Interfering reflections from instrument cluster covers in automotive interiors can be prevented with high-precision anti-reflective coating systems, e.g. special display covers (figures 1 to 6: Flabeg)

Scratch-Resistant and Anti-Reflective

PMMA Surfaces. Instrument displays in vehicle interiors must be glare-free. For this purpose, an anti-reflective, scratch-resistant display cover has recently been developed that meets the highest requirements of the automotive industry.

THOMAS HÖING
SVEN SCHRÖBEL
BURKHARD WALDER

The sun is low in the sky and the light is blinding. This is no problem for portable displays such as those on smart phones, for example. They can be moved as necessary out of the light and the information becomes readable or clear again. It does not work this way with the instrument cluster cover glass in vehicle interiors. When the sun shines, it dazzles and impedes clear vision of the dashboard instruments (**Fig. 1**). The only solution to this lies in the cover material itself. For example, glass finishing specialist Flabeg Deutschland GmbH, Nuremberg, Germany, has for many years now been preventing interfering reflections on glass instrument display covers with high-precision anti-reflective coating systems (**Title picture**). These guarantee car drivers clear vision and therefore safety. And they also enable vehicle designers to dispense with using bulky instrument cluster hoods to eliminate glare.

Glass covers from Flabeg therefore have both a very fine surface microstructure that scatters the incident light (so-called anti-glare effect) and a special coating to reduce brightness (anti-reflective effect).

It is important to adjust the scattering properties of the microstructure so that the incident light is scattered as widely as possible and the cover therefore becomes glare-free. At the same time, the driver must be able to see the information on the display as clearly as possible. So the aim is to strike the right balance between transmission on the one hand and light scattering on the other. Normally, transmission values of more than 98 %, reflection values of less than 1 %, and gloss levels of 80 to 110 at 60 °C are required. →

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Contact

Evonik Industries AG
PR Management Acrylic Polymers
Performance Polymers
D-64293 Darmstadt
Germany
TEL +49 6151 18-4079
→ www.evonik.com
→ www.plexiglas.net

Design Freedom with Plastics

Until now, Flabeg has only used its anti-reflective process with glass – mainly for instrument clusters in the automotive sector. But the requirements of the automotive industry are changing. For example, vehicles are having to become more user-friendly and, as a result, certain shapes, such as the microstructures of touch elements in touch displays or three-dimensionally shaped displays are receiving increasing attention. These shapes can easily be created with plastics, which offer the additional benefits of light weight and wide color choice. But plastics cannot simply replace glass on a one-for-one basis. This is because so far no adequate process has been available that can impart anti-glare and anti-reflective properties to the material, while at the same time ensuring that it is robust enough for long-term service.

The problem lies particularly with the anti-glare effect. To ensure clear vision, an anti-glare surface must have a very fine microstructure. In the case of glass, this can be produced by a special etching process. In combination with a vapor-deposited anti-reflective coating, this makes it possible to obtain an anti-glare surface with reflection values of less than 0.5 %, which is also robust. Although injection molding of plastics can produce textured surfaces, the materials selected are usually too prone to scratching or, because of their rheological properties, are incapable of exactly replicating very fine structures. Alternatively, a display could first be injection molded, given a scratch-resistant coating, and then provided with the required fine surface microstructure by hot embossing. But this approach is very costly. Post-coating of microstructures produced by the injection compression molding process is not recommended since the fine textures are filled up again with the coating **(Fig. 2)**.

Fig. 1. Non-anti-glare surfaces on automotive dashboard instrument displays reflect the light and interfere with vision while driving

Scratch Resistance an Essential Requirement

The challenge was therefore to find a process in which an anti-glare structure of etched glass quality could be protected with a scratch-resistant coating. To achieve this, Flabeg made use of CoverForm surface technology jointly developed by Evonik Industries AG, Darmstadt, Germany, and KraussMaffei Technologies GmbH, Munich, Germany. This solution makes it possible not only to coat polymethyl methacrylate (PMMA) moldings with a solvent-free, acrylic-based, multi-component reactive system directly in the injection mold but also to provide the parts with a microstructure at the same time **(Fig. 3)**.

Advantage: Surfaces produced like this in one process are highly scratchproof and also resistant to many chemicals. At the same time, CoverForm provides the exact reproducibility of the microstructured cavity surface required to produce an anti-glare texture. This is because, in the uncured state, the acrylic-based reactive system used has a low viscosity of

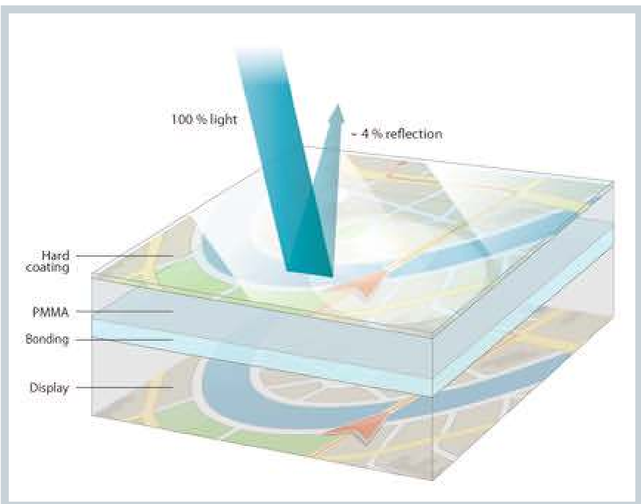

Fig. 2. Instrument display cover without anti-glare microstructure and anti-reflective coating: 4 % of incident light is reflected and the display is unreadable

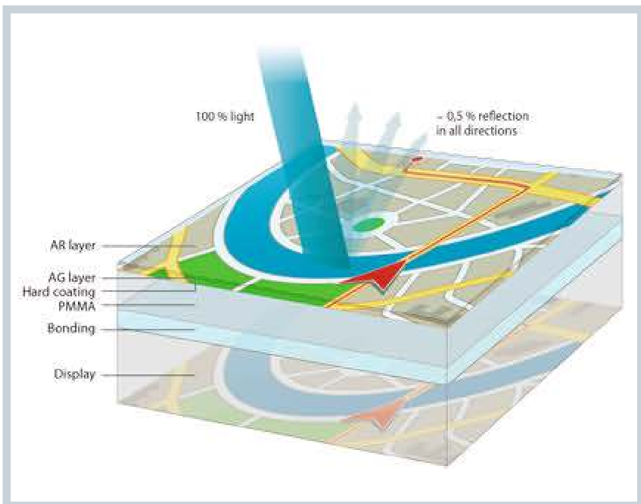

Fig. 3. Instrument display cover with an anti-glare microstructure (AG) incorporated in the CoverForm scratch-resistant layer and a subsequently applied anti-reflective coating (AR): only 0.5 % of incident light is reflected, which makes the display much clearer to read

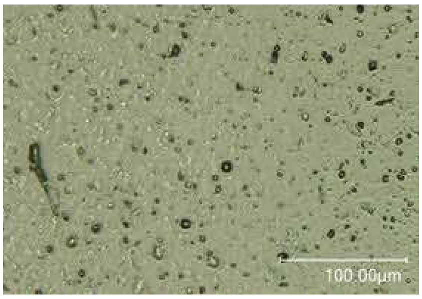

Fig. 4. Micrograph of the mold insert surface with a roughness value Ra of 0.07 µm

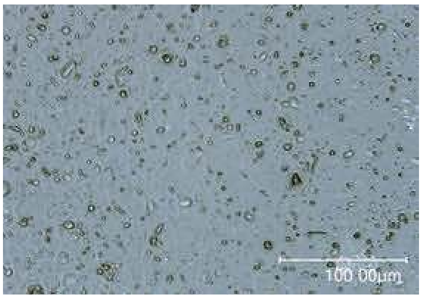

Fig. 5. Micrograph of the surface reproduced in the CoverForm process with a roughness value Ra of 0.06 µm

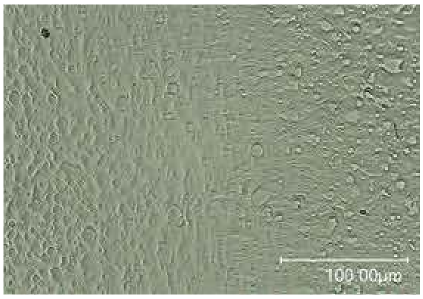

Fig. 6. Micrograph of the PMMA microstructured surface with a roughness value Ra of 0.03 µm

22 mPa s at room temperature and therefore in the injection compression molding process is in a better position to penetrate the texture depth than conventional amorphous thermoplastics. The melt viscosity values of the latter exceed those of the reactive system by a factor of around 10^5 to 10^6. The micrographs of the surfaces clearly confirm that that the surface texture reproduced on the cover in the CoverForm process corresponds visually with the pre-etched microstructure in the mold insert. On the other hand, the surface texture reproduced on the uncoated PMMA cover is significantly smoothed over. This can also be seen in the profilometrically determined (Talysurf, Taylor Hobson) roughness values (Ra):

- Mold insert surface (field NK5) Ra = 0.07 µm **(Fig. 4)**,
- CoverForm surface Ra = 0.06 µm **(Fig. 5)**, and
- PMMA surface Ra = 0.03 µm **(Fig. 6)**.

Besides high replication accuracy, the process also enables extremely good adhesion. No phase boundary can be detected between the reactive system and PMMA substrate, since the reactive system interpenetrates with the substrate during the process and is firmly anchored. The coating produces no optical distortions or undesirable rainbow effects, either, since it has the same refractive index as the PMMA substrate to the third decimal point. Optical interference and associated rainbow effects are therefore prevented.

Climatic cycle test	-40 °C for 4 h / +80 °C for 4 h, 5 cycles / 120 h
CASS test	DIN EN ISO 9227 CASS, 24 h
Salt spray test	DIN EN ISO 9227 NSS, 48 h
Humidity test	DIN 50017, 50 °C / 95 % RH, 144 h
Chemical resistance	spirit, cleaning solvent, Ajax cleaner
Chemical resistance acc. to ISO/DIS 16750-5	distilled water, isopropanol, glass cleaner, acetone
	salt solution, artificial perspiration, coffee, cola
Adhesion test	adhesive tape (DIN 58196-6-K2)
	cross-hatch adhesion test (GT 0.1)
Boiling water test	boiling in deionized water (DIN 58196-2-C60)
Abrasion resistance	10 N load with soft cloth, 10 mm wheel, 600 cycles
	10 N load with cloth impregnated with 2-propanol, 100 cycles

Table 1. Tests passed by test specimens produced in the CoverForm process with reference to current automotive standards

Test Series

The process is therefore able to provide a scratch-resistant, anti-glare microstructure for a plastic display in one operation. To find out whether the technology met Flabeg's requirements in practice, the developers conducted a series of tests in the CoverForm Competence Center at Evonik in Darmstadt, Germany. There, customers can become acquainted with CoverForm surface technology in operation using a specially equipped injection compression molding machine from KraussMaffei (type CX80) and experiment with it for their applications. They do not therefore need to purchase their own CoverForm mold bases for these trials. →

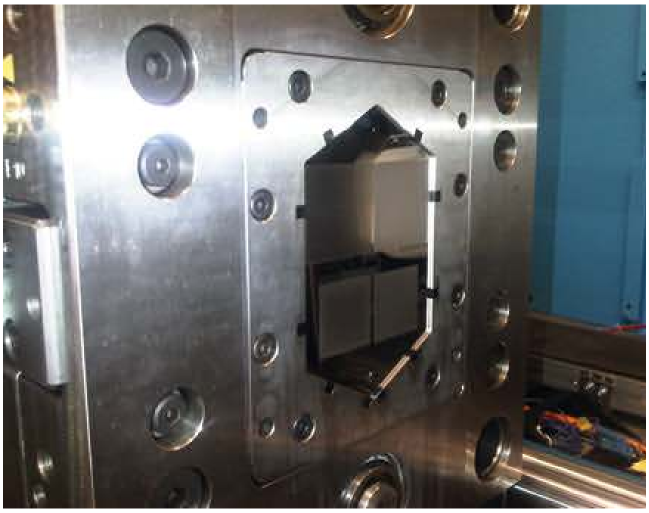

Fig. 7. Core insert with four different test zones in the CoverForm mold of an injection compression molding machine (photo: Evonik)

For the tests, Flabeg first prepared a cavity insert with a microstructured surface for the injection compression molding machine **(Fig. 7)**. On this insert, four different microstructured zones were created to find the optimum combination for an anti-glare effect. Evonik then trialed the microstructured insert with Plexiglas FT15 cf and CoverForm Reactive-Liquid CF30.

Flabeg coated the test specimens produced in this way with an additional anti-reflective coating at its Fürth im Wald site in Germany using the physical vapor deposition (PVD) process. Thin layers in the nanometer range were applied in a sputtering line. This inorganic anti-reflective film consists of several optical layers with alternating high and low refractive indices. The surface then becomes almost invisible, because no more interfering reflections can occur. The materials used are also very hard and abrasion-resistant.

Finally, Flabeg subjected the specimens to exhaustive tests according to current automotive standards, focusing on optical properties, compatibility with the PVD coating, and service life. **Table 1** shows which tests were passed.

Other tests included a microscopic and visual assessment, as well as tests of roughness (Talysurf), reflection and transmission (direct, total), haze and clarity (Hazegard), and gloss 20/60/85 degrees (Glossmeter BYK Gardner) **(Table 2)**.

		Test zone 4 / NK5				Etched glass (without AR)	
		Mold	PMMA	Cover-Form	CoverForm with AR	GW100	GW50
Roughness Ra	µm	0.07	0.03	0.06	0.06	0.1	0.2
Reflectance (C/2°) with gloss(1)	%		7.59	7.69	4.96	8.5	8.4
Reflectance (C/2°) without gloss	%		0.58	1.09	0.64	0.08	1.4
Transmittance (C/2°)	%		93.9	93.4	95.5	92.4	92.1
Haze	%		2.81	11.9	12.4	2.2	11.7
Clarity	%		93.6	89.8	90.2	78.7	46.1
Gloss at 20°			61.4	57.3	41.7	67.2	24.5
Gloss at 60°			89.5	82.2	53.9	101	52.4
Gloss at 85°			96.6	83.9	74.5	93.8	75.3

(1): In the reflection with gloss, rear-surface reflection of approx. 4 % is included, although this would disappear after bonding onto a display.

Table 2. Testing and assessing the optical properties of glass and CoverForm surfaces

Result: High Reproducibility

The results show that one of the four test zones in the CoverForm process achieves a replication accuracy almost matching that of etched glass. It is considerably better and finer than the result achieved by alternative processes, for example anti-glare films. The microstructure and coating of this zone also passed service life endurance tests according to the requirements of the automotive industry, including abrasion resistance.

So Flabeg has found a solution that delivers an anti-glare PMMA surface matching the quality of etched glass as well as an anti-reflective surface with a residual reflection of less than 1 % **(see Fig. 3)**. The cover surface is also extremely scratch- and abrasion-resistant. This is made possible by a combination of the CoverForm process, which provides a scratchproof microstructure with high replication accuracy, and a PVD anti-reflective coating.

In future, plastic covers like these will be used mainly for touch displays, particularly when they have a 3-D shape, which would be very difficult to achieve in glass. ■

THE AUTHORS

THOMAS HÖING is a development engineer at Flabeg Deutschland GmbH, Furth im Wald, Germany, where he is responsible for R&D projects in the automotive and industrial glass sectors; thomas.hoeing@flabeg.com

SVEN SCHRÖBEL is senior manager business development in the Acrylic Polymers Division at Evonik Industries AG, Darmstadt, Germany; sven.schroebel@evonik.com

BURKHARD WALDER is managing partner at BWengineering GmbH, Hagen, Germany, and was responsible for project planning; B.Walder@bwengineering.de