No fear of scratches

Painted surfaces are more scratch-resistant than ever before thanks to silane-modified isocyanates. Developed by Evonik, the technology has already generated strong interest among car manufacturers.

[TEXT Dr. Hans Görlitzer, Markus Hallack, Dr. Stephan Kohlstruk, Dr. Rainer Lomölder]

AUTOMOTIVE PAINTS HAVE to take a lot—whether it is dirt from the road, road salt or UV radiation. They protect the car's body against mechanical and environmental influences, but they also serve an important optical purpose. Most of today's automotive paints have four components. The topmost layer—the clear coat, which is only about 40 micrometers thick—is crucial to a car's visual presentation. For design reasons, it has to be transparent and shiny but also both strong and flexible so it does not just splinter when hit by foreign objects.

Modern polyurethane-based two-pack clear coats are remarkably resistant to chemical influences. Over time, however, and with regular visits to the carwash, brushes, as well as dust and dirt, leave behind visible micro-scratches in these clear coats. This is why a new vehicle's clear coat loses its shine over the years—even when the vehicle is not used that much. And even today, coatings that are labeled as "scratch-resistant" and formulated with nanoparticles only start out as scratch-resistant. The problem is that the binding agent weathers, causing particles on the surface of the clear coat to be "washed out" by brushes and cleaners—which means scratches occur again.

All coatings are not created equal

Many automobile manufacturers recognized these challenges years ago. Coatings are no longer all the same. Automobile manufacturers are already using clear coats with improved scratch resistance, particularly beginning with upper midrange vehicles. On the one hand, this is an attempt to meet the demands of the customer. On the other hand, improved scratch resistance also reduces the costs of maintaining vehicle fleets and leased vehicles—an important consideration when the vehicles are meant to be sold again after a couple of years. Before being resold, they should look like new—without time-consuming polishing, if possible.

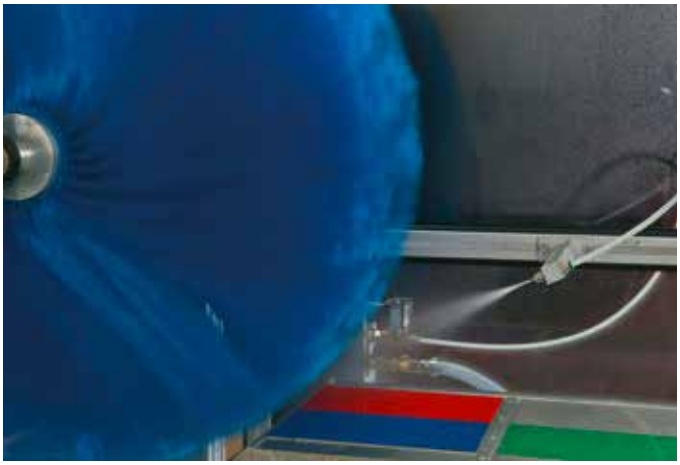
But even the clear coats available at the moment are not yet the ultimate in terms of scratch resistance. Evonik employees from the Coatings & Additives Business Unit have now developed a technology platform that can be used to significantly improve the scratch resistance of clear coats. For this development, they received the Evonik Innovation Award 2013 in the New Products/New System Solutions category.

For over 30 years, scientific literature has shown that silane-modified resins can significantly improve the properties of adhesives and coatings. But a key component of these resins is difficult to produce in high yields on an industrial scale, which has a noticeable impact on the price. This is why the technology is currently limited to niche applications, such as high-performance adhesives. When it comes to automotive clear coats, which are far more price-sensitive, silane-modified resins had not even been considered up to now.

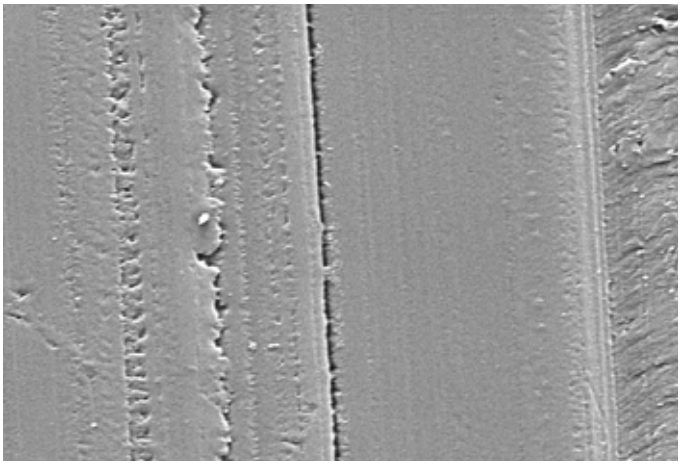
Development with an eye toward the market

With the goal of producing industrially relevant quantities at competitive prices, and with the involvement of multiple business units, the participants in this project at Evonik researched and tested the technology's potential for coating formulations, and developed a process for manufacturing the coating resin. This included finding suitable catalyst systems. The development work covered vast sections of the entire value-added chain, all the way to the automotive paint. To do this, the team networked and used the Group's existing expertise in silane chemistry and isocyanate production processes. Intensive and cooperative collaboration with the Functional Silanes Business Line was a major contributor to the success of the project.

With the goal of developing market-aligned products, Evonik employees also worked with a coatings formulator and an automobile manufacturer at an early stage. The key component ▸▸▸



The stresses that coated surfaces undergo in carwashes are simulated realistically in testing facilities. In the Amtec laboratory carwash facility, test panels are moved back and forth under horizontally rotating washing brushes. The contact pressure is adjustable. To simulate the surface contamination, a fixed quantity of quartz powder can be mixed with the cleaning water



Scratches in the surface of a standard automotive clear coat created in a carwash simulation test can be seen clearly under a scanning electron microscope

▸▸▸ in the production of urethane-modified poly(alkoxysilane) is a silylisocyanate, 3-isocyanatopropyltrimethoxysilane (IPMS). With one silane and one isocyanate group, the molecule is bifunctional and particularly well-suited to crosslinking (fig. 1). In producing this silane-modified isocyanate, it was important that Evonik masters a phosgene-free production process. Such a process prevents the simultaneous destruction of the sensitive silane at the other end of the molecule when the isocyanate group is chemically synthesized. Yields, then, improve distinctively. Evonik has since filed patent applications for the innovative crosslinking concepts and for new catalyst concepts.

The IPMS has been produced on an industrial scale at a new plant at the Marl site since June 2013. As everyone involved in the project has been able to prove—based on tests commonly used in the automobile industry—this key component for innovative resins can significantly improve the scratch resistance of clear coats (fig. 2). The reason for the improved scratch resistance is the higher crosslinking density that, at the same time, allows the clear coat to be highly flexible, and also allows the formation of hard SiO_2-like areas solidly integrated into the coating matrix—comparable to quartz.

In their own tests, the project participants were also able to prove that clear coats based on the new technology stand up to

Figure 2

Tests conducted by a coatings formulator on the carwash resistance of coatings with the new coating binders from Evonik show that the coatings permanently retain their scratch resistance. Even after 1,000 and 1,500 hours of "accelerated weathering," which simulates months and years outdoors, these coatings can hold up to 80 to 90 percent of their original gloss in the test. The standard for scratch resistance (in gray) is still only a little over 70 percent.

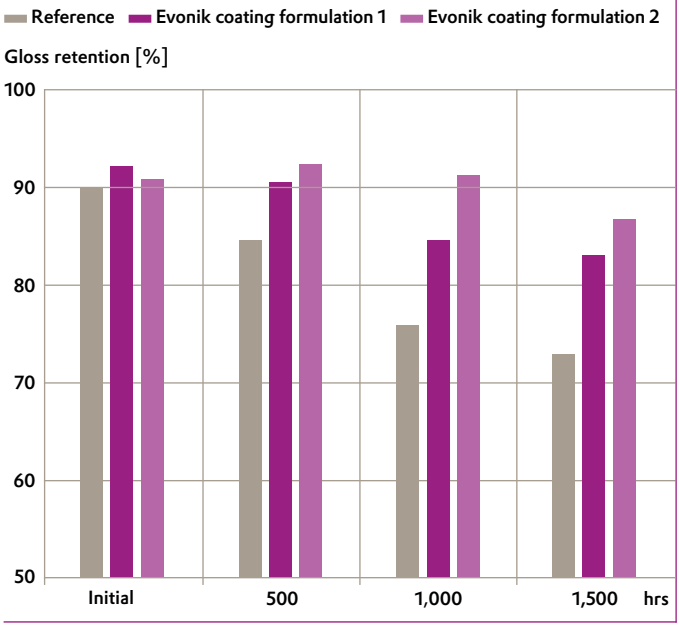
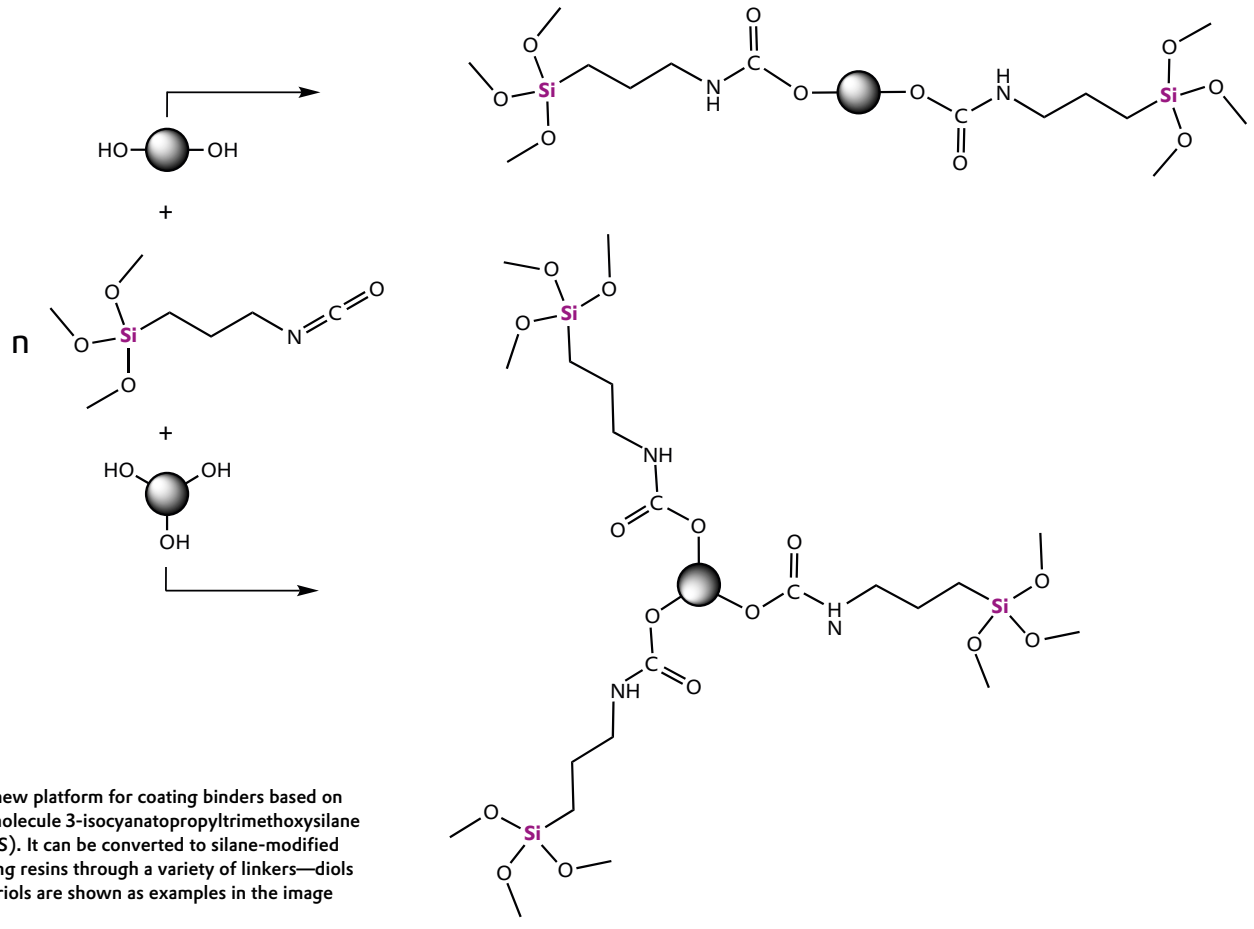
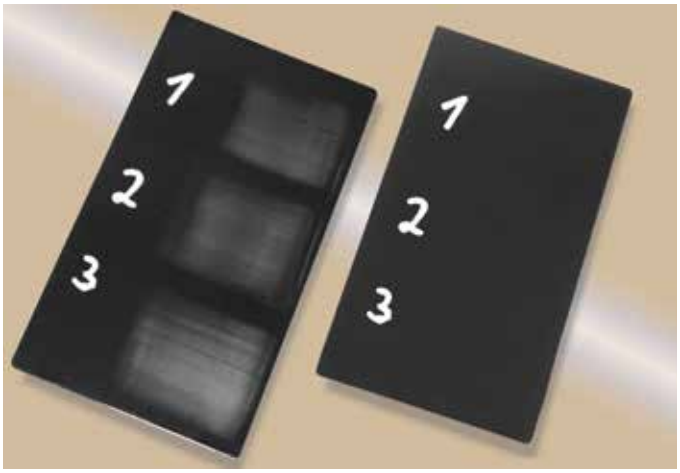


Figure 1



The new platform for coating binders based on the molecule 3-isocyanatopropyltrimethoxysilane (IPMS). It can be converted to silane-modified coating resins through a variety of linkers—diols and triols are shown as examples in the image



Coated panels after a scratch test (wet). On the left, the control panel, and on the right, a test panel coated with a polysilane-based clear coat

chemicals and weather as well as conventional two-pack polyurethane coatings. Another advantage is that the new materials are a relatively simple matter for Evonik's customers, because only fine-tuning is required to integrate them into established coating formulations. The technology is fully compatible with conventional two-pack polyurethane coatings. For a car manufacturer, this means coatings with the new resin can be easily applied in existing production lines.

A toolbox for custom-designed solutions

The new development opens up even more possibilities. The flexibility, chemical resistance, adhesion and surface energy of coatings, as well as their solubility in solvents, can be adjusted by selecting particular organic crosslinkers. The processing window can also be set by combining various resins and catalysts within a wide range of temperatures—from ambient temperature to 160 °C. This gives Evonik employees a toolbox they can use to design a customized solution for each application. So IPMS provides the basis for members of an entire product family. In addition to clear coats for the automobile industry, the technology could also be used for a host of other applications that would benefit from extreme scratch resistance for aesthetic or functional reasons.

Evonik is the market leader in functional silanes and aminosilanes. The specialty chemicals company masters the phosgene-free production of isocyanates, an expertise not many other companies possess. But Evonik does not simply supply IPMS as a building block for resins to coatings manufacturers, because this material would be difficult to store and, above all, handle. In fact, Evonik supplies the coating manufacturer with a customer-specific resin that is no longer subject to classification in a risk class.

Clear coats based on this technology are now on their way to being approved by selected automobile manufacturers. A manager at one automobile manufacturer has indicated that the silane technology could become the standard for clear coats of premium vehicles at his company in the next few years. Thus, silane technology from Evonik is making a solid contribution to more valuable vehicles. ◂◂◂

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