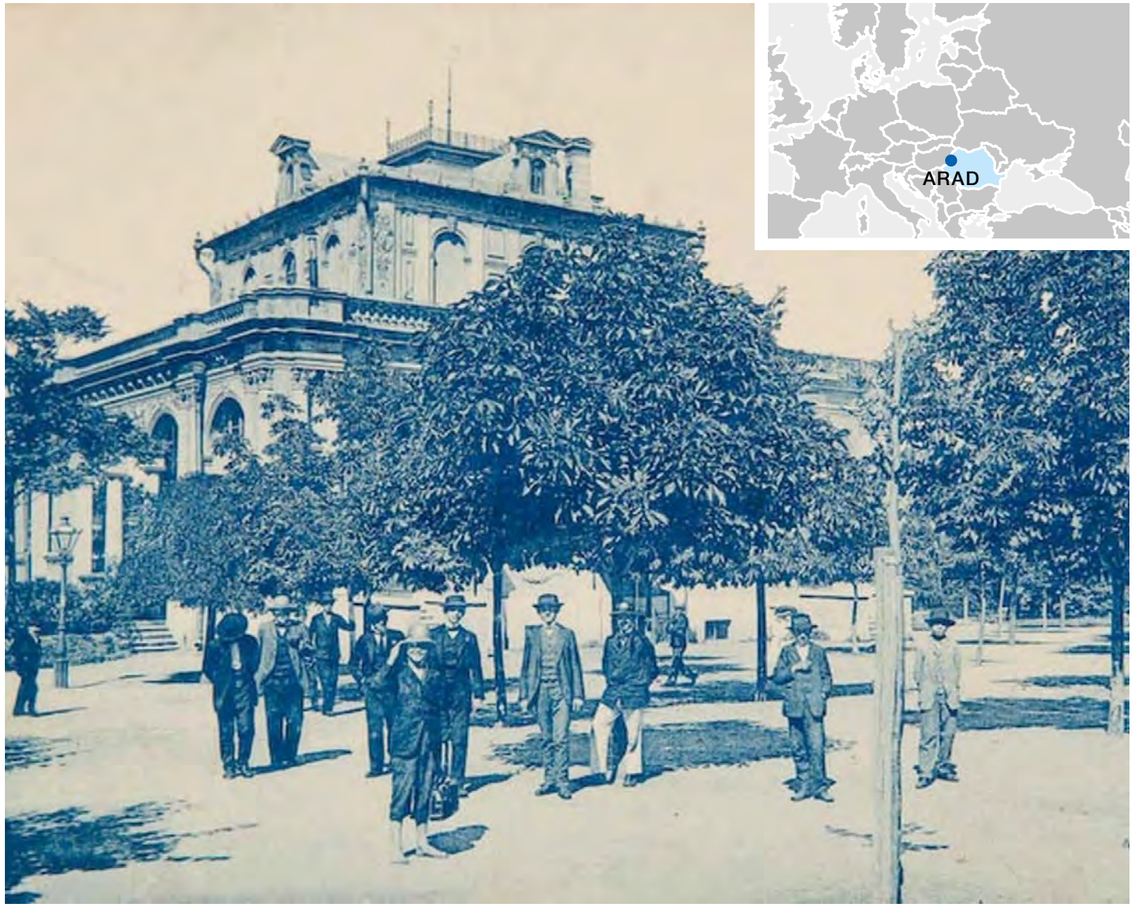
WWW 2.19 ▸ INNOVATIONS ▸ **SILICONE FILM**



WACKER production plant for NEXIPAL® laminates. Electrode printing is flexible, so it can be tailored to individual customer needs.

RESTORING THE ORIGINAL

Using WACKER silicone rubber, restorers make molds of the opulent ornaments in the Arad Old Casino in order to replace damaged pieces with identical copies of the originals. The restoration work is giving back to this western Romanian city a place fondly remembered by many of its inhabitants.



Arad, a city of 160,000 inhabitants, is located in the very west of Romania, on the Hungarian border. The Old Casino, which dates back to 1872, is still one of its attractions.

As a mural painting restorer, Annamaria Baciu spent a few months in Florence restoring frescoes painted by the famous medieval artist, Giotto. Afterward, she returned home to Romania, and has spent the last four years in Arad, a city of 160,000 inhabitants located in western Romania on the Hungarian border. "The casino we're working on at the moment is by no means a Giotto," she says, explaining that it is a protected historical monument and is on the list of important local heritage sites. "Nevertheless, this place is more important than Giotto to the people of Arad."

"The Old Casino used to be the most popular spot in Arad," continued Baciu. "In summer, families sipped lemonade and beer on the terrace; in winter, there was an ice rink in front of the casino and it was also used as a venue for many weddings."

HABSBURG HEYDAY

Situated on the Mures River, the neo-Baroque Old Casino, which dates back to 1872, is surrounded by beautiful historical buildings testifying to the city's heyday in the 19th century. Back then, during the rule of the House of Habsburg, Arad was home to Romanians, Hungarians, Germans, Serbs and Jews, who whiled away their time in the casino playing roulette and cards. During the Communist era, the building housed a bar.

After the political revolution of 1989, the building became increasingly dilapidated. The tenants operating a Chinese restaurant on the upper floor for several years lacked sensitivity in their treatment of the neo-Baroque stucco ornamentation.

"The Old Casino changed owners many times. Some were good, others less so," noted Baciu. In the end, it was sold at a public auction to an Arad-based entrepreneur, the owner of Arsat Industrie, a company manufacturing aerospace components and other goods. He wished to give back to his home town the building that occupies a special place in the memories of Arad residents – so, he commissioned Baciu to restore the historic fabric of the building. There are plans to use the building as a venue for events, with splendid areas being available for hire by both businesses and private parties.

Past splendor: view of the interior of the casino, which was built in 1872.

A RESTORATION SPECIALIST

Historical buildings are in the best of hands with Professor Baciu. She studied art history and has given lectures on restoration methods at the most important Romanian universities – in Bucharest and Cluj-Napoca – for 25 years. She is hailed at home and abroad as an eminent mural painting restoration specialist. Since early 2019, her team of restorers has been removing the various layers that were added to the original Old Casino in the past 150 years. On the eastern facade, for example, there were between five and eight coats of paint – and even more of them closer to the river because the humidity is higher there, causing the paint to

> "The casino changed owners many times. Some were good, others less so."
>
> **Prof. Annamaria Baciu**

The restorers carefully remove the many layers of the past decades to reveal the original fabric of the building.

deteriorate faster. All kinds of different colors and materials were used on the ceiling and the interiors: orange, white and green; gypsum, concrete and cement, plastics and a host of other materials.

"None were true to the original, none of the work was professional," says Annamaria Baciu. The past hundred years – the world wars, the economic instability of the inter-war period, 40 years of Communist rule and finally the sudden adoption of a market economy with its many new and not always suitable materials – have left their mark on the Arad casino. "We are freeing the original from an assortment of layers comprising different materials dating back to various periods and are transporting the architect's design into our day and age," she explains.

A WEALTH OF ORNAMENTATION

Typically, the neo-Baroque style features a wealth of exuberant ornamentation both inside and out. The restorers generally strive to be faithful to the principles of historic monument conservation – to retain as much of the original building fabric as possible. Their guiding principle "primum non nocere" – first, do no harm – is similar to the Hippocratic Oath, says Baciu. "It only takes a few seconds to destroy centuries."

> "It only takes a few seconds to destroy centuries."
>
> **Prof. Annamaria Baciu**

Carefully, the art historian strokes an ornamental sun on the wall from which parts have broken off. "Many of the ornaments are damaged," she says. Some 20 percent of the fabric must be replaced. This is where WACKER comes into play.

Cautiously, the restorers remove intact ornaments – capitals with plant motifs, small pillars, stucco flowers – from the facade, the ceiling and the interior walls. Then a negative mold is made from WACKER silicone rubber. This mold is used to make an identical copy with the original material.

Annamaria Baciu with a negative mold made from silicone. The material perfectly renders even the smallest details of the original, enabling copies of the highest quality to be made.

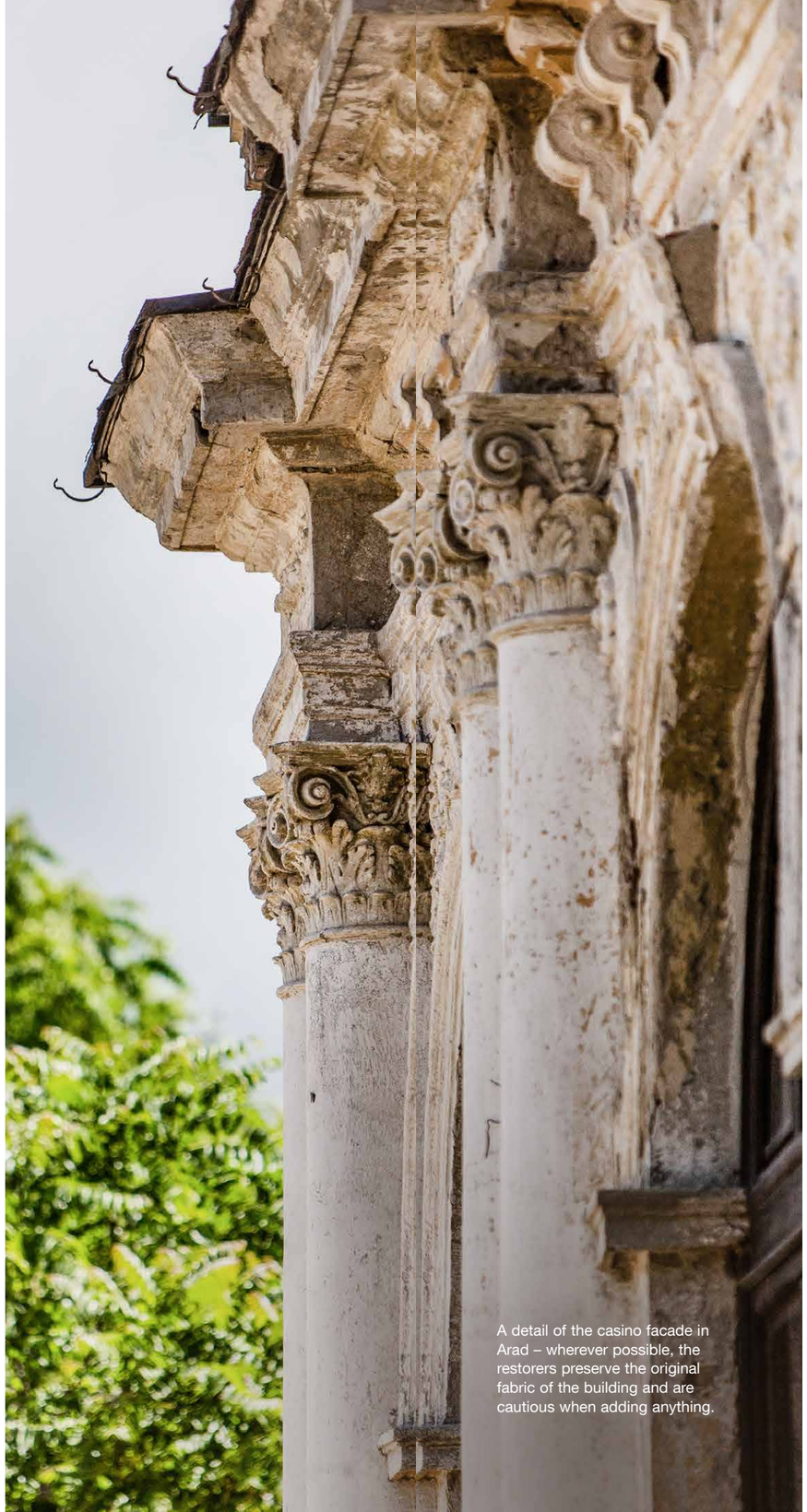
As it is so elastic, the blue silicone mold is placed in a gray support mold made of concrete or gypsum so that a copy can be made.

500 KILOGRAMS NEEDED

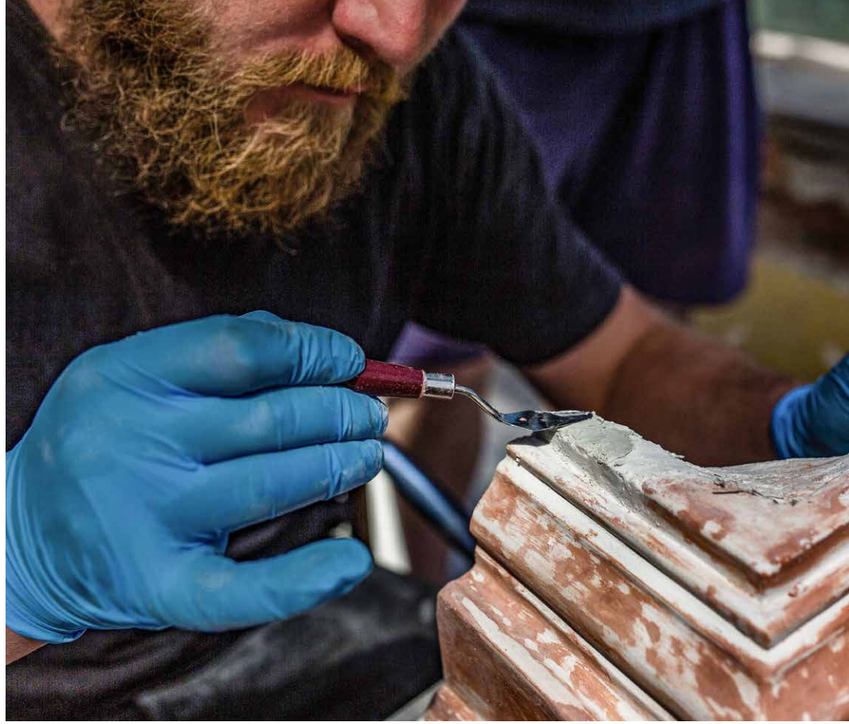
Baciu and her team use ELASTOSIL® M 4600 and 4630 to make the molds. These two-component, pourable, addition-curing silicone rubber grades cure at room temperature. The curing process begins as soon as the A and B components are mixed. Baciu's team needs around 500 kilograms of this material for the casino. If the mold is made on a vertical surface, WACKER's Stabilizer 43 can be added to make the rubber compound sag resistant. The products were supplied by Contras, WACKER's local partner.

"I used different materials at other locations," she notes, "but with silicone, it was love at first sight. It is easy to mix, easy to use, feels good and accurately reproduces the details on the original." She feels it's important that the mold replicates the marks left on the original by the passage of time – little scratches, tiny signs of breakage – so that the copy is authentic and doesn't look like a brand new item from a DIY store.

> "With silicone, it was love at first sight. It is easy to mix, easy to use, feels good and accurately reproduces the details on the original."
>
> **Prof. Annamaria Baciu**



A detail of the casino facade in Arad – wherever possible, the restorers preserve the original fabric of the building and are cautious when adding anything.



A passion for detail and craftsmanlike care are the qualities of an ideal restorer.

The restorers use a brush and trowel to apply the still-viscous silicone rubber to the original ornamental sun. White silicone is used for the first step, followed by a blue coat, and finally, to finish off, another white coat is applied.

"We work with colored silicone so that the different coats are visible," she explains. She sets aside an entire day for drying, to be on the safe side. Then the mold is ready. One advantage silicones have over polyurethane elastomers, which are also used in moldmaking, is that they don't need release agents. Even without these additives, the negative mold can easily be removed from the original. Release agents are undesirable in the moldmaking process because they leave stains and destroy the water equilibrium of the replica.

Generally, making and drying the negative mold takes three days. Then a so-called support mold is made. This second – hard – mold is needed to stabilize the first – elastic – silicone rubber mold. The restorers make the support mold out of gypsum, concrete or epoxy resin, as required. They have even experimented with polyurethane foam.

REPLICAS MADE OF ROMAN CEMENT

Many original ornamental elements are made of Italian stucco, a mixture of gypsum, clay and sand in various ratios; some of the pillars in the facade were terracotta. Baciu is having the replicas made from Roman cement, although the word cement is not meant literally. Rather, it is a traditional building material made of clay, sand and lime mortar with various additives. While the restorers are making a copy of a small pillar

Annamaria Baciu checks whether the original ornamentation can be preserved – which is her preferred option – or whether it needs to be replaced.

in the silicone mold, they add straw to the Roman cement – this too is a traditional artisanal technique to increase the strength of a structural part.

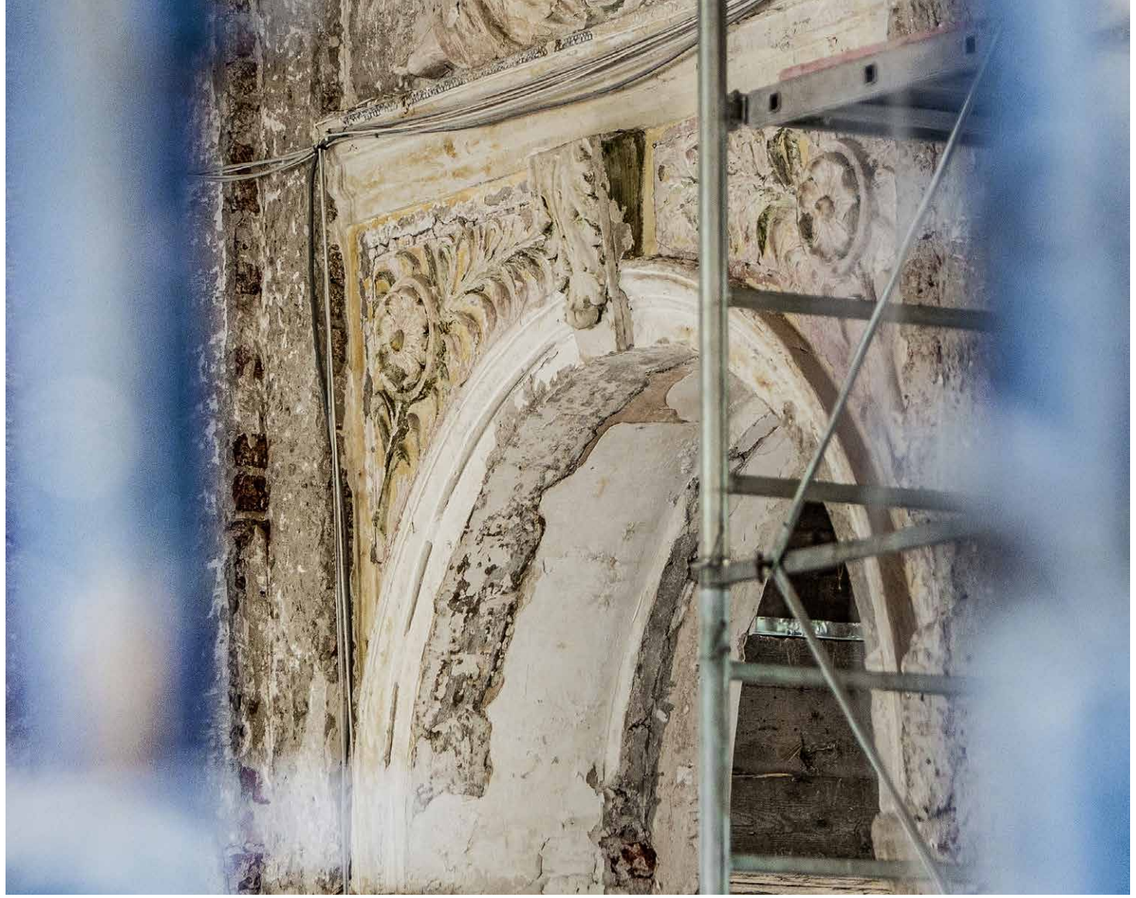
In Arad, the restorers use neither genuine cement nor other modern building materials. “Often, the compatibility of the newly applied coat and the original stone substrate is problematic,” she notes. Her team experiments a lot and develops its own mixtures. “Restoration work,” she says “is never-ending research.”

The team plans to complete its work by the fall, then the interior can be transformed into a modern event center. “Some couples in Arad have especially postponed their wedding until we have finished,” says Baciu laughing. “So we’d better hurry.” ■

CONTACT

For more information on this topic, please contact:

Andrea Bogner
Senior Marketing Manager
Industrial Solutions
WACKER SILICONES
Tel.: +49 89 6279-1375
andrea.bogner@wacker.com



SILICONE RUBBER FOR ARCHITECTURAL MOLDMAKING

Besides applications in the field of restoration, WACKER silicone rubber compounds are used to manufacture new building elements. Accurate detailed molds can be made of even complex structures and surfaces with ELASTOSIL® M. These structures can then be reproduced using concrete, artificial stone or gypsum. The silicone rubber molds have good alkaline hydrolysis resistance and thanks to their long-term stability, a high number of castings can be achieved. Our addition-curing ELASTOSIL® M products are the industry benchmark in this field.

Advantages:

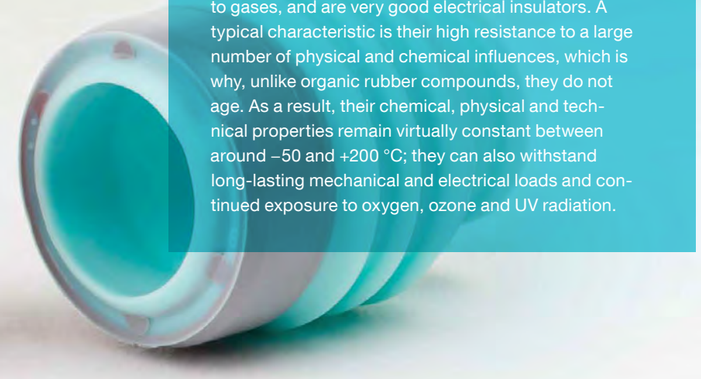
- High dimensional stability / non-shrink properties
- No release agent needed
- High number of castings for concrete, artificial stone or gypsum

Applications:

- Facade and decorative elements
- Indoor and outdoor facing bricks
- Dies for “stamping” concrete
- Curb stones and paving slabs

SELF-ADHESIVE YET LOW-FRICTION

WACKER has developed new grades of liquid silicone rubber that adhere well and yet have a low-friction surface immediately after curing – without bleeding any oil. The development opens the door to hard/soft combinations that are easy to process.



SILICONE ELASTOMERS

Silicone elastomers – rubber-elastic solids based on polyorganosiloxanes – are obtained from silicone rubber in a process known as crosslinking or vulcanization. Here, the polymer chains of the organosilicon macromolecules form a three-dimensional network. Silicone elastomers are characterized by a property profile that makes them indispensable in many industrial applications: extraordinary heat resistance, low-temperature flexibility, chemical inertness and biocompatibility. Silicone elastomers possess a highly hydrophobic (i.e. water-repellent) surface, are selectively permeable to gases, and are very good electrical insulators. A typical characteristic is their high resistance to a large number of physical and chemical influences, which is why, unlike organic rubber compounds, they do not age. As a result, their chemical, physical and technical properties remain virtually constant between around –50 and +200 °C; they can also withstand long-lasting mechanical and electrical loads and continued exposure to oxygen, ozone and UV radiation.

Composite parts have become significantly more important over the past twenty years. Reasons for this include growing cost pressures and new requirements for component quality, function and design. Selectively combining different materials to form a composite allows manufacturers to integrate multiple functionalities in a single part while giving designers more freedom. One widely used type of composite combines a soft, elastic component with a hard component that strengthens the composite and lends it its shape. Metal is frequently used as the hard component, although suitable thermoplastic materials are becoming increasingly common as well.

In hard/soft combinations like these, the soft component forms a seal or absorbs vibrations or sound. “More and more manufacturers are choosing silicone elastomers, especially if the final part will be used under harsh conditions, in medical devices, or in contact with food or medicines,” says Dagmar Rische, a marketing manager for Rubber Solutions at WACKER SILICONES. This is where the property profile of silicone elastomers comes into play: silicones are chemically inert, biocompatible, heat-resistant, flexible at low temperatures, resistant to aging and remain elastic for long periods.

Unless they are specially modified, however, silicone elastomers adhere poorly to other materials, which makes stable multicomponent parts difficult to produce. “In order for conventional silicone elastomers to achieve good adhesion, you have to pretreat the surface of the hard component extensively,” she emphasizes. “For parts manufacturers, that means an additional step.”

A number of applications are negatively impacted by yet another characteristic of silicone elastomers: their typically rubber-like surface, which generates a great deal of frictional resistance. That property can make processing difficult and cause problems in practical applications whenever the final product needs to move along another hard surface.

The ISO 813 adhesion test was conducted to demonstrate the adhesive properties of new self-adhesive liquid silicone rubber grades that crosslink to form an intrinsically low-friction surface. The silicone components (turquoise) adhere firmly to the thermoplastic hard components (black), even though the thermoplastic substrate was not treated ahead of time. This opens up the possibility of using two-part injection molding for cost-effective mass production of multicomponent parts made of thermoplastic and silicone elastomer components.

This equipment is used in the applications laboratory to perform the adhesion test on a test piece (on its side, top left).

WACKER solved the first problem – poor adhesive properties – back in 1999 with a patented self-adhesion technology that produces a permanent chemical bond between the two components. Since that time, the availability of specially modified liquid silicone rubber products – self-adhesive grades – has eliminated the need for pretreating hard components. The technology opens the door to using the 2K injection process as a fast, cost-effective method for mass-producing multicomponent parts consisting of silicone elastomers and either a thermoplastic material or metal.

INTRINSIC PROPERTY

In 2007, WACKER presented a solution to the second problem, i.e. the dull surface: a patented technology that creates a low-friction surface on silicone elastomers immediately after they cure – without releasing a lubricating oil as had been the case up to that time. “In silicone products that use this technology, the capacity to reduce friction is an intrinsic property of the material,” stresses Dr. Christof Wörner, who heads an applications laboratory at WACKER SILICONES.

His team of developers has now successfully combined both technologies. The result is a portfolio of liquid silicone rubber grades that are not only self-adhesive – they also yield elastomers with a low-friction yet dry surface. The portfolio includes the ELASTOSIL® LR 3671 and LR 3675 product lines, as well as the SILPURAN® 6760/50 grade.

The friction typically produced by silicones makes silicone products more difficult to work with during assembly and use – it takes considerable effort, for example, to thread silicone tubing through sleeves. One way of resolving the issue of surface friction is through the use of silicone elastomers that bleed oil. These materials contain a special silicone fluid that continuously migrates to the surface of the cured material to produce an oily liquid film, which, in turn, generates the desired low-friction effect.

Oil-bleeding silicone elastomers could be implemented in any applications where the oil discharge is not a problem. Weather packs and sealing mats made of self-lubricating silicones like these have been used in automotive electronics for years, for example. In addition to making the seals easier to install, the exuded oil also offers additional protection from moisture penetration. The oil and dust that stick to the oil film are generally not a concern under the hood.

COMPLICATED WORK STEPS

In applications that require cleanliness, however, this kind of oil film can be a problem. In medical and food technology applications, for instance, the use of oil-bleeding silicones is prohibited entirely. Up until 2007, the only options in these cases were either to accept the high level of frictional resistance or to modify the surface properties with a subsequent treatment, such as the application of a thin coating. But this meant additional work steps that, in some cases, were complicated and time-consuming.

WACKER technology that produces an intrinsically low-friction silicone surface offers an alternative here, as it reduces friction without the formation of a silicone fluid film. The surface of the silicone elastomer remains dry yet low friction, resulting in a material that feels very different from other silicone elastomers.

The reduced friction produced by the surface has a positive effect on the end product, both during assembly and in the final application. The resulting parts are easier to assemble and are also easier to disassemble for purposes such as maintenance or cleaning. The low-friction surface is particularly helpful when installing parts in tight spaces. Because assembly is easier, manufacturers can produce devices more quickly, and, in many instances, even automate the assembly process.

The ability to reduce friction without the use of oil produces another effect that is likewise highly desirable in a range of applications: when two surfaces of a silicone elastomer come into contact, as is the case in valve openings, for example, they often fuse together at high temperatures. The WACKER technology reduces that tendency, allowing slits in metering valves to remain open.

FAST AND INEXPENSIVE

Up to now, manufacturers had to choose between using either self-adhesive technology or oil-free friction reduction technology. Both have proven their merit in countless applications for many years now – what’s new is their combination. Bringing them together paves the way for fast, cost-effective mass production of multicomponent parts that consist of silicone elastomers combined with either thermoplastics or metal and that have an intrinsically low-friction silicone surface.

“Our unique formulation concept allows us to tailor grades specifically for sensitive applications.”

Dr. Christian Wörner, Technical Marketing, Rubber Solutions, WACKER SILICONES

CONTACT

For more information on this topic, please contact:

Dagmar Rische
Marketing Manager
Rubber Solutions
WACKER SILICONES
Tel.: +49 +49 6279-1332
dagmar.rische@wacker.com

POSTCURING

In the materials sciences, the term “postcuring” generally refers to a heat treatment that provides a material with its end properties. This also applies to silicones. Postcured silicone parts are superior to their non-postcured counterparts, both in terms of their engineering properties and biocompatibility. In the case of cured products of addition-curing silicone rubber compounds – a category that includes liquid silicone rubber – postcuring degrades excess crosslinker, improves filler bonding and drives out low-molecular-weight silicone components. This results in a modest increase in hardness, a significant improvement in tear strength, low compression set and a reduction in the content of volatiles. The established standard method is to postcure silicone pieces at 200 °C in an oven especially designed for this purpose. For safety reasons, the rate of air flow is held continuously high. Since the entire volume of air that flows through the oven has to be heated to 200 °C, postcuring consumes a great deal of energy.

Thanks to their low-friction surface, sealing elements made of ELASTOSIL® LR 3675 make cables easier to assemble in cars. Liquid silicone rubber grades in this product line adhere well to hard components, with no pretreatment required.

The Munich chemical company has conducted extensive tests in its applications labs on the innovative liquid silicone grades that excel in precisely this combination of technologies. The applications engineers working in Dr. Wörner’s lab paid particularly close attention to adhesive properties and surface friction.

NO NEED FOR PRIMING

The ISO 813 adhesion test demonstrated that the new silicone grades adhere well to a number of thermoplastic materials and metals, with no need for priming or plasma-treating the substrate ahead of time. The materials form a powerful bond on polyamide and polybutylene terephthalate, both of which are frequently used as the hard component in two-part injection molding. Other suitable substrates, however, included polyether ether ketone, polyethylene terephthalate and polymethyl methacrylate. “But processors still always have to test the adhesive properties of their substrates before launching large-scale production,” Wörner advises. That’s because the thermoplastics available on the market may contain additives that affect surface properties and thus adhesion.

The chemical bond generated by WACKER self-adhesive technology offers considerably more design freedom than traditional, mechanical bonding techniques in which the two components of a hard/soft combination are joined through interlocking openings or undercuts. In addition, a chemical bond means that there are no spaces between the hard and soft components where dirt can collect or where bacteria or fungi can become established – an important issue for 2K parts that are used in pharmaceutical or medical devices or that come into contact with food.

All of the grades in this innovative portfolio yield elastomers with lubricating surfaces. Their coefficients of dynamic friction lie between 50 to 70 percent below that of standard self-adhesive silicone elastomers that are equally as hard. The coefficients of friction were measured as directed in EN ISO 8295.

“We applied a unique formulation concept in order to combine the two technologies,” says Wörner. As the WACKER chemist then goes on to explain, “What we did was adapt the formulation components to the applications that the liquid silicone rubber grades had been designed for.” This allowed the developers to do more than simply tailor products for purely technical applications – they were also able to create grades specifically for sensitive applications.

SILPURAN® 6760/50 – THE MEDICAL TECHNOLOGY GRADE

Designed for applications in medical and pharmaceutical technology, WACKER’s self-adhesive, intrinsically lubricating SILPURAN® 6760/50 – the first product in this innovative portfolio to be ready for the market – was unveiled at the COMPAMED 2016 medical technology tradeshow. Following a fine filtration process, WACKER visually inspects this liquid silicone rubber and dispenses it under cleanroom conditions. The product then crosslinks to form an elastomer with a hardness of 50 Shore A.

After postcuring, objects made from SILPURAN® 6760/50 are biocompatible, as demonstrated by select tests meeting ISO 10993 and United States Pharmacopeia (USP) Class V1 standards. The materials were tested according to ISO 10993 with regard to cytotoxicity, pyrogenicity and sensitizing properties. USP Class VI tests included the examination of acute systemic toxicity, intracutaneous toxicity and short-term implantation.

This makes SILPURAN® 6760/50 the silicone soft component of choice for seals used in medical technology or pharmaceutical applications in which a seal moves along another part, as is the case for sealing elements in syringes or piston-type dosing pumps. In both of these cases, the sealing elements are attached to pistons or plungers. During the process of injecting or dispensing a medicine, the seal slides along the inner surface of the syringe and/or pump cylinder.

If the surface of the seal is dull and rubber-like, this movement will be jerky, which can have a negative impact on dosing accuracy and result in pressure surges that feel unpleasant to patients receiving injections or having their blood drawn. If made of SILPURAN® 6760/50, on the other hand, the sealing elements glide uniformly and smoothly along the syringe wall. Plus, the silicone surface does not bleed oil, eliminating the risk of contaminating the medicine.

ELASTOSIL® LR 3671 – COMPATIBLE WITH FOOD

ELASTOSIL® LR 3671 was developed especially for food technology applications. This product line includes 30 and 40 Shore A grades, both of which contain only formulation ingredients approved for use in foods. Postcured parts made

Syringes with a sealing element made of SILPURAN® LR 6760/50 allow medical personnel to inject medications gently and smoothly.

of ELASTOSIL® LR 3671 are food grade and suitable for contact with food according to the recommendations of Germany's Federal Institute for Risk Assessment (BfR Recommendation XV Silicones) and the US Food and Drug Administration (21 CFR 177.2600).

Their self-adhesive properties and their intrinsically low coefficients of friction make both grades of ELASTOSIL® LR 3671 suitable for applications in which the silicone components of a multicomponent part move in contact with another surface, either during assembly or in later use. Typical applications here include shaft seals of kitchen appliances, piston seals of dosing pumps and thermos lids with molded-on sealing elements.

ELASTOSIL® LR 3675 – DESIGNED FOR AUTOMOTIVE ENGINEERING

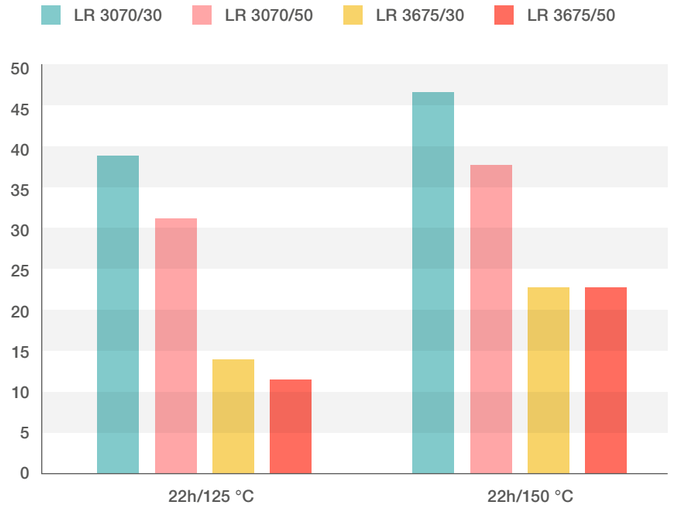
The ELASTOSIL® LR 3675 product line likewise includes two grades, in this case with Shore A hardness values of 30 and 50. When developing this product line, WACKER chemists worked with an eye to technical applications, particularly in the automotive sector. The developers turned to an extraordinarily effective adhesion promoter system, to which they then introduced an additive that lends the elastomer a low compression set, even without postcuring. Neither component of the formulation is approved for sensitive applications.

Compression set provides information on the elastic recovery of the elastomer, making it an important parameter for elastomer seals. The ideal value for compression set is 0 percent, which means that the material is perfectly elastic. A completely inelastic material, by contrast, would have a compression set of 100 percent – a seal made of this material would fail.

If the cured rubber is not postcured, the compression set of ELASTOSIL® LR 3675/30 – the 30 Shore A grade – is 14 percent. The compression set of the harder grade (ELASTOSIL® LR 3675/50) is somewhat lower at 12 percent.

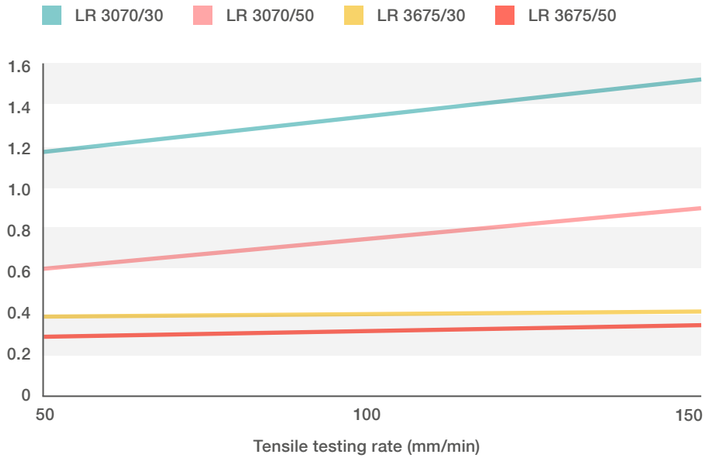
COMPRESSION SET (%)

Cured liquid silicone rubber grades from the ELASTOSIL® LR 3675 product line exhibit low compression set and hence considerable elastic recovery with no postcuring.



LESS DYNAMIC FRICTION

ELASTOSIL® LR 3675/30 and ELASTOSIL® LR 3675/50 exhibit a reduced coefficient of dynamic friction.



COMPRESSION SET

If deformed over a long period of time, an elastomer seal will no longer return to its exact shape after release, instead remaining more or less deformed. The extent of this sustained deformity depends on how greatly the elastic recovery of the material decreases under the prevailing storage conditions – deforming forces, the medium that is impacting the material, and the temperature. This information is provided by compression set, a parameter that is determined in a standardized testing procedure. To determine the compression set, an elastomer test specimen (whose shape and dimensions are defined in testing standards) is placed in a compression mechanism, where it is compressed to a previously defined extent and stored in this state for a specific period of time under the testing conditions. Once the test specimen is released, it will no longer return to its original thickness. The thickness of the test specimen is measured before and after compression as well as after relaxation. Expressed as a percentage, the compression set is the ratio of the reduction in thickness following relaxation to the thickness to which the test specimen was compressed. A low compression set is favorable – this shows that the material has high elastic recovery.

Liquid silicone rubber grades in the ELASTOSIL® LR 3675 product line are perfect for use in automotive electronics, as they adhere well to the thermoplastic polymers used in connector housings – with no pretreatment required.

Those are very good values: testing results for cured, standard self-adhesive silicones of the same hardness and without postcuring are generally much poorer. Sealing elements made of ELASTOSIL® LR 3675, in other words, retain their function for long periods of time. At the same time, these cured silicones also exhibit excellent mechanical properties, even without postcuring. This allows manufacturers of multicomponent parts to eliminate the postcuring step, thus improving productivity.

As with other silicones in this innovative portfolio, ELASTOSIL® LR 3675 likewise forms an intrinsically lubricating surface. For both grades, the coefficient of dynamic friction – measured as described in EN ISO 8295 – is roughly two-thirds lower than standard self-adhesive grades of equal hardness. When cured, ELASTOSIL® LR 3675 naturally exhibits properties typical of silicones, which makes these two grades of liquid silicone rubber the perfect sealing materials for applications under the hood, such as automotive electrical systems.

ELASTOSIL® LR 3675 is therefore the material of choice for producing single-wire seals and connector housings with molded-on radial seals – for any area of an application where a lubricating silicone surface is needed but where a film of exuded silicone fluid would be undesirable. Plugs with molded-on ELASTOSIL® LR 3675 sealing elements are easy to connect, and cables readily slide through molded-on single-wire seals. The risk of contaminating other objects with oil during assembly or later use is never an issue.

RELIABLE FIRE-FIGHTERS

Fire-safety regulations for trains have always been very high, but they have now become even tighter across the EU. Even so, most of the new specifications are still met by WACKER high-performance silicone rubber compounds for fire-sensitive applications. The company has now rounded out its portfolio with a new grade.

5,000

plus different substances that are harmful to humans are lurking inside smoke fume.

Unconsciousness strikes after just a few breaths. Toxic fumes are the most common cause of death among fire victims. Billowing fumes blind and disorientate, preventing victims from seeing the nearest escape route. But even more dangerous are the toxic compounds they contain. Carbon monoxide, the cause of unconsciousness, is the best known example. But nowadays we also know that smoke can contain over 5,000 different substances which are harmful to humans. More than 90 percent of fire victims die from smoke inhalation, not from being consumed by flames. They fall unconscious and cannot save themselves.

"That is the reason why means of public transport, such as trains, are particularly subject to very stringent fire-safety codes – train passengers need to be able to escape in an emergency with as little harm as possible," says Dr. Martin Bortenschlager, senior marketing manager for Rubber Solutions at WACKER SILICONES. Fire-safety codes are tightened up at regular intervals. They were made much tougher in 2018, with the adoption of a new pan-European standard that supersedes national norms and is binding on all makers of rolling stock. Since then, all components installed in rolling stock must comply with EN 45545-2.

Silicone rubber compounds are becoming more and more popular with producers of elastomeric components. "Generally, the cured rubbers or silicone elastomers are flame-resistant rule and produce only small amounts of smoke when burned. This makes them ideal for use in rolling stock and public buildings – all applications where fire-safety is paramount," continues Dr. Bortenschlager. What is more is that when silicones burn, they do not release any halogenated compounds and the fumes are much less toxic as a result.

Chinese high-speed trains in Shanghai station.

Production of ELASTOSIL® R 771 in a strainer being demonstrated in the silicone pilot plant in Burghausen.

STRICTER REQUIREMENTS

With the new ELASTOSIL® R 771 solid silicone rubber, WACKER provides producers of rolling-stock components with a material that meets the R1 and R7 requirement sets of the European fire-safety standard EN 45545-2. Among the applications which it covers are profile strips for doors and windows, as well as the bellows used in gangways to connect coaches.

The new fire-safety standard distinguishes different classes of rolling stock: These four operating classes reflect the specific type of infrastructure in which the trains operate and thus indicate the speed at which they can be evacuated. The highest-level operating class applies, for instance, to underground tunnel sections where side evacuation is not possible.

The standard also identifies four different design categories, called structural train classes. These specify, for example, whether the coach is a sleeping car or a bilevel car. The operating and structural classes are then used to derive hazard levels which specify the fire-safety requirements which must be met by installed components and materials. For example, all the materials in sleeping cars that travel through long tunnel sections must be of a higher specification than in regional trains that frequently stop above ground and can be evacuated more quickly.

The resulting matrix of operating and structural classes is then used to establish hazard levels or HLs. HL1 denotes the lowest specification and HL3, the highest. The hazard level reflects the requirements and limit values which a component must meet in order that the fire risk may be reduced to an acceptable level. Components on 80 to 85 percent of rail vehicles need only meet the HL 2 specification.

"That was the minimum goal we set ourselves when developing the specialty grades in the ELASTOSIL® series," says Dr. Andreas Bacher, who heads up an applications laboratory for silicone rubber at WACKER in Burghausen. Following numerous tests performed to the new European standard, a number of silicone rubber grades and Shore A hardnesses were awarded the corresponding certificates. "This gave us the proof that the existing ELASTOSIL® portfolio which WACKER supplies to manufacturers of certain modules already contains HL 3 products that are in compliance with requirement sets R22 and R23," he continues. New test methods, such as a new way of determining the spread of a flame, have identified further possible market needs." Compounders have a need for silicone elastomers

European standard EN 45545-2 establishes three different hazard levels (HLs)

	Operating Class
1	Vehicles operating on the surface
2	Vehicles operating in tunnels shorter than 5 km
3	Vehicles operating in tunnels longer than 5 km
4	Vehicles operating in tunnels in which side evacuation is not possible

	Design Category
A	Automatic train having no on-board staff trained in emergency procedures
D	Bilevel rail cars
S	Sleeping cars
N	Other, standard vehicles

	N	A	D	S
1	HL1	HL1	HL1	HL2
2	HL2	HL2	HL2	HL2
3	HL2	HL2	HL2	HL3
4	HL3	HL3	HL3	HL3

> “Public transport systems, such as trains, have to meet very stringent fire-safety regulations so that passengers can escape without harm in an emergency.”
>
> **Dr. Martin Bortenschlager**,
> Senior Marketing Manager, Rubber Solutions,
> WACKER SILICONES

which have been optimized even more for such fire-safety-critical applications. Components made from ELASTOSIL® R 771 meet HL2 for the more stringent R1 and R7 requirement sets.

COMBINATION OF FILLERS

Formulation know-how proved useful in a number of ways while our experts were developing ELASTOSIL® R 771. To meet the new fire-safety standards, they modified the silicone content and worked out the best combination of fillers to use. The outcome is that the silicone rubber compound has the optimal rheology for ensuring that the molecules have the ideal crosslinking density. That, in turn, makes it possible for customers to tailor the mechanical properties of their products to the level they desire.

Silicones have the general advantage of being difficult to ignite, which means that they have an inherently high level of fire safety. What is more, they do not continue burning by themselves: as soon as the ignition source is removed, the flame quickly extinguishes. And, because the combustion products are mostly carbon dioxide, water and silicon dioxide, hardly any toxic gases are released. Yet another advantage is that ELASTOSIL® produces white rather than black smoke. Consequently, it transmits more light and causes less disorientation in danger zones.

Silicone rubbers possess a range of other advantages as well. They are highly heat stable, do not age even when continually exposed to UV light, oxygen or ozone, and are permanently elastic at low temperatures down to -40 °C without the need for plasticizers.

ELASTOSIL® R 771 is, like its predecessor ELASTOSIL® R 770, a peroxide-curing system. The peroxide needed for crosslinking is added during production, but pre-mixed products are also available.

ELASTOSIL® R 771 is currently supplied in Shore A hardness values of 60 and 70. When cured, the two variants have an elongation at break of 430 and 260 percent. WACKER is already working on a further version that has a Shore A hardness of 50. Manufacturers of train parts will see no changes when it comes to handling the new silicone rubber. It can be molded, extruded and calendered by the usual methods. It lends itself to the production of elastic molded parts and profiles and of panels, films and fabric-reinforced silicone sheets.

New EU directives are also increasingly superseding national standards governing public buildings. Just as in the case of rolling stock, smoke density and toxicity feature prominently in them. As all silicones in the ELASTOSIL® series are halogen-free and so release no harmful, corrosive hydrogen chloride in a blaze, the products are finding new applications in fire curtains, insulation, and door and window seals.

“We can expect fire-safety regulations to become even tighter in the future,” says Bortenschlager. He went on to say that stricter regulations meant that materials manufacturers were going to be kept very busy meeting new challenges. “And we will continue to expand the ELASTOSIL® series so that the makers of such components can avail themselves of suitable regulatory-compliant silicone products – whether for rolling stock or for public buildings.” ■

Typical profiles extruded from ELASTOSIL® R 771.

Passenger compartment in a high-speed train used by Polish railways.

CONTACT

For more information on this topic, please contact:

Dr. Martin Bortenschlager
Senior Marketing Manager
Rubber Solutions
WACKER SILICONES
Tel.: +49 89 6279-1982
martin.bortenschlager@wacker.com

SMART PLAY SAFE

Two US companies have developed a new type of helmet that will better protect players of American football against traumatic brain injuries and their long-term consequences. WACKER has provided assistance in the form of its ACEO® 3D printing technology.

The Buffalo Bills (in light jerseys) and the Pittsburgh Steelers faced each other at the Three Rivers Stadium in Pittsburgh (PA, USA) on December 16, 1979. Michael Webster, wearing Number 52, was the Steelers' center, which meant he always played right at the front.

Michael Lewis Webster, also known as “Iron Mike,” suffered from chronic traumatic encephalopathy after retiring from professional football. Multiple concussions or mild traumatic brain injuries, from which American football players frequently suffer, are considered to have caused his condition.

PLAY SMART PLAY SAFE

Fans of the Pittsburgh Steelers called him “Iron Mike” because he was tough and hard – even on himself. Michael Lewis Webster, a professional footballer for 16 years, won the Super Bowl with the Steelers four times between 1975 and 1980. Though an inductee into the “Pro Football Hall of Fame”, it was not his extraordinary performances on the field that made him known outside of football circles and even beyond America’s shores. It was the tragic fate that befell him and that was so movingly portrayed in the movie “Concussion.”

After he retired from active sports, Iron Mike suffered from impaired speech, hearing and concentration, not to mention amnesia, along with hand tremors and depression. He spent periods of time living in his car, knocked out his own teeth when delirious and eventually died at the age of 50, officially because of a heart attack.

When Nigerian pathologist Dr. Bennett Omalu – portrayed in “Concussion” by Hollywood star Will Smith – autopsied Webster’s brain along with that of another footballer, he discovered a disease which is known in medical circles as chronic traumatic encephalopathy or CTE. Current medical opinion is that CTE is caused by repeated concussions or minor traumas to the skull and brain. It often takes the symptoms ten to twenty years to appear after the damage has been done. CTE occurs not only in footballers. It is increasingly afflicting boxers, as well.

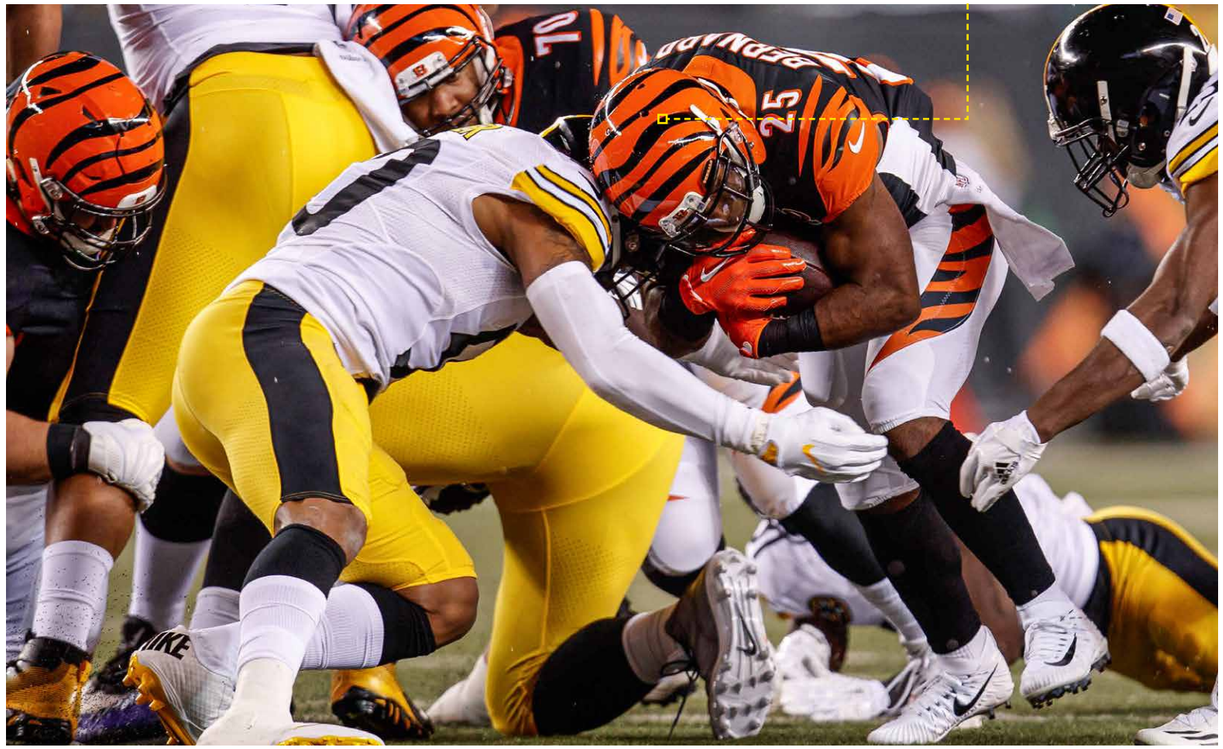
ENHANCED PROTECTION

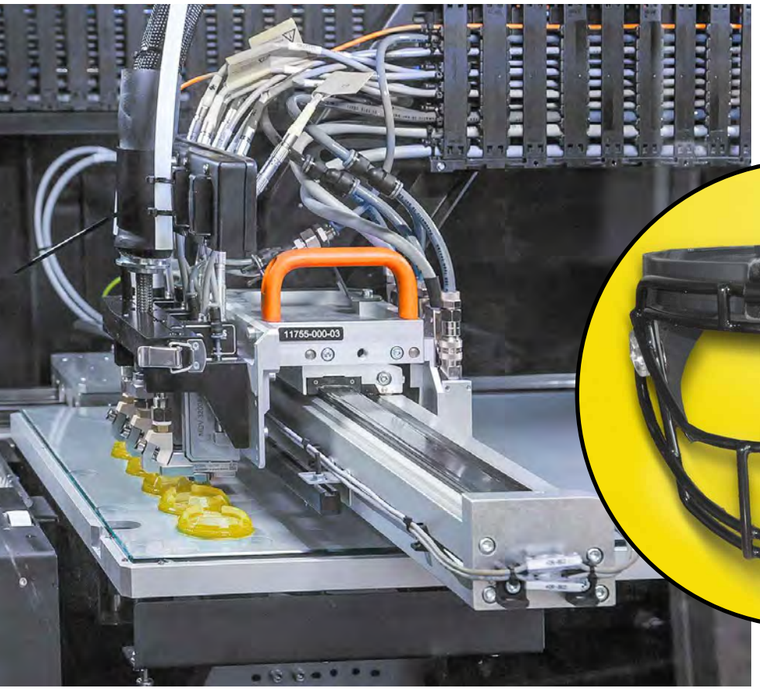
The National Football League (NFL) now actively promotes measures to prevent injuries that might have life-long consequences – such as concussions – or at least to treat them effectively. One such measure is the NFL’s “Play Smart. Play Safe.” initiative, launched in 2016 and involving a pledge of $100 million in support of independent medical research and engineering advancements. The NFL also announced an annual “HeadHealthTECH Challenge” which invites companies to submit proposals for improvements in football helmets and other protective equipment.

In late 2017, Baytech Products, based in Asheville, North Carolina, entered the second HeadHealthTECH Challenge because its founder and CEO, Robert T. Bayer, had conceived of a novel type of helmet. He had been supported in this by Brad Maloney, whose South Carolina-based company HelmetComp designs helmets for different types of sport, the military and the police.

“Our football helmet has a groundbreaking two-piece design, comprising an upper shell and a lower shell,” says Maloney. “The upper shell is attached to the lower section by flexible struts. The upper section can move in any direction after impact, and independently of the lower section and the football player’s head.” This design helps to absorb the energy of linear and rotational hits and prevent them from

The highly physical nature of American football entails a high risk of injury.





The 3D-printed silicone damper on the lower shell is located behind the four screw connections.

3D PRINTING WITH SILICONES

ACEO® is based in Burghausen, from where it provides a global service for 3D-printed silicone elastomers. The silicone damper for the new helmet was designed there too.

being transmitted to the head. “After impact, the upper shell returns to its original position,” he adds.

Bayer and Maloney entered the competition with a 3D-printed prototype, backed up by preliminary lab test results. The jury was so impressed that it declared Baytech a TECH Challenge II winner. What is more, the NFL awarded Baytech $178,000 for continued design advancements.

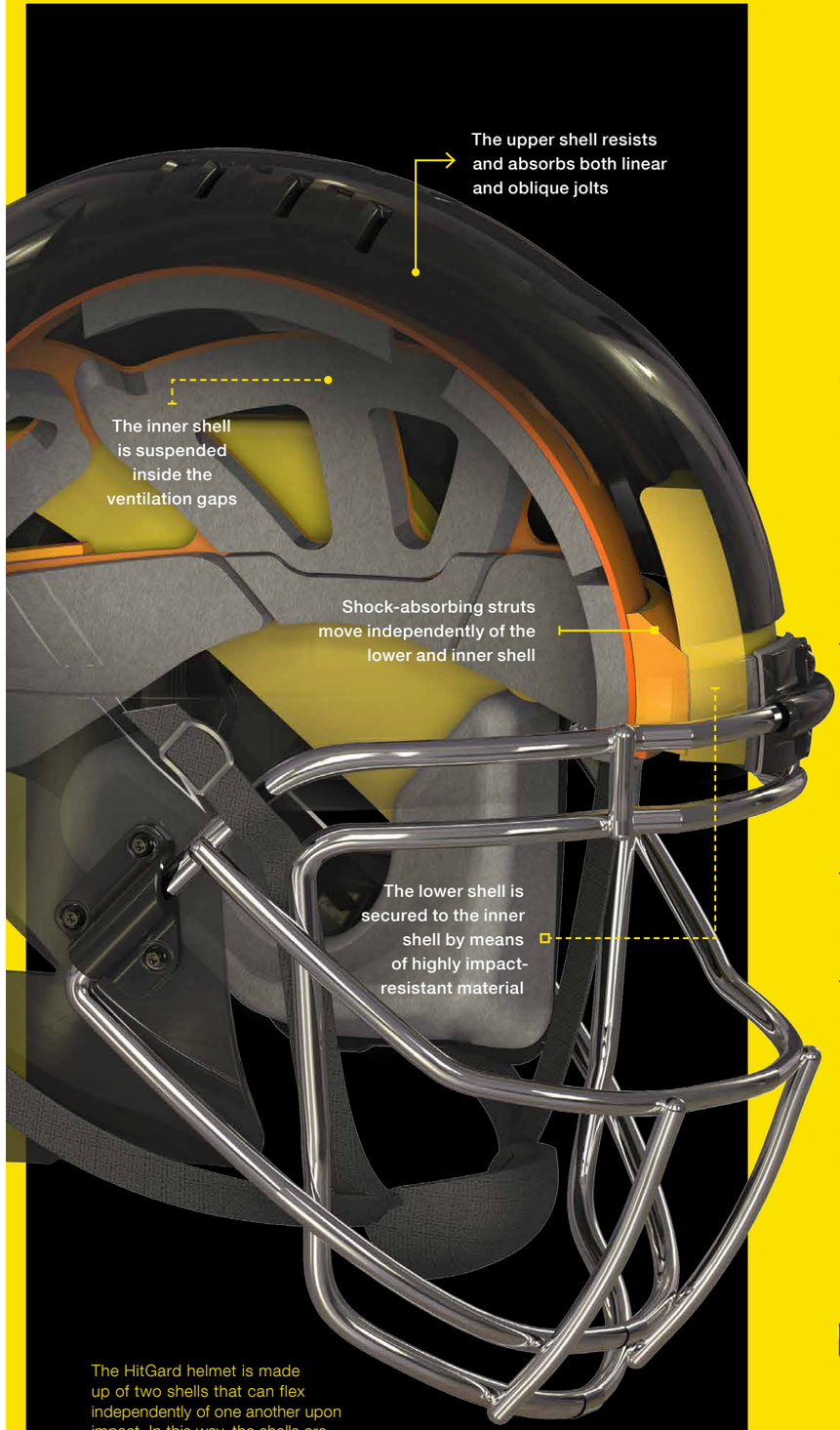
Bayer and Maloney have since partnered with a view to enhancing their helmet technology, called HitGard™, and achieving the goal of production release. After winning the challenge, they began injection molding the shells for the helmet, using high-impact absorbing foams for the inner shell and redesigning the face mask. All the while, they were determined to meet the requirements of the stringent lab tests commissioned by the NFL for checking a helmet’s safety and toughness. These include the use of a pneumatic ram tester to strike specific, predetermined points on the helmet with great force.

One such point is located in an area designed to protect the forehead, because American football players are particularly prone to frontal collisions. Directly below this point, the face mask is anchored in the helmet – here, too, collisions can generate enormous forces. The HitGard™ designers therefore specified that a special damping element made from thermoplastic polyurethane (TPU) be incorporated into this part of the helmet. “However, when the face mask was struck in the lab tests, this material fractured because it couldn’t absorb enough energy to cause it to deform,” says Maloney.

CONTACT

For more information on this topic, please contact:

Egbert Klaassen
Global Marketing Director
ACEO® – 3D PRINTING WITH SILICONES
Tel.: +49 1520 935 2545
egbert.klaassen@aceo3d.com



The HitGard helmet is made up of two shells that can flex independently of one another upon impact. In this way, the shells are intended to protect the head more effectively from injury due to shocks.

HitGard™

HOW IT WORKS

HitGard’s patent-pending technology is a groundbreaking split-shell design consisting of an exterior upper and lower shell and an inner shell suspension system.

The exterior upper and lower shells are connected by high-impact absorbing struts. Upon impact, the upper shell can move independently of the head, thus absorbing/dispersing direct impact forces before the energy is transmitted to the head.

The upper shell absorbs both linear and oblique impacts before returning to its original position.

The inner shell suspension system is anchored to the exterior lower shell with high-impact absorbing materials. The player’s head is fitted inside the inner shell which is surrounded by an air void and thus is independent from direct impact energy to the upper shell.

NFL HeadHealthTECH Challenge Winner

SILICONE DAMPER

The product developer therefore started looking around for alternatives in spring 2018. His research led him to WACKER's ACEO® 3D printing service with silicone rubber. He contacted the ACEO® team via LinkedIn. "After we had talked about the specifications the material would have to meet, Brad came straight out and asked if we could produce and ship such a damper to HelmetComp within ten days," explains Egbert Klaassen, Global Marketing Director for WACKER's ACEO® 3D printing solutions. The reason for the urgency: major tests had been scheduled with external testers.

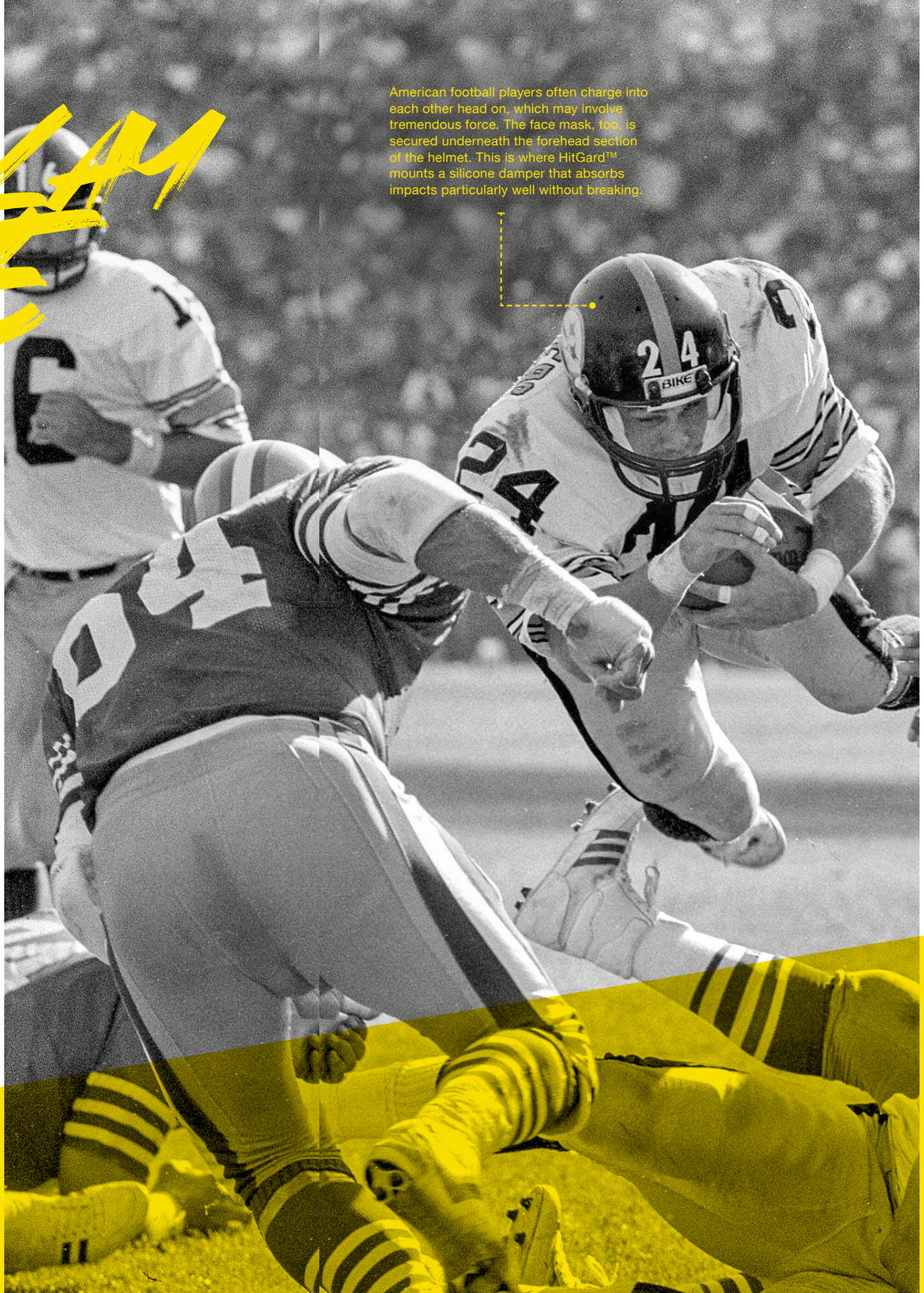
Maloney's request would have been an absolute impossibility for any company that produces silicone parts by conventional injection molding. That company would usually need eight to twelve weeks to create the corresponding mold – at huge expense – from the submitted CAD design files. The customer would then have to approve it before the silicone could be molded into the desired part. But thanks to the collaboration with the ACEO® 3D printing center in Burghausen, Maloney's wish was quickly granted. The silicone damper, which has exactly the same properties as its injection-molded counterpart, was delivered ahead of the scheduled tests with a day to spare. Maloney installed it inside the helmet, which subsequently went on to pass the tests. Maloney's take on the whole experience: "The WACKER ACEO® 3D printing service proved to be an extremely capable solution provider and will be supporting us further as we continue our development work."

HELMET TRENDS: FROM LEATHER TO HIGH-TECH

Approx. 1950
Early football helmets were made entirely of leather. In the 1950s, more and more players started to wear helmets with a plastic upper shell.

Approx. 1975
To prevent facial injuries, the helmets started to be fitted with large protective visors from around the mid-1970s.

2019
Fitted with two moving shells, the HitGard helmet heralds the next generation and is designed to protect the head even more effectively.



American football players often charge into each other head on, which may involve tremendous force. The face mask, too, is secured underneath the forehead section of the helmet. This is where HitGard™ mounts a silicone damper that absorbs impacts particularly well without breaking.

3D SILICONE PRINTING SAVES TIME AND MONEY

The helmet designer is thoroughly convinced of the merits of using the ACEO® 3D printing service for developing and launching products onto the market. "Parts often need design tweaks after they have been made. 3D printing is a simple, rapid and cost-effective way of sourcing optimized parts – injection molding is a much more complicated process that would entail starting all over again.

There is one final, crucial step to be taken before the patent-pending HitGard™ helmets can be brought to market: Bayer and Maloney need to either partner with an established helmet maker or find a sponsor so that they can start up their own production. In view of the performance produced by the HitGard™ helmet, that should not take too long: its scores were among the highest ever achieved at any of the three major accredited US test labs.

Maloney believes that the future of the innovative, two-part shell design lies not only in American football. Cyclists, climbers, winter sports athletes and horse riders would all benefit from helmets that are better now than ever before at absorbing impact forces and torque. "The incredible properties of silicone rubber, its versatility and durability make it a prime candidate for this application," stresses Maloney. ■

SETTING NEW STANDARDS

Up to now, silicone products often required postcuring to achieve the desired properties. But help is now on the way, because WACKER has considerably reduced the residual volatile substances in its liquid silicone rubber products.

Liquid silicone rubber – which professionals also refer to by its acronym LSR – has become firmly established on the market since it was introduced in the 1980s. "A key reason why is because you can use a fully automated injection-molding process to turn silicones like these into molded silicone parts," explains Dr. Thomas Frese, who runs an applications lab for the Rubber Solutions business team within WACKER SILICONES. "That allows us to produce parts in large quantities – quickly, efficiently, cost-effectively and very precisely."

In most cases, the molded parts are postcured. Examples of when this downstream heat treatment is required include silicone objects made from conventional liquid silicones and intended for use in food, babycare or medical applications. The treatment removes any residual volatiles or extractable substances from the elastomer. This is the only way of meeting the strict regulatory requirements for silicone items used in these sensitive applications.

The industry is also increasing pressure on silicone compounders to reduce the content of volatiles in finished products. As a result, silicone manufacturers are receiving increasingly frequent requests for low-volatile LSRs – for liquid silicone rubber grades, in other words, that contain very low levels of volatile substances.

VOLATILES CONTENT REDUCED

"We rose to the challenge and significantly reduced the volatiles content of the LSR grades we manufacture in Europe," explains Dr. Wolfgang Schattenmann, who heads up the Rubber Solutions business team at WACKER SILICONES. "In the process, we upgraded our LSR line to a low-volatile product portfolio."

The company is also introducing ELASTOSIL® LR 5040, a product line especially for manufacturing silicone goods for the food, babycare, pharmaceuticals and medical industries. "This product line in turn goes well beyond the new standard that our low-volatile LSR product portfolio sets," explains Claudia Berghammer,

Putting the mechanical strength of cured liquid silicone rubber to the test at an applications laboratory in Burghausen; the image shows a baby bottle nipple undergoing a bite test.

senior marketing manager at WACKER SILICONES. "Molded parts made from ELASTOSIL® LR 5040 meet the legal requirements for sensitive applications with no need for postcuring." The company had already unveiled this product line at K 2016, and now a broad customer base has access to the full spectrum of grades in the series.

In an ideal scenario, injection-molded silicone parts are ready for use without any further processing. In practice, though, it is often expedient and usually even necessary to bake out parts at high temperatures for several hours in a well-ventilated oven. The benefits of this thermal treatment step, which is known as postcuring, include improved mechanical properties of the elastomer (see info box on p. 79). In addition, however, it ensures the removal of volatile components, which form as a manufacturing byproduct of the raw materials used and which are not incorporated into the elastomer network when the rubber is cured later on. Low-molecular-weight siloxanes account for the bulk of these volatile components.

"ELASTOSIL® LR 5040 completely eliminates all of the usual postcuring work so that we can gear our production directly toward final packaging."

Martin Rapperstorfer, head of sales, RICO GROUP GmbH

STRICT SAFETY STANDARDS

Whether thermal post-treatment is necessary depends on the composition of the silicone rubber compound and on the intended use of the molded part. Imposing strict purity criteria is one way that legislators have set high safety standards for products intended for sensitive applications. Silicone products for food and babycare applications must be especially pure – the content of volatiles in these cases must not exceed 0.5 percent.

This is the threshold identified in the following recommendations: "XV. Silicone" from the German Federal Institute for Risk Assessment (BfR), France's "Arrêté du 25 novembre 1992," and the Swiss Ordinance No. 817.023.21 on Food-Contact Materials and Articles. European Standard EN 14350-2 applies to silicone products used in cups and bottles for infants and toddlers, while EN 1400 must be met for pacifiers.

As a measure of volatiles content, these regulations specify the weight that silicone objects lose when subjected to a precisely defined heat treatment – often for four hours at 200 degrees Celsius. Dried samples of molded parts must not lose more than 0.5 percent of their mass when treated in this way. Cured products of commercial liquid silicone rubber must be postcured in order to comply with these regulations.

Volatile silicone components are often undesirable in silicones used for technical applications as well. "The focus in these cases is on the effects that low-molecular-weight siloxanes can have," says Dr. Frese. As the WACKER chemist explains, "They can spread from the silicone to other media or other objects in a number of different ways – evaporation, extraction or migration – and cause unwanted effects there. That's why a lot of industries, including the automotive industry, are really interested in silicone rubber compounds that contain very little in the way of residual low-molecular-weight components – even though these particular regulations differ from those for sensitive applications."

UNIQUE REQUIREMENTS

WACKER takes an approach that accounts for these different needs: on the one hand, the company has turned its entire line of LSR products into a low-volatiles portfolio; on the other, it has launched a product line on the market that is specially tailored to the unique requirements of the food, babycare, medical technology and pharmaceuticals sectors – the ELASTOSIL® LR 5040 series.

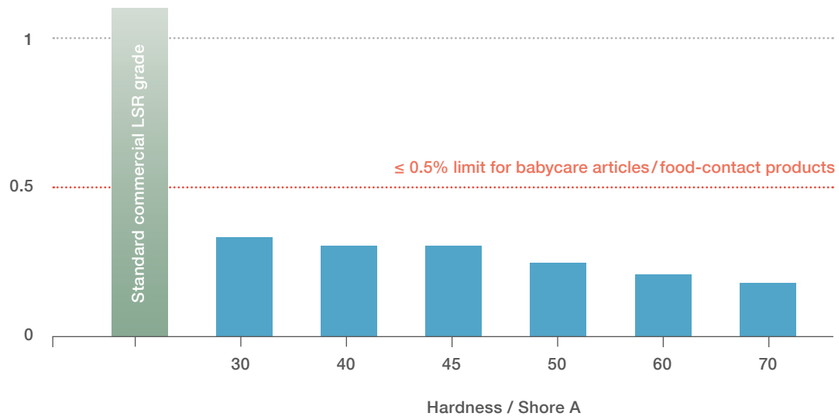
For silicone compounders, postcuring constitutes an additional processing step that not only entails considerable energy consumption

CONTACT

For more information on this topic, please contact:

Dr. Thomas Frese,
Head of Technical Marketing for Rubber Solutions
WACKER SILICONES
Tel.: +49 8677 83-4947
thomas.frese@wacker.com

VOLATILES CONTENT*

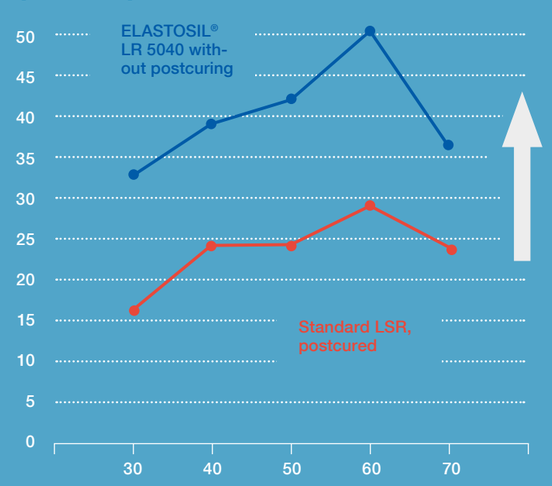


The volatiles content of non-postcured items made of ELASTOSIL® LR 5040 (blue bars) is below 0.2 to 0.3 percent, far below the threshold of 0.5 percent required for food applications by agencies such as the German Institute for Risk Assessment (BfR). A standard commercial liquid silicone, by contrast, has a volatiles content in the range of 1 to 1.2 percent prior to postcuring and, as a result, has to be postcured to stay below the threshold.

* in weight percent

Babies' teething ring made of ELASTOSIL® LR 5040: tear strength plays a key role in such applications.

TEAR STRENGTH (N/mm)



The tear strength of cured ELASTOSIL® LR 5040 rubber without postcuring (blue curve) is significantly higher than that of standard postcured liquid silicone rubber (red curve). That is why injection-molded parts made from ELASTOSIL® LR 5040 do not require thermal post-treatment to improve their mechanical properties prior to shipping.

and generates emissions – it also restricts productivity. Whereas injection molding and product packaging are fully automated processes with quick cycle times, postcuring is performed largely by hand. Subsequent thermal treatment interrupts the process chain and limits production capacity. Plus, if the postcuring process is not carried out correctly, explosive mixtures can form in the oven.

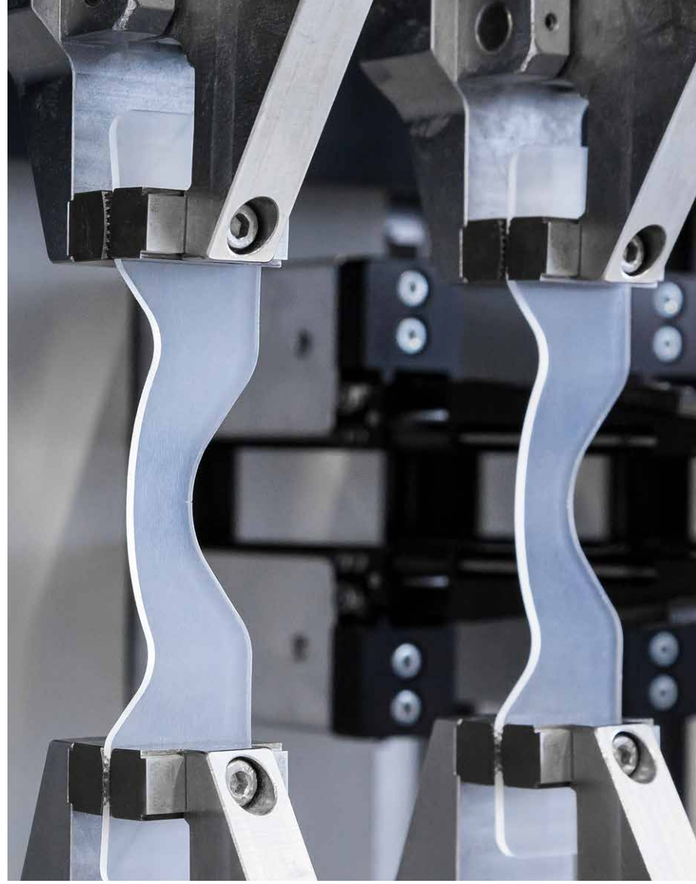
This is why WACKER aimed to take this highly involved process off of silicone compounders' hands A team headed by Dr. Frese developed ELASTOSIL® LR 5040 specifically for sensitive applications. Using a novel, proprietary WACKER process technology and a new formulation concept as their starting point, the scientists were able to develop ELASTOSIL® LR 5040, a product line within the LSR portfolio with by far the lowest concentration of components that are volatile, extractable or capable of migrating into other materials – the products also comply with regulations governing the content of volatile substances in sensitive applications.

In addition, silicone items made from these rubber grades exhibit the excellent mechanical properties needed – even without postcuring. The postcuring process will no longer be necessary in these applications in the future.

From the perspective of a compounder like the RICO Group, an international full-service provider of customized polymer solutions, the material combines several benefits that ultimately translate into savings for customers. "Right now, every kilo of liquid silicone rubber we process into finished parts has to be put in drums or on trays and taken over to the postcuring ovens," says Sales Manager Martin Rapperstorfer, an engineer from Austria. "This is followed by packaging – a process in which the LSR parts have to be staged yet again. ELASTOSIL® LR 5040 completely eliminates all of that postcuring work so that we can gear our production directly toward final packaging," he points out. "Not only

POSTCURING

In the materials sciences, the term "postcuring" generally refers to a heat treatment that provides this material with its end properties. This also applies to silicones. Postcured silicone parts are superior to their non-postcured counterparts, both in terms of their engineering properties and biocompatibility. In the case of cured products of addition-curing silicone rubber compounds – a category that includes liquid silicone rubber – postcuring degrades excess crosslinker, improves filler bonding and drives out low-molecular-weight silicone components. This results in a modest increase in hardness, a significant improvement in tear strength, low compression set and a reduction in the volatiles content. The established standard method is to postcure silicone pieces for four hours at 200 °C in an oven especially designed for this purpose. For safety reasons, the rate of air flow is held continuously high. Since the entire volume of air that flows through the oven has to be heated to 200 °C, postcuring consumes a great deal of energy.



Examining the tear strength of ELASTOSIL® LR 5040 test pieces in an applications laboratory.

does that reduce the number of work sequences involved – it also saves valuable resources in the form of energy and personnel costs." Plus, he adds, it virtually eliminates the risk of contamination during manual steps.

The developers and technical managers on Dr. Frese's team at WACKER also took a careful look at the various degrees of hardness available within the new ELASTOSIL® LR 5040 series. Their work revolved around the question of whether the cured rubber would meet ambitious goals in terms of workability, purity and mechanical properties.

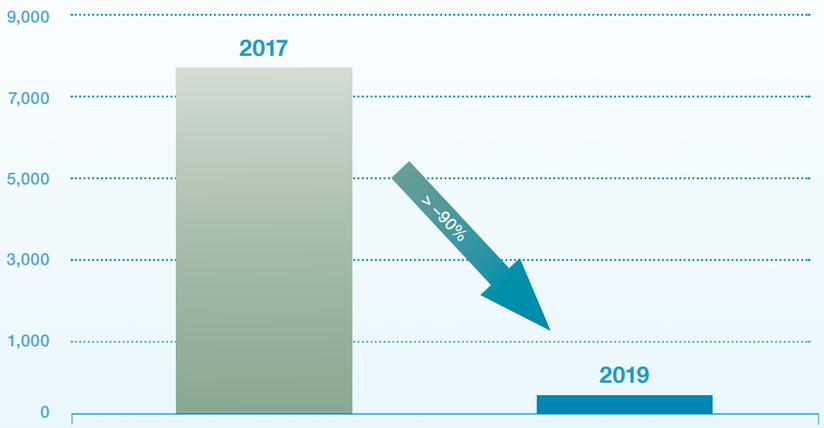
SUITABLE FOR INJECTION MOLDING

Their studies show that the liquid silicones cure very rapidly and can readily be used in injection-molding processes. Hardness levels between 30 and 70 Shore A are available, including a 45 Shore A grade suitable for numerous applications in the baby-care sector. The hardness values specified here refer to materials that have not undergone postcuring – which is not the case for conventional silicone rubber. And with ELASTOSIL® LR 5040, these values fall within a very narrow tolerance of ±3 Shore A points, allowing compounders to respond to their customers' hardness requirements with exceptional precision.

The volatiles content was checked by determining the weight loss as recommended for food applications by the German Institute for Risk Assessment – a process that involved experiments with non-postcured test pieces two millimeters thick. The team performed additional studies to assess the impact of differences in geometry, and found that the weight loss was between 0.15 and 0.4 percent for all of the grades in the new product line – decidedly below the 0.5 percent hurdle. The margin of safety between these results and the threshold is so large, in other words, that legal requirements can be met in most cases without postcuring, regardless of component geometry. The scale of the weight loss was similar when samples were tested according to other European standards as well.

For silicones used in sensitive applications, there are also numerous laws and standards that specify extraction and migration

EXTRACTABLE SUBSTANCES FROM STANDARD NON-POSTCURED LSR BEFORE AND AFTER BEING UPGRADED AS A LOW-VOLATILES PORTFOLIO (in ppm[1])



Thanks to its low-volatiles initiative, WACKER has reduced the volatiles content of its entire liquid silicone rubber portfolio by over 90 percent. Heptane extracts were prepared from cured rubber that had not undergone postcuring and were analyzed via gas chromatography to demonstrate the reduction in volatile components.

[1] Extractable Dx siloxanes from a heptane extract of ELASTOSIL® LR 3003/60, GC analysis

limits. The corresponding requirements can be found in regulations such as CFR 21 § 177.2600 of the US Food and Drug Administration (FDA), in Section 3.1.9 of the European Pharmacopoeia, in BfR Recommendation "XV. Silicone" and in the laws of several other EU member states. ELASTOSIL® LR 5040 in its non-postcured state complies with these requirements, too. Furthermore, the non-postcured rubber products of the new liquid silicones are biocompatible as per the specifications of United States Pharmacopeia (USP) Class VI and ISO 10993.

PURE AND TEAR RESISTANT

A key reason that the new liquid silicones can claim to be especially pure is their optical appearance: they are translucent and have a pale blue sheen. The resultant molded parts create an impression of particularly high quality and purity. Furthermore, the tendency to yellow, which often occurs with postcured liquid silicone articles in storage, has been reduced to a minimum.

In many sensitive applications, the demands are high with regard to not just purity, but also the mechanical properties. "The only way to achieve the necessary bite resistance in pacifiers, teething rings, nipples for baby bottles and other babycare items is to use a highly tear-resistant material," explains Marketing Manager Claudia Berghammer. "Small cracks should not propagate when the elastomer is stretched. This is another area where our innovative silicone rubber grades perform well," she adds. The tear resistance of her cured rubber products extends up to 50 Newtons per millimeter, measured as directed in ASTM D 624 B – even without postcuring. Cured rubber made from conventional liquid silicones does not usually achieve values like these until postcuring occurs, and then only in the cases of products specially designed to be highly tear resistant.

100 OUT OF 100 PASS THE TEST

The developers on Thomas Frese's team refused to be satisfied with that, however. They also wanted to know how the new silicone behaves in various babycare applications. To do this, they subjected injection-molded baby-bottle nipples made of ELASTOSIL® LR 5040 to a simulated bite test as described in EN 14350-1. The first step was to make small cuts in the nipples in a defined manner, after which the nipples were stretched and had to withstand a tensile force of 9.5 kilograms. All 100 of the nipples tested have to pass this sophisticated mechanical test – no nipple can tear prematurely.

Non-postcured bottle nipples made from the new 45 or 50 Shore A silicone fared particularly well in these tests. Even though the geometries of the nipples varied, none of them failed. The results are thus comparable, and in some cases superior, to those for postcured bottle nipples made from commercial LSR rubber compounds.

"ELASTOSIL® LR 5040 is setting a new standard thanks to its exceptionally low content of residual volatiles and to the outstanding technical properties that its cured products exhibit – even without postcuring," says Schattenmann. As the head of the WACKER team also noted, "The products in this series define the technological frontier and have already proven themselves to be the market's benchmark for sensitive applications."

For the new silicone grades, WACKER has established narrow tolerances for weight loss and tests each batch to make sure it lies within these limits. Because cured rubber made from these liquid silicones – even without postcuring – falls far below the legal thresholds for volatility, extraction and migration, their use offers a great deal of safety. Whereas silicone compounders used to have to make sure that their products comply with legal limit values, ELASTOSIL® LR 5040 shifts that responsibility to a certain degree onto WACKER – relieving compounders of an appreciable burden.

NEW PROCESSING POSSIBILITIES

ELASTOSIL® LR 5040 opens up new possibilities for silicone compounders. The elimination of the postcuring step allows component manufacturers to streamline production and boost productivity

Among the things on display at the WACKER booth during this year's K plastics tradeshow will be this injection-molding machine from ACH, a leading manufacturer of silicone-processing equipment and molds. The image shows how ELASTOSIL® LR 5040 is used to produce lids for portable and reusable coffee cups.

Even without being postcured, this baby pacifier made of injection-molded ELASTOSIL® LR 5040 meets all the legal requirements.

substantially, paving the way for a lean, fully automated production process that can take place entirely inside a cleanroom if need be. And because omitting the postcuring step also completely obviates the risk of explosive air mixtures, these silicones help make the production process safer.

In addition to babycare products, typical examples of silicone items that can now be made without postcuring include those that come into contact with food and those used in medical and pharmaceutical technologies – from seals for kitchen appliances, coffee makers and storage containers to metering valves and respirators.

Demand for silicone products in which the content of volatile, extractable components is as low as possible is growing in areas beyond the food, babycare and medical technology sectors, however, and applies to parts used in technical applications as well. In response, the Munich chemical company has likewise removed the volatiles from most of its liquid silicone rubber products. Significantly reducing the residual content of volatile siloxanes has greatly enhanced the value of the company's product portfolio. Its low-volatiles initiative was concluded in early 2019 and impacts all of the LSR grades that WACKER produces in Europe, specifically its ELASTOSIL® LR 3xxx and LR 6xxx and SILPURAN® 6xxx products.

The company was able to reduce the volatiles content through process engineering optimization. This upgrade revolved around specific volatile, low-molecular-weight silicone components known as Dx siloxanes, for which there exist maximum limits in some sectors, such as the automotive industry.

ENTIRE LSR PORTFOLIO UPGRADED

This means that the volatiles content in WACKER's new, upgraded LSR portfolio is so low that silicone compounders can meet government and industry-specific regulations more easily and with greater certainty than before. And, in some cases, compounders can actually dispense with postcuring altogether. The automotive industry is a good example here: a benchmark known as the Toyota standard defines 350 ppm as the maximum allowable amount of certain volatile Dx siloxanes[2] used for connector seals or single-wire seals made of oil-bleeding silicones. Thanks to WACKER's low-volatiles initiative, oil-bleeding products in the ELASTOSIL® LR 384x series meet this exacting standard set by Japanese automakers, even without postcuring.

According to Dr. Frese, the following issue is important for silicone compounders as well: "Upgrading the LSR portfolio has absolutely no impact on the mechanical and chemical properties of the elastomer," he emphasizes. "Product approvals and certificates are all just as valid as they ever were." Reducing the volatiles content also represents major progress when it comes to sustainability, he feels, because the low-molecular-weight siloxanes that are removed from these products are fed back into the production cycle, which protects the environment and preserves resources. ■

[2] The standard refers to cyclic siloxanes D4 through D8.

"The silicone rubber grades in this product line define the technological frontier on the market."

Dr. Wolfgang Schattenmann, director of Rubber Solutions, WACKER SILICONES

WWW 2.19 ▸ APPLICATIONS ▸ **LIQUID SILICONE RUBBER**

Food storage containers: an ELASTOSIL® LR 5040 silicone seal has been fitted into the organic rubber lid.

"Making Good Progress": Dr. Robert Gnann, President of WACKER SILICONES

"A LOW-VOLATILES CONTENT IS THE TREND OF THE FUTURE"

All liquid silicone rubber grades supplied by WACKER SILICONES will contain significantly fewer volatile components in the future, and processing will not always require postcuring, announced Dr. Robert Gnann, divisional president.

Who was behind the low-volatiles initiative?
Mainly our customers, processors, and the authorities. This trend is not, however, new in the industry. The move to reduce volatiles began quite some time ago, for example with the so-called Toyota standard, which aimed at lowering automotive exhaust emissions. Liquid silicone rubber, or LSR, with low-volatiles levels offers our customers many advantages. As a major LSR supplier, it is our aim to take the lead in this field.

Which strategic goals is WACKER pursuing with its low-volatiles initiative?
The future belongs to liquid silicones that can be processed without postcuring. Our strategy is threefold: a significant increase in efficiency for our customers; improving quality; and making a strong contribution toward sustainability. Energy savings are made during further processing and the environmental impact is lower because fewer volatiles are emitted. That's why we have introduced low-volatiles levels not only in individual products, but across our entire LSR product range.

How has WACKER positioned itself in the silicone manufacturer sector with the low-volatiles standard?
Our LSR portfolio consists of two low-volatiles platforms: As I mentioned earlier, our entire LSR product range will have far fewer volatiles than required by existing regulations. This offers processors definite advantages, especially when it comes to complying with emissions limit values. Also, we will have products such as pacifiers that fulfill standards and limit values in terms of volatiles content but require no postcuring.

Removing volatiles was announced as early as 2017. Why was this work only completed at the beginning of 2019?
Achieving our goal of enhancing the quality of both products and processes simultaneously was challenging. The low-volatiles platform development phase gave us a great deal of knowledge about LSR, especially in connection with process parameters and product properties. We also wanted to ensure our ability to manufacture the volumes required by the market. During the course of the project, we realized that our system and process can still be optimized further. I am confident that we have made good progress and commend all those involved for their tremendous achievement. But we will not rest on our laurels. Demands made on products and processing properties are continuously rising. LSR, the only liquid rubber that is easy to pump, has plenty of unexploited potential.

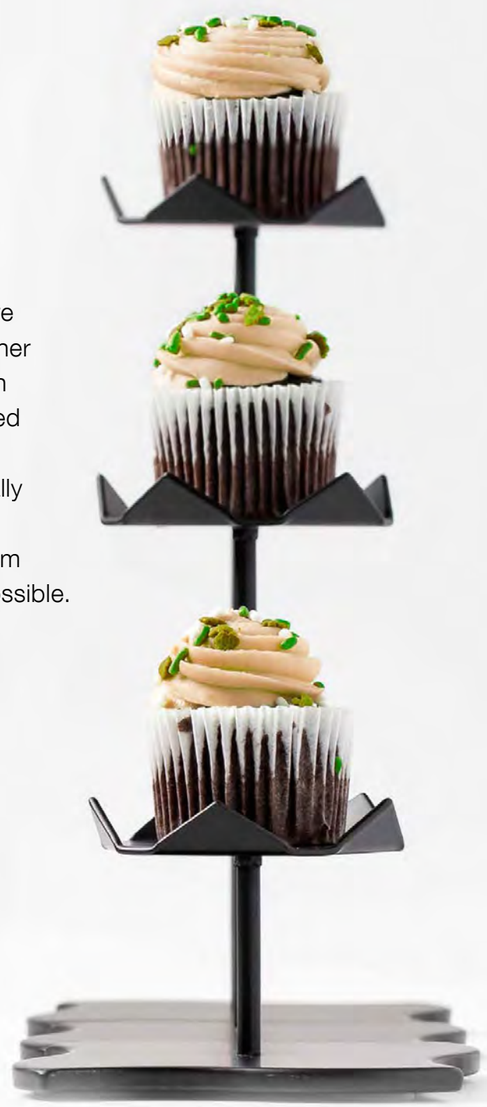
What benefits do LSR processors gain from an LSR portfolio stripped of volatiles?
It's important to us that our customers benefit from increased productivity. This applies not only to there being less of a need to handle molded parts, such as the mostly manual loading of postcuring ovens, but also to energy savings made by eliminating postcuring. Additionally, the time-consuming scrubbing of gases emitted during processing could be eliminated. Stringent specifications on the volatiles content, as in the Toyota standard I mentioned, can easily be met with our products. The important thing is to ensure that product and process quality is on no account compromised.

The stripping of volatiles currently only affects LSR grades manufactured in Europe. Are any plans underway to extend the low-volatiles initiative to production sites in other parts of the world?
We strive to offer our customers the same level of product quality worldwide. However, this won't be feasible overnight as the technology requires considerable investment.

Why did WACKER decide on a low-volatiles strategy for the LSR portfolio and not for the solid silicone rubber range or room-temperature-vulcanizing silicones?
The low-volatiles trend will affect our entire portfolio of silicone products. This trend has developed its own momentum as customers seek to increase productivity by eliminating process steps. At the same time, WACKER is committed to sustainability and would like to minimize the emission of volatiles into the environment during further processing of silicone products. The whole silicone industry has signed up for this approach, some aspects of which are required by the authorities. However, as I mentioned before, this will require extensive development and investment. We will also find out how much this effort is worth to our customers. Nevertheless, we will surely not stop with LSR. We are set to ramp up our development of low-volatiles solutions. And it's no secret that stripping volatiles from high-viscosity products such as HTV rubber grades requires far more complex technology. But here too, we're working on solutions.

Vegan Cupcakes & More

A birthday without a birthday cake? Allergies and food intolerances don't always have to mean doing without. Whether you need gluten-free or vegan alternatives, JP's Pastry, based in North Carolina, USA, has cupcakes and more for virtually every taste and every dietary need. A special ingredient from WACKER is what makes it possible.



All the baked goods at JP's Pastry are gluten-free, several are now vegan, too.

The bakery is a hive of activity. Employees are mixing batter and greasing pans. A batch of brownies has just emerged fresh from the oven. Piping hot and giving off the heavenly smell of nuts and chocolate.

JP has tuned out the commotion surrounding him. He has to concentrate. One cupcake after another: onto each creation he adds a dollop of chocolate cream, squeezing the right amount from the pastry bag at the right speed and with the right amount of pressure. The key to the perfect topping.

JP's cupcakes are as alike as two peas in a pod. As if the cupcakes had been decorated by a machine, rather than by the hand of the business owner himself. It's a delicate operation.

JP, whose real name is Joe Parker, is the founder of his eponymous bakery, JP's Pastry. It has been five years since he turned his hobby into a career. Joe is actually a dentist. "That's why I have such a steady hand," he laughs.

"I like to bake cakes, but that wasn't the only reason I decided to open my own bakery," he points out. "It was also because I normally can't eat cake." Joe has celiac disease, which means that he cannot tolerate gluten – a component of ingredients like wheat. "I can remember birthdays with no birthday cake," says the baker-in-chief. "I know how it feels to have to do without something that's perfectly normal for other people."

NO ANIMAL PRODUCTS

The idea behind JP's Pastry is to create baked goods that everyone can eat – even people with allergies and food intolerances. "We started out with gluten-free products," Joe explains. "Now we also offer vegan products for people who are lactose intolerant, are allergic to eggs, or who just simply make a conscious decision to live a vegan lifestyle."

> "CAVAMAX® gave us a perfect recipe after just three test runs."
>
> **Joe Parker**, JP's Pastry

No animal products: it sounds simple at first, but it really is not that easy. "We experimented for a full year before we made the first vegan brownies we were half-way satisfied with," he recalls. The biggest problem? Conventional baked goods such as cakes, muffins and waffles generally contain egg or egg powder, because the emulsifying properties of egg stabilize the structure of the batter. "Anytime we left out the eggs, it changed the texture and taste of the batter. The finished product just wasn't what we were wanting," he explains.

Joe Parker is actually a dentist. Despite a gluten intolerance, he loves to bake cakes, and five years ago, he decided to turn his hobby into a career by opening his own bakery – JP's Pastry.

Joe Parker's bakery has a selection of around 50 different kinds of cakes, 20 of which are vegan. There are plans to expand this range, as the demand for vegan goodies is rising.

Baking at JP's Pastry is almost entirely by hand, from kneading the dough, through to decorating the cakes and packaging them.

The solution to the problem was a truly special ingredient: alpha-cyclodextrin (or alpha-dextrin for short), which WACKER manufactures under the CAVAMAX® W6 brand name. Cyclodextrins are oligosaccharides formed through the breakdown of starches from plants such as corn or potato. "The emulsifying, soluble dietary fiber supports whipping and foaming, while stabilizing oil-in-water emulsions in cake batter made with vegetable oil or margarine. That makes it possible to replace eggs ," explains Patrick Polchinski, a specialist for bakery products at WACKER. Polchinski and his team have already developed a number of recipes for egg-free baked goods. In cupcakes, pound cake or brioche, the combination of CAVAMAX® W6, protein and water can completely replace the egg normally found in the batter.

The alpha-dextrin that Joe uses in his bakery is produced at the WACKER site in Eddyville, Iowa, where the company uses a biotransformation process to convert plant starch to cyclodextrins. The site began producing innovative cyclodextrins back in 1999, and development has been proceeding steadily ever since. That has generated a great deal of expertise in this field – one in which WACKER leads the global market.

"The secret of the molecules lies in their donut-like shape," adds Polchinski . "The exterior shell is hydrophilic – it's drawn to water in other words. The inner cavity, on the other hand, is lipophilic, or fat soluble. That structure lends cyclodextrins excellent emulsifying properties, allowing them to encase residual fatty acids and bind what otherwise wouldn't mix: oil-based and aqueous solutions." Lecithin, the emulsifier in egg yolk, normally produces this effect in cake batter, evenly distributing the fats, while alsostabilizing the batter. The egg white supports foaming – a function now also performed by the alpha-dextrin.

"FREE FROM" PRODUCTS

No eggs, no milk, no meat – more and more people are voluntarily abandoning food prepared with animal ingredients. Some are also forced by health problems or allergic reactions to cut certain foods from their diet. Consequently, "free from" products are becoming ever more popular. In one survey, 24 percent of consumers indicated that they had bought food of this type within the previous three months. Among 16-to-24-year-olds, the figure was as high as 40 percent. The food industry is responding by seeking out new ingredients for traditional recipes that will provide the customary taste and reassuring mouthfeel, while catering to trends toward sustainable, vegan, and allergen-free products.

> "Now we can make pretty much all of our products vegan – without having to sacrifice consistency or flavor."
>
> **Joe Parker**, JP's Pastry

CONTACT

For more information on this topic, please contact:

Patrick Polchinski
Bakery Products Specialist
WACKER BIOSOLUTIONS
Tel.: +1 517-264-8494
patrick.polchinski@wacker.com

CAVAMAX® MEANS PLENTY OF BENEFITS

"When we used CAVAMAX®, we had a perfect recipe after just three test runs," says Joe. Nothing like the painstaking experiments without alpha-dextrin – all JP's Pastry had to do was add the white, water-soluble powder to the batter in place of the eggs. No additional bakery equipment needed. And cyclodextrins do not affect leavening or the viscosity of the batter. "Now we can make pretty much all of our products vegan – without having to sacrifice consistency or flavor," he adds. A welcome side-benefit: using CAVAMAX® can reduce costs by up to 40 percent relative to products that contain eggs. The availability and price of eggs plays a role here, as they are often subject to major seasonal fluctuations.

Besides catering to the vegan trend, cyclodextrins are also healthy: blood-sugar levels do not rise as sharply after starchy meals containing alpha-dextrin – a health benefit of alpha-dextrin that was certified by the European Commission in 2013. Since that time, foods containing at least five grams of alpha-dextrin per 50 grams of starch may now

bear a label stating that consumers can lower their blood sugar by eating a defined portion of the product as part of a meal.

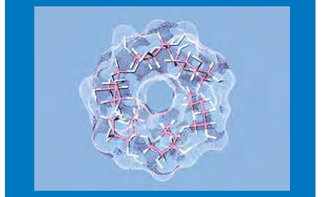
THE VEGAN DIET IS TRENDING

Vegan versions are now available for about 20 of the 50 different cakes and varieties of bread at JP's Pastry. And Joe is planning to offer many more vegan products. Demand is rising, after all. "You see more and more people going vegan," he notes. That is not just his own personal opinion: studies show that veganism is a sustained trend. According to the Mintel market research firm, 5 percent of all food and beverages marketed throughout the world were recently found to be vegan. Whereas the number of new vegetarian products is now relatively stable, the number of vegan foods has more than doubled over the past five years.

The market for vegan baked goods remains modest – especially for handmade treats that go straight from the oven to the display case. Like they do at JP's Pastry. "We have customers who come hundreds of kilometers to shop here. They love our vegan baked goods," Joe says.

Bakery personnel are now packaging the vegan chocolate brownies and getting them ready for delivery. Everything from mixing and baking to packaging happens right here in this 500-square-meter space – Joe's kingdom. An employee places the little treats into bags one at a time and attaches a list of the ingredients to each one. The list also includes alpha-dextrin from WACKER – the ingredient that turns Joe's brownies into vegan brownies. ■

Joe Parker in front of his bakery in Benson, North Carolina (USA).

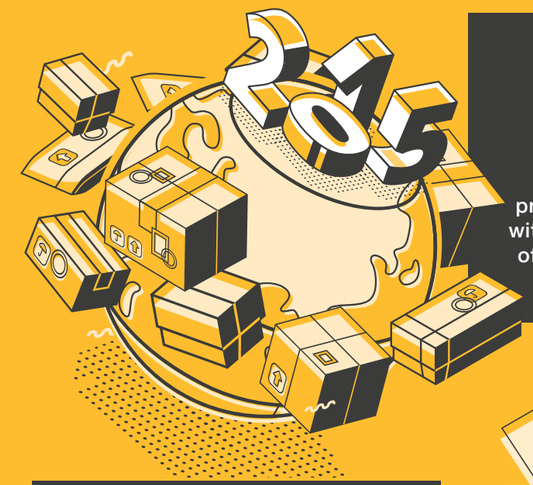


CYCLODEXTRINS

Cyclodextrins consist of multiple glucose molecules linked together to form a ring. The difference between α, β and γ-cyclodextrin lies in the number of glucose units – and thus the size of the ring. Cyclodextrins occur in nature when starch breaks down. The glucose units in cyclodextrin molecules are arranged to form an inner lipophilic (i.e. fat-soluble) cavity that can accommodate another lipophilic guest molecule, provided it is of the appropriate size and shape. The cohesion between the two molecules is produced by relatively weak van der Waals forces, enabling the guest molecule to be released again under suitable conditions. The weak van der Waals interactions within an inclusion compound do not chemically alter the guest or host molecules involved.

WACKER IN FIGURES

WACKER is a globally operating company that collaborates with suppliers throughout the world. In order to ensure sustainable business practices, the WACKER Group places great emphasis on equally sustainable supply-chain management. It is vital to minimize any risks affecting issues that are potentially critical – such as working conditions, ethical standards, safety standards (especially for hazardous materials) and local-resource management (e.g. water use and energy consumption). That is why WACKER makes every effort to ensure that raw materials and technical goods and services originate from suppliers who take their responsibilities seriously.



2015 was the year that WACKER joined the

"TOGETHER FOR SUSTAINABILITY" (TFS) INITIATIVE

TfS is developing a global program for responsible procurement of goods and services in the chemical industry, with the aim of improving the ecological and social standards of suppliers. WACKER covers 70 percent of its procurement volume with suppliers that are committed to TfS.

24 years is the length of time that the Group's

SUPPLIER DAY

has been in existence. Major German suppliers are invited to attend it. Similar events recently started to be held in China and the USA.

Some 11,000 companies provide WACKER's Procurement department with a wide variety of

GOODS AND SERVICES

900 companies supply WACKER with

RAW MATERIALS

FOREVER CONTEMPORARY

Leather manufacturing is one of the oldest crafts known to mankind. People began making leather from animal skins in the Paleolithic Age, around 8,000 B.C., with the aid of animal fat, smoke or bone marrow. In around 4,000 B.C., the ancient Egyptians used tanning agents made of plants or oils. All of these processes took a lot of effort and time. It was only in the 19th century that tanning with chromium salts made it possible to process animal skins much more quickly into pleasantly soft leather. Today, leather can be produced in virtually any form or color. Silicone fluid emulsions from WACKER contribute by offering individual formulations – to optimize durability, improve the feel or even make the leather permanently water repellent.

WACKER

SIPELL® silicone fluid emulsions offer a wide range of performance benefits to meet various requirements in numerous application areas, for example in the automotive, furniture and clothing sectors, and in leather accessories such as handbags and wallets.