High Quality and Permanently Scratch Resistant

Surfaces. Even after years of use polypropylene surfaces in vehicles should look like new. In order to meet this tough requirement various polypropylenes were treated with specially developed additives based on siloxanes. Compounds manufactured in this way give component parts exceptionally good and in particular permanent scratch resistance. The experience gained with these additives in polypropylene has also been applied to engineering plastics such as polyamide, PMMA and PC/ABS blends.

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Anybody buying an automobile today expects the interior of their vehicle to look as good as new even after many years of use. A car whose dashboard or center console develops nasty scratches after gentle knocks does not meet these expectations. Customer satisfaction and resale value are lowered with every scratch. Apart from that all drivers want a high quality and appealing ambience nowadays. Accordingly plastic parts often have a grained and matt rather than smooth finish that in terms of both haptic and looks has to make a pleasing and high class impression. In particular there is a desire for grained dark surfaces that is virtually independent of model, manufacturer and price and can be observed worldwide. Figure 1 shows the dual plaque insert from an injection molding tool with typical grained surfaces for automobile interiors.

Plastics now account for up to 20% of the weight of a vehicle. From the wide spectrum of polymers polyamide (PA), acrylonitrile butadiene styrene copolymers (ABS), polycarbonate (PC), thermoplastic polyurethanes (TPU) and polypropylene...
(PP) are just some of the ones used in vehicle construction. There are several ways to make polymer surfaces scratch resistant. One of these involves the use of high performance polymers such as polyamide or ABS, which are however relatively expensive. Alternatively, the surfaces can be additionally coated, although this degree of effort can only be justified in the premium model sector.

In contrast, with mid-range and compact automobiles every cent saved per kilogram compound counts. For this reason low cost polypropylene is generally used which gains the necessary strength through the addition of up to 20% talc as filler (PP talc compounds). TPOs (thermoplastic polyolefins) are often also added to such compounds to improve both the mechanical properties as well as the look and feel of the surface (PP/TPO talc compounds).

Cost Effective, Grained and Scratch Resistant

A permanent scratch resistant polypropylene with an attractive price/performance ratio represents a substantial challenge for manufacturers of plastic parts for vehicle interiors. Door handles, dashboards, bumpers, door panels and center consoles have to be on the one hand light, mechanically stable and cheap and on the other grained and as scratch resistant as possible. Grained and scratch resistant are at first glance two properties that are difficult to combine with each other. This is because the grain has a serious disadvantage: Finger nails, ball point pens or car keys can more easily catch in the fine structure than on a smooth surface and so a grained surface is getting scratched more easily. Additives are often used to minimize these effects so that pointed objects can more easily glide across the surface.

Normally in order to make talc filled PP materials scratch resistant additives such as amides, silicone oils or grafted polymers are used. However, many of these additives do not confer a long-lasting solution. Long term tests show that these materials have a relatively high fogging potential. Thus sooner or later the component part will lose its scratch resistance. In addition many of the additives are not odorless and vehicle passengers can feel disturbed by the volatile components. Silicone oils and amides also migrate to the surface and form oily stains or result in a sticky haptic. Grafted polymers and additive combinations of these substances migrate less, but are more expensive than straight amides. On top of this, they negatively affect the flow properties of the compound during injection molding of the part. The flow properties are typically investigated using a flow spiral (Fig. 2) since the determination of the MFI (Melt Flow Index) is not sufficient.

A new additive from the Consumer Specialties business unit of Evonik Goldschmidt GmbH, Essen, Germany, now promises to put this right. The organically modified siloxane Tegomer Anti-Scratch 100 does not exhibit the disadvantages of conventional additives and also offers an attractive price/performance ratio. In order to study the influence of various raw material parameters in the formulation, a number of compounds based on PP and PP/TPO were produced in which the particle size and content of the talc as well as the quantity of the modified siloxane were varied. Fundamentally, the smaller the particle size of the talc the better the scratch resistance is. On top of this grey talc grades produce less white scratches than white, often very fine talcs.
The instruments available at Evonik to measure scratch resistance, shown in Figure 3, make it possible to conduct tests that are well established at automobile manufacturers and compounders. One of the most important is the Erichsen test in which a fine diamond pattern is engraved into the surface using a steel needle subject to various loads (5 to 30 N depending on the polymer).

In all the scratch tests the talc in the PP/TPO played a decisive role. This is because the deeper the scratch, the greater the difference in lightness between the dark surface and the exposed talc on the scratched surface. This difference can be measured as a Delta L value, created from the brightness difference between a scratched and non-scratched surface. The depth of the line can be measured using CLSM (Convocal Laser Scanning Microscopy). Naturally materials with high levels of talc (up to 40 %) are particularly susceptible and even light scratches can be clearly seen.

Multiple Demands on Additives

It can be seen that newly developed additives have to satisfy multiple demands. Firstly they must be able to provide immediate scratch resistance for the material so that the component part does not become damaged during transport or assembly. For this reason scratch resistance is measured 24 h after injection molding the test piece. In the long term, however, the scratch resistance has to be guaranteed even after many years of use, which is important for the end customer. Therefore the component part is held in a climate chamber for 7 days at 70 to 80°C and aging tests at 120°C check the deterioration in the mechanical properties. The additive has to be effective in various formulations for the widest possible range of talc and TPO contents and, regardless of the surface graining, a low Delta L value in the Erichsen test has to be guaranteed.

The results with Tegomer AntiScratch 100 are very encouraging in all respects. The siloxane additive does not migrate, which is due to the positive interaction between the PP and the organic side chains of the siloxane. Components based on this newly developed anti-scratch additive are therefore odorless and do not display any glossing or an oily appearance of the surface. The scratch resistance is expected to be retained over the entire life cycle of the product.

Scratch Resistant with as Little as 2 to 3 % Additive

The investigations have shown that PP compounds with 3 % Tegomer Anti-Scratch 100 have particularly small Delta L values both in short as well as long term tests. Fig. 4 shows this for the scratch resistance of a PP/TPO compound with 20 % talc alongside the key mechanical properties. For this reason scratch resistance is measured 24 h after injection molding the test piece. In the long term, however, the scratch resistance has to be guaranteed even after many years of use, which is important for the end customer. Therefore the component part is held in a climate chamber for 7 days at 70 to 80°C and aging tests at 120°C check the deterioration in the mechanical properties. The additive has to be effective in various formulations for the widest possible range of talc and TPO contents and, regardless of the surface graining, a low Delta L value in the Erichsen test has to be guaranteed.

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IMI FABI has produced a specially treated talc grade. Fig. 5 illustrates how the application of a special coating to a standard talc makes it more hydrophobic, which the significantly lower contact angle shows. As a result, improved wetting of the talc surface by the polymer can be seen in the corresponding SEM picture (scanning electron microscope) of the special grade. Looking at the relevant mechanical properties and in particular the scratch resistance of the PP/TPO formulation discussed in Fig. 4, the picture shown in Figure 6 emerges. In comparison to the standard grade IMI FABI HTP1, the special talc grade IMI FABI NS 140 shows not only an improvement in the scratch resistance of the surfaces K09 and K31, which are relevant for VW, but also an improvement in the notched impact strength (Charpy impact strength at 23°C and at -20°C). This means that there is a large optimization potential for future compound development. The developer is not limited to selecting the talc grade in terms of the required target mechanical parameters and scratch resistance, but can also, by combining this with 2 to 4 % of Tegomer AntiScratch 100, achieve an excellent level of scratch resistance without negatively affecting the haptic and odor of the compound.

**Market Potential and Know-How Transfer**

Since the siloxane additive is particularly easy to distribute in comparison to other technologies, it is possible to conduct initial injection molding tests without prior compounding. In the supply chain, it was therefore possible to assess the effectiveness at injection molding companies with automobile applications (e.g., air bag covers and center consoles) and then, where appropriate, optimize the formulation in partnership with OEMs and compounders.

The insights gained with the use of siloxane additives in PP were then also evaluated in PC/ABS blends, PMMA and PA. Here it was more appropriate to test high gloss polymer surfaces for example with the Crockmaster, which results in the scratch patterning seen in Fig. 7. As an example in the test the PC/ABS blend with 2 % Tegomer M-Si 2650 was virtually undamaged even after 2,000 strokes at 9 N. This shows that the Crockmaster allows a significantly better differentiation of the compounds compared to the otherwise more common pencil hardness test.

The siloxane additive Tegomer Anti-Scratch 200 has been developed for polyamide applications which alongside improvements in the scratch resistance of glass fiber filled polyamide compounds also improves the flow properties during the injection molding process so that even dark colors can be realized without surface problems, i.e., fewer glass fibers with unwetted ends oriented to the surface, caused by unintentional fiber breaks. It is therefore particularly interesting for applications such as automobile door handles (Title picture) and other high-quality items.

**THE AUTHORRESS**

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