

A Strong Rust-Fighting

MARKUS HALLACK

Rust is everywhere – and corrosion protection is a permanent challenge. Experts estimate that one-third of all iron and steel products manufactured worldwide in a year are used to replace corroded structural components. The economic damage, therefore, is enormous. According to the Batelle Institute of Columbus, Ohio, the United States alone suffers damage in the amount of US \$300 billion each year, while the renowned Karl-Winnacker Institute of DECHEMA puts that figure at well over €50 billion per year for Germany. A matter of equal importance is sustainable corrosion protection using suitable methods and materials. The primary focus here is on systems with high durability and a long lifespan, good color retention and stability, that are as good for the economy as they are for the environment – systems like the new silicone-epoxy hybrid resins from Evonik.

The VOC (volatile organic compound) legislation has become a pivotal event in the area of environmental protection. Its purpose is to reduce volatile organic solvents because of their role in forming tropospheric ozone – the “summer smog” that is so damaging to the environment and human health. With its “Organic Solvent Paint and Coatings Ordinance” of December 2004, Germany implemented the corresponding EU directive, and aims to eliminate 280,000 metric tons of VOCs per year in the paints and coatings industry. Various branches of the industry – including the automobile, rolling stock, and aircraft production sectors – are currently working on reducing the VOC content of paint formulations to 100 grams per liter by the year 2010.

Other countries, such as the United States, are making similar efforts to limit VOCs. Because some states have set their own VOC standards, information on the success of such restrictions or goals is difficult to obtain. Experts predict, however, that in the long run the most stringent requirements will be implemented. Currently, such requirements provide for a VOC content of 250 grams per liter for Europe and North America.

Against this backdrop, Evonik has developed new binder systems with a high solids content. The systems are based on silicone-epoxy hybrid technology and are as strong as they are environmentally compatible. Originally, silicone and silicone combination resins were used for any application requiring heat resistance. Additional properties are good resistance to weathering and yellowing. Fields of application include equipment assembly, exhaust systems for cars and two-wheeled vehicles, as well as stoves and fireproof coatings.

In the past, the focus was on pure silicone resins and silicone-polyester combination resins. The applications were always in the area of heat-resistant corrosion protection. To expand the product range, developers placed a stronger emphasis on weather-resistance when they conceived the new silicone-epoxy hybrid binders. This is where Evonik can leverage its core expertise to produce an optimal and unique profile of properties by selectively combining various organic resins with a silicone resin.

Base resin with epoxide and alkoxy groups

All silicone resins of Evonik’s Tego brand are produced according to a uniform reaction scheme in which the resin starting products are produced with a defined molecular-weight distribution. As reactive groups, these resins carry practically no SiOH groups, and almost exclusively SiOR groups. These then further react with OH-functional compounds to a hybrid resin that contains both epoxide and alkoxy groups.

An amino alkoxy silane is used as the hardener. Its amino groups react with the epoxide groups, and the three alkoxy groups react under the addition of water and the influence of atmospheric humidity with the alkoxy groups in the resin, with the amine as a catalyst. This “double cross-linking” creates a silicon-epoxy hybrid backbone chain with an extremely high level of cross-linking.

Varying the siloxane starting products and polyols used also makes it possible to produce silicone-epoxy hybrid binders (trademark SILIKOPON®) that are 50 percent silicone. The aliphatic epoxides contribute good corrosion and chemical resistance. The alkoxy siloxanes display good UV stability and resistance to yellowing. Both components react with each other to create the innovative hybrid binders. For its part, the hardener from the group of the amino alkoxy silanes, which is not added until application, reinforces resistance to corrosion and chemicals.

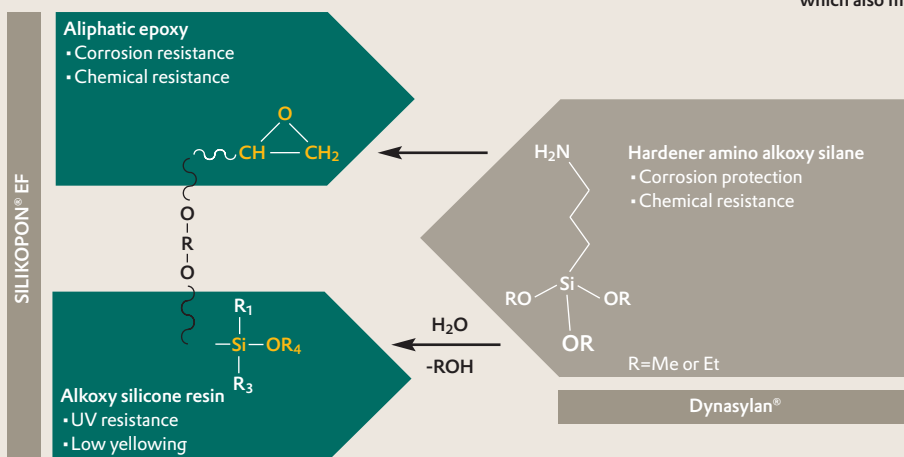
Using similar methods, Evonik has already created systems based on aromatic epoxides that are distinguished by their extreme heat resistance and, therefore, are preferred coatings for the exhaust systems of two-wheeled vehicles. They also adhere so well to steel substrates that paints formulated with them do not delaminate, even in extreme temperature changes. This kind of binder system is outstanding for the production of paint formulations for the exhaust systems of cars and aircraft engines. Both applications must exhibit this material property.

With the new method of using aliphatic epoxides, Evonik has made it possible to produce formulations that contain >>>

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The new silicone-epoxy hybrid resins are suitable as corrosion protection for steel, but also work well as coatings for wood, concrete, or composite materials. Their key advantages are low flammability and, above all, a low VOC content of below 100 grams per liter, which also makes them a clear improvement over existing systems



Reaction scheme for producing silicone-epoxy hybrid resins. An aliphatic epoxide and an alkoxy silicone resin react with OH-functional compounds to a hybrid resin that carries both epoxide and alkoxy groups. When cross-linked with an amine alkoxy silane, this amino group reacts with the epoxide groups and the alkoxy groups under the influence of atmospheric humidity with the alkoxy groups in the resin



only 5 percent solvent – or 75 grams of VOCs per liter. This is significantly below the systems currently available on the market. Typically, a paint formulation consists of over 60 percent SILIKOPON® EF. The hardener – Dynasylan® AMEO or AMMO, for example – is added at a ratio of 100:16. Additionally, “EF” denotes a considerably more flexible version than its predecessor ED (extremely durable), which was formulated to be exceptionally hard. Pigments also contain an equally high share of more than 20 percent. The mixtures offer the benefit that both the manufacturing and processing machines require only very minimal adaptation. Not least, this means high cost savings for paint producers and processors.

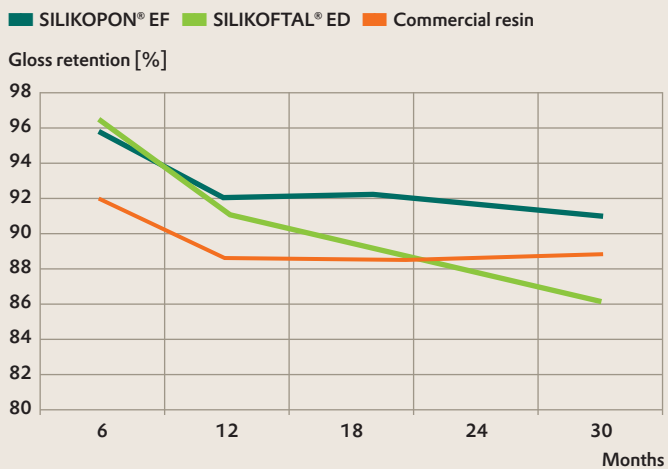
Outstanding results in the Florida test

The new coating systems performed extremely well in an intensive series of tests under Florida conditions, which are accepted by the paint industry worldwide. There is now over two years worth of data from the South Florida test. On the whole, the data reveals extraordinary gloss retention and weather resistance. Yellowing is so minimal that it is barely detectable by the human eye. The results for corrosion protection are also outstanding.

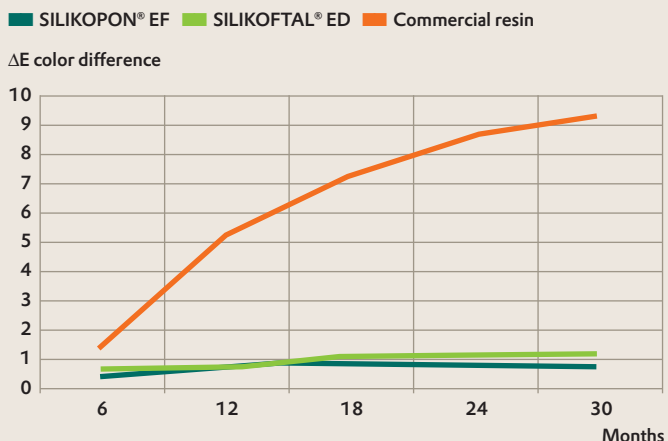
Because of their low solvent content, these types of systems are also suitable for ultrahigh-solids coatings. Developers have also successfully demonstrated that they are easy to clean and



Gloss retention measured at a 60-degree angle under the challenging conditions of the Florida test: Compared not only to similar resins currently on the market but to its predecessor SILIKOFTAL® ED, SILIKOPON® EF displays outstanding gloss retention, even after two-and-a-half years



The ΔE color difference, which describes the change in color as compared to the original color, as well as the yellowing, in the Florida test. Just like its predecessor SILIKOFTAL® ED, the yellowing of SILIKOPON® EF is so minimal that it can hardly be detected by the naked eye. The commercial resin, on the other hand, shows extreme yellowing



can be used as anti-graffiti coatings. Clear coats for these applications have already been formulated. The drying conditions are comparable to those of conventional two-component polyurethane systems. In this case, however, because the alkoxy cross-links in a hydrolyzation reaction, drying depends not only on the temperature but also on the atmospheric humidity. Drying time, therefore, can be controlled through these two parameters.

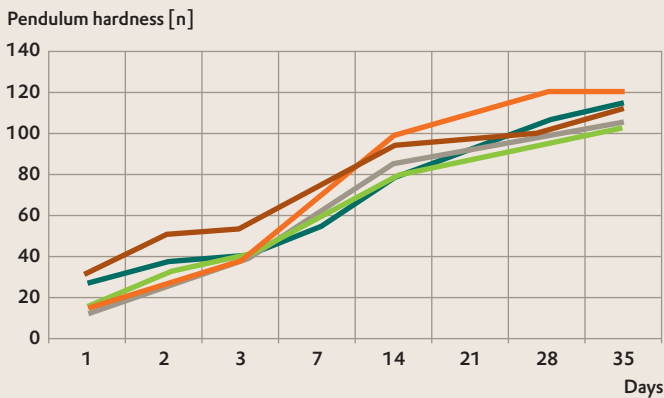
All told, Evonik can supply the market with an excellent variety of hardeners. Amino-functional silanes – an area in which Evonik has been active for about 50 years under the trademark Dynasylan® – are the hardeners normally used for epoxide

resins. For the hardening of the new systems, the main compounds under consideration are AMEO (3-aminopropyltriethoxysilane) and AMMO (3-aminopropyltrimethoxysilane), which can also be used in a 1:1 mixture or catalyzed with dibutyl tin dilaurate (DBTL), as well as with bismuth compounds.

The hardness of the lacquer film remains unaffected by the choice of hardener – the same values are always achieved by the end of the process, no matter which hardener or catalyst is used. The advantage here is that the hardening process can be accelerated or slowed, depending on the environmental conditions, through the selection of the hardener and, if needed, the catalyst, and still produce the same result – a significant advan- >>>

The speed of the hardening reaction can be controlled through the choice of hardener (AMEO stands for 3-aminopropyltriethoxysilane, AMMO for 3-aminopropyltrimethoxysilane) and, if necessary, catalyst (DBTL stands for dibutyl tin dilaurate). These choices have no effect on the final hardness of the paint film, however, as the pendulum hardness, illustrated in the figure, shows

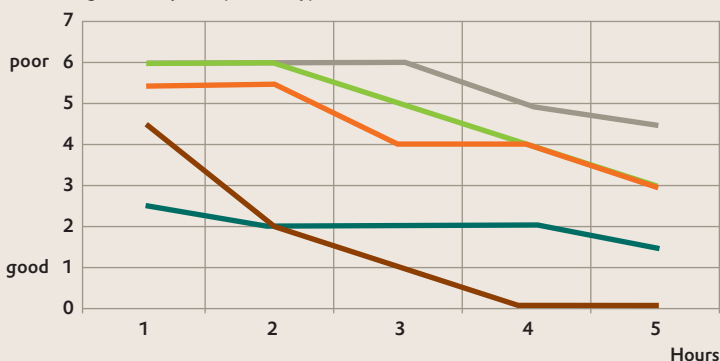
■ ED AMEO 100:16 ■ EF AMEO 100:16 ■ EF AMEO/AMMO 100:14
 ■ EF AMEO/DBTL 100:18 ■ EF AMEO/DBTL 100:14



The different drying times for hardeners (AMEO stands for 3-aminopropyltriethoxysilane, AMMO for 3-aminopropyltrimethoxysilane) and catalyst (DBTL stands for dibutyl tin dilaurate): Whether in high atmospheric humidity or extreme temperatures – with SILIKOPON® EF, the speed of hardening can be adapted to the prevailing conditions

■ ED AMEO ■ EF AMEO ■ EF AMEO/AMMO 100:14
 ■ EF AMEO/DBTL 100:18 ■ EF AMEO/DBTL 100:14

Degree of dryness (touch dry)





tage over two-component polyurethane systems. In long-term tests developers also proved that, unlike its predecessor ED, SILIKOPON® EF does not tend toward brittleness.

Another criterion is drying speed. This particularly applies to larger objects, such as rail cars, that are still painted by hand. For the coating process to proceed as it should, the paint cannot harden too quickly. It must still flow well when the painter arrives back at the point where he started his work. These time periods can also be adapted to the requirements of the application by varying the hardener-catalyst system.

There are cases, however, in which large objects have to be bone-dry fast, or even rainproof because the paint shop needs the space for some other purpose. The same is true of dry docks for ships, where time means money and every hour counts. Moreover, the important thing in these cases is not the beauty of the paint but efficient application and reliable corrosion protection. The new development from Evonik can even bridge the

gap between the extremes of climate that influence the painting of a metal building in the bitter cold and dry of Murmansk and the coating of a crane in hot, humid Singapore.

Eco-friendly paint formulations with low VOC content

With the new SILIKOPON® EF systems, highly eco-friendly paint formulations are available that contain 70 to 90 percent Evonik products, depending on the pigment used. Their specific advantage lies in their unmatched low VOC content of less than 100 grams per liter, which makes them a clear improvement over existing systems.

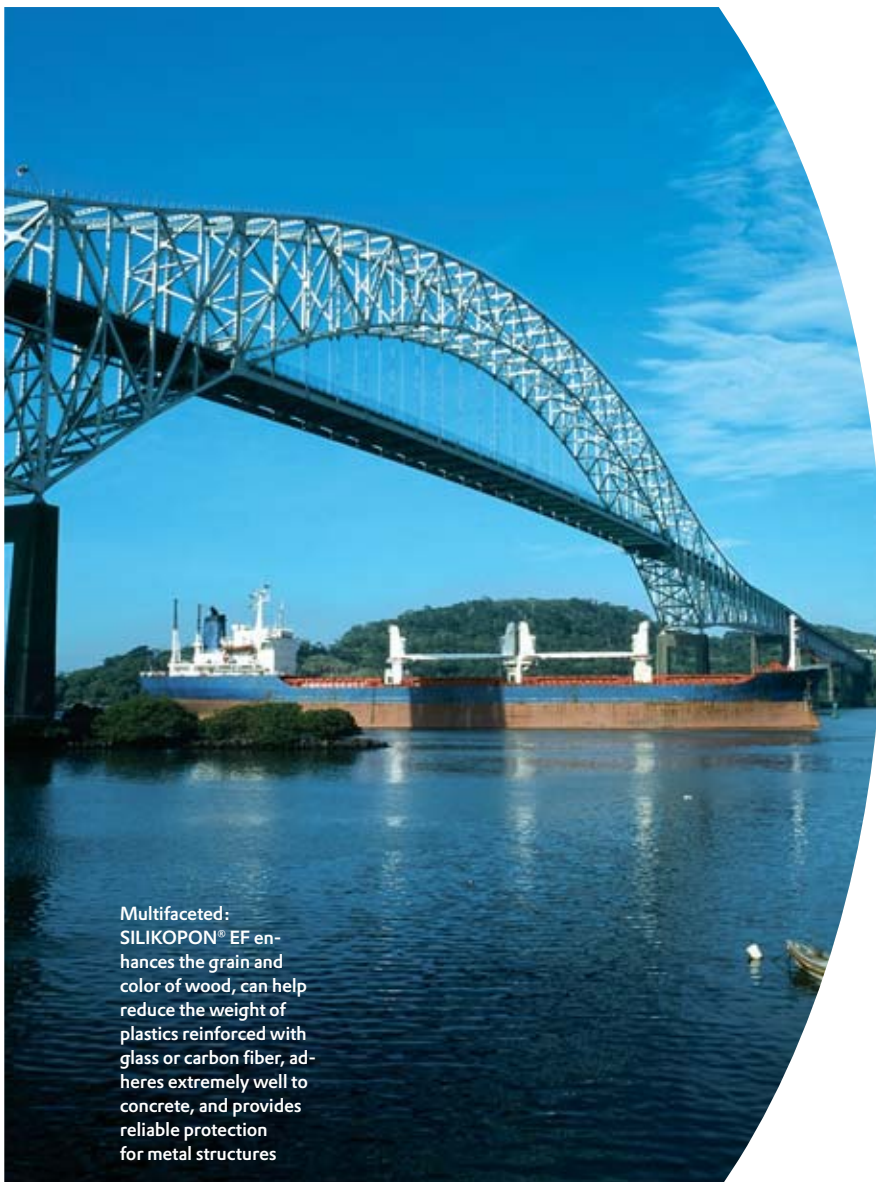
But SILIKOPON® EF is not just for steel. It also exhibits an excellent appearance on a variety of woods. Also, the VOC content can be kept below 100 grams per liter for these applications. Finished coats give the wood a special appeal, drawing attention to grain and color, which are brilliantly enhanced.



Additional benefits for wood applications include flame- and abrasion resistance. These properties open up high-grade applications such as the interior design of yachts, aircraft, and highly durable floors. These solutions are also economical. Today, the interiors of aircrafts and yachts require up to seven coats – with the new systems, they only need three.

The systems also open up new opportunities in difficult cases of corrosion protection. Filled with a large quantity of zinc dust, SILIKOPON® EF can be used as a two-component silicone-epoxy primer. Several large customers are already researching and developing combinations of the two systems to achieve an optimal property profile. The inorganic solution based on silica esters delivers the advantages of fast drying and corrosion protection. The organic alternative, on the other hand, earns points for improved adhesion and higher flexibility. Formulations based on SILIKOPON® EF combine both properties in one product.

We may be nowhere near realizing the full potential of these new paints, but one thing is certain right now: SILIKOPON® EF can be used as easily on metals as on concrete or composite materials like fiberglass- or carbon-fiber-reinforced plastics. The latter are becoming increasingly important in rotor blades for wind-powered plants and in aircraft construction, where single-layer construction can also help reduce weight. Lower weight is also a key issue for automobile manufacturing – a field regarded as the uncontested major leagues for painters. It might well be that the industry will one day open its doors to SILIKOPON® EF. ●



Multifaceted:
SILIKOPON® EF enhances the grain and color of wood, can help reduce the weight of plastics reinforced with glass or carbon fiber, adheres extremely well to concrete, and provides reliable protection for metal structures



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