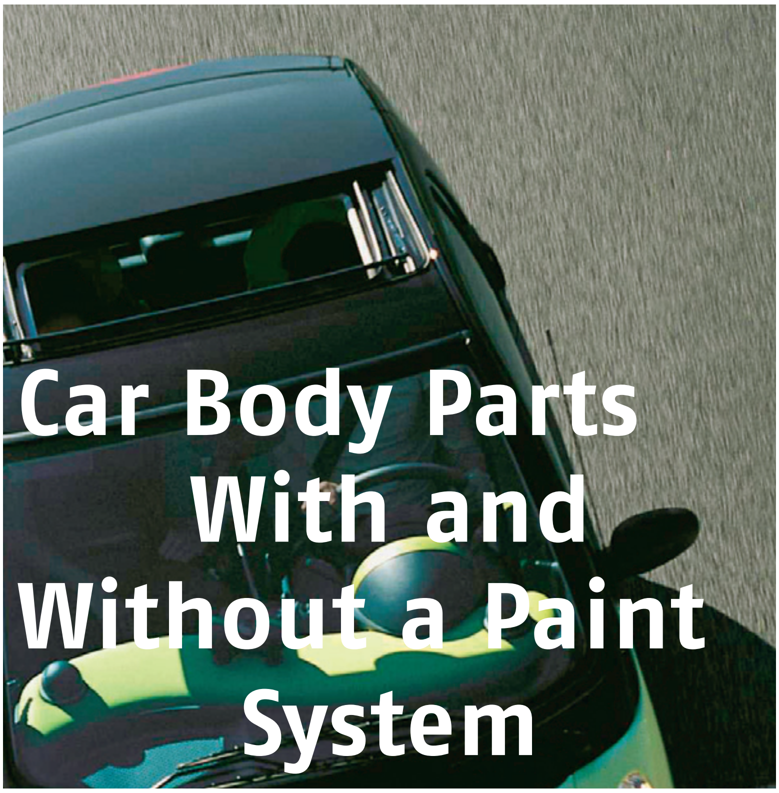
Roof module of the smart Spoiler Plus
(manufacturer: ArvinMeritor; photo: smart GmbH)



Car Body Parts With and Without a Paint System

Thermoplastic Films. The range of thermoplastic films suitable for use as a substitute for paint systems for car exteriors has grown consistently since the development started, depending on the particular part and specifications. Various concepts have been verified or are being further refined. Other concepts, especially involving coatable films, are under development.

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The films currently available on the market are basically manufactured by two different production processes. Firstly, we have the so-called "dry-paint" films, in which a special thermoformable coating system (colour coat plus clear coat) is printed on a polymer film substrate or applied to it by doctor blade or by casting. The layers of paint are partially crosslinked and can therefore be processed like thermoplastics. As a rule, however, these systems are only suitable for low stretch applications, because the hiding power of the coating is not good enough due to the low film thickness and the stretching. Secondly, we have the coextruded films, in which the coloured and clear coats are applied directly in the coextrusion process. The functional film thicknesses are higher, making higher stretching possible. Some of the demands made on the films are unrelated to the relevant component and some are. The properties that are not dependent on the particular component include:

- UV resistance,
- scratch and abrasion resistance,
- chemical resistance and sensitivity to stress cracking,
- colour matching (isotropic properties with effect colours compared with normal paints) and
- mechanical properties of the facing layer (e. g. hailstone resistance).

Component-related properties include

- heat resistance,
- mechanical resistance (crash behaviour and hailstone resistance),
- formability and
- optical requirements depending on surface specifications (e. g. gloss, haze, orange peel and inhomogeneities)/visible zone.

Because the layer structures of the various systems and thus also the properties vary considerably, other advantages and disadvantages of the individual developments will now be described in detail.

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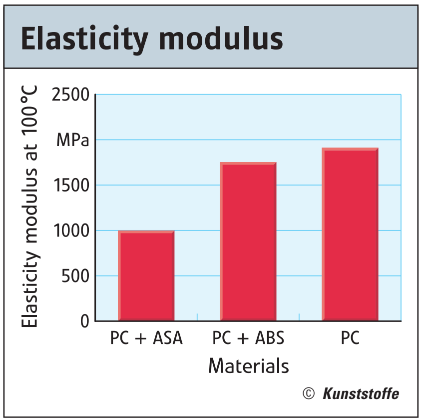

Fig. 1. Stiffness characteristics of different film materials

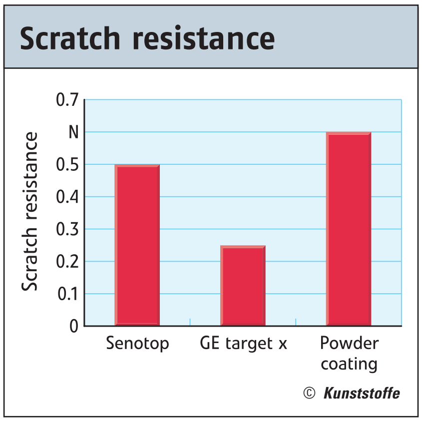

Fig. 2. Determination of the needle scratch resistance of film surfaces according to DIN 53 799-4.15

Films in the Thickness Range of 0.5–2 mm Coated with a Paint System

Avery Dennison: Avery Dennison Performance Films Division, Schererville/USA, produces formable films under the name Avery Dennison Avloy. These films consist of a colour coat and a clear coat. Both coats are based on PMMA/PVDF combinations. The films, with a thickness of 0.25 mm, are laminated onto ABS or TPO backing sheet. The resultant composite is thermoformed and reinforced with thermoplastic by backmoulding (IMD). Possible uses for the Avloy films include lamination to sheets with a thickness of 3.0 to 6.0 mm for non-reinforced thermoformed parts. Avloy films can be used to produce both matte and high-gloss solid and metallic finishes.

Avery Dennison is currently focusing its outdoor application projects on smaller parts, primarily decorative elements. Examples are body side mouldings for the Honda Civic and rear tailgate garnish for the Ford Mercury Grand Marquis [1].

Soliant: Fluorex films from Soliant LLC, Lancaster/USA, consist of a total of three layers: A top layer of an acrylic/fluoropolymer blend, a colour coat of the same material and a tie coat or adhesive layer. The three-layer films are laminated by extrusion onto backing layers of ABS, TPO, PVC or PC, depending on the selected reinforcement material [1]. The thickness of the backing layer can vary between 80 µm and 8 mm. Alternatively, however, the films can also be inserted unformed into an injection moulding tool and backmoulded, in which case the thermoforming of the film takes place during the injection moulding process.

Soliant films are used for stone chip protection of the US models, Toyota Avalon, A and B pillars, outer body panels of the Cadillac Seville, upper and lower grille parts of the Renault Laguna and roof strips for Audi, VW, Nissan and Volvo.

At present, no applications are known for horizontal parts that use films from Avery Dennison or Soliant. This might well be due to inadequate heat resistance.

Senoplast: To go with the Senotop brand coextrudates, Senoplast Klepsch & Co GmbH & Co KG of Piesendorf/Austria has developed, specifically for the coating technique, a range of films based on polycarbonate (PC) with two outer layers of (PC+ABS) blend. The back layer is intended to ensure good adhesion to polyurethane foams, while the facing layer of (PC+ABS) blend has advantages in paint adhesion compared with straight PC, which is sensitive to stress cracking. The films can be coated with formable coatings using a doctor knife or be painted as thermoformed films like conventional plastic parts. These films have been developed in close cooperation with Dow Europe. PC was selected as the base material because, compared with (PC+ABS) and (PC+ASA) blends, it shows very good stiffness characteristics in the elasticity modulus at 100 °C (Fig. 1), and thus conforms to the OEM specifications with regard to heat exposure. The preliminary tests with LFI-backfoamed parts showed excellent results on heat exposure at 110 °C over a period of 1 h. No deformation of the parts or deterioration of the Class A surface was observed.

Bayer MaterialScience: Bayer offers a paintable film with a backing film of PC. A thin (PC+ABS) layer is coextruded to provide adhesion to the polyurethane foam system. The paint layers are applied to the surface of the PC by foil coating and pre-crosslinked. Post-crosslinkage is carried out after thermoforming. According to the paint factory Wörwag, metallic shades without anisotropic metallic colour properties can be produced in this way.

BASF: BASF is working on two concepts [2, 3]. One of them involves thermoforming a monofilm of ASA or (PC+ASA), reinforcing it and then painting it. The second approach is based on the same film types but in this case they are foil-coated, dried, provided with a protective film, thermoformed and subsequently crosslinked by brief radiation with UV light.

Coextruded Films in the Thickness Range of 0.5–2 mm

The demands made on the surfaces of coextruded films in which Class A quality is achieved in one step are basically identical to those that apply in the surface coatings industry. For parts in which automotive paints are replaced by extruded thermoplastics, however, there are two major technical challenges [2, 4], namely the scratch and abrasion resistance of the finishes and the colour matching of the parts to be coated.

Let us begin with the demands made by the automotive industry on the scratch and abrasion resistance of the thermoplastic surface. In this respect, the testing concepts of the OEMs differ significantly. Figs. 2 and 3 show the scratch resistance of an automotive powder coating, a PC-based film from GE, and the Senotop film with facing layers of PMMA. Test method A (Fig. 2) shows the needle scratch resistance according to DIN 53 799-4-15, while test method B (Fig. 3) shows the abrasion resistance according to DIN 55 668 in a laboratory car wash. By method A, the Senotop film is much more scratch-resistant than the PC film, and according to test method B, the PC finish has better abrasion resistance than the Senotop PMMA surface.

As regards colour-matching, it is true to say that, in most projects, plastic body parts have painted metal parts added on. Since different pigments are generally used for conventional automotive paints than for the colouring of plastics, it is not always possible to achieve perfect matching of the shades of the painted and plastic finishes.

Solid-coloured Senotop films can now be combined very successfully with painted components (Fig. 4), but plastic and metal parts with a metallic finish can only be satisfactorily combined when optical parting lines (e. g. decorative strip in contrasting colours) are used.

For all coextruded film systems, a major challenge is to prove that the full automotive colour shade range is possible.

Mayco Plastics: IC films (moulded-in-colour) from Mayco Plastics, Sterling Heights/USA, consist of four layers. The extruded films are based on a clear coat and a colour coat of ionomers, followed by an adhesive coat and a backing layer [1]. The backing can be made of polypropylene (PP) or TPO. These films are used for the bumpers of the Daimler-Crysler Dodge Neon 2002.

Senoplast: The four-layer films from Senoplast Klepsch & Co GmbH & Co KG have been used for the series production of the Spoiler Plus variant of the smart (title picture) since April 2002. The films, based on backing sheet made of a (PC+ASA) blend from BASF plus facing layers of PMMA from Degussa-Röhm, are thermoformed and subsequently backfoamed with glass fibre-reinforced polyurethane using the LFI technique. With this method, the manufacturer of the roof modules, Arvin Meritor, Gifhorn/Germany, was the first company to comply with the specifications made on a Class A high-gloss surface using the film technology.

Because the heat resistance of the (PC+ASA) layer at 110 °C is inadequate with more complex parts (also depending on the particular foam system), Senoplast decided to develop some new film composites [4, 5].

To improve the dimensional stability under the effect of heat, the backing layer of (PC+ASA) was replaced by a blend of (PC+ABS) with a very high PC content, while retaining both the typical structure of Senotop films and the processing parameters. Fig. 1 shows the improvement in the heat deformation resistance on determining the elasticity modulus at 100 °C compared with the conventional (PC+ASA) blend.

To comply with even the highest demands made on the thermal properties of the film, a new film is additionally being developed with a substrate of PC. At the same time, a newly developed PMMA type aims to combine the many advantages of a PMMA surface with the mechanical and thermal properties of PC. On the one hand, the PMMA grades available on the market show inadequate adhesion between the PMMA and the PC coats, and, on the other, the recycling of such composites leads to incompatibilities and thus to a marked reduction

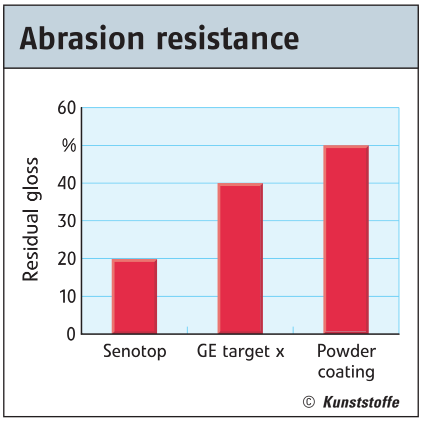

Fig. 3. Determination of the abrasion resistance of film surfaces according to DIN 55 668 in the laboratory car wash

in the mechanical data. For this reason, Degussa-Röhm has developed a PMMA copolymer [6] with a specific compatibility with PC and a suitable processing viscosity. In this way, optimum composite adhesion and good recyclability are achieved while largely retaining the typical PC properties at the same time. The corresponding PC grades were selected and provided by Dow, based on the technical extrusion data and the market requirements.

Alongside the previously mentioned advantages, a composite such as this also shows optimised creep behaviour under the effect of heat. Initial extrusion trials and tests on the film-coated parts produced highly promising results. The development partners Röhm and Dow are currently modifying the raw materials, while Senoplast is carrying out modifications to the process.

GE Plastics: GE Plastics, Pittsfield/USA, offers a film with a facing layer of the polycarbonate copolymer Lexan SLX with a UV blocker built into the molecule chain. Beneath this is an integrally coloured layer of PC, optionally followed by a layer of (PC+ASA) blend to guarantee adhesion to the polyurethane foam. This film was used for the first time as the facing layer for the roof half-shells of the smart Roadster in 2003. The film complies with the specifications made on the heat resistance of backfoamed components. The mechanical data are good, while the sensitivity of the modified PC surface to scratching seems to be higher than PMMA, although the composite shows better values in the very frequently used Amtec Kistler test than in the washing brush test (see Figs. 2 and 3).

BASF: In recent projects, BASF has developed a system of coextruded film consisting of modified (PC+ASA) blends as the backing layer and a SAN layer as a high-gloss facing layer [2, 3]. According to BASF, the SAN has favourable properties with regard to weather stability and heat resistance, and the composite is also recyclable.

Thermoplastic Films with a Thickness above 2 mm

Since the processing of thin-walled films is usually very complex and post-processing represents an additional cost factor, thicker sheets have been developed specifically for truck and utility vehicle out panels. These sheets are thermoformed, cut to size and assembled without any additional reinforcement. In some cases, the thermoformed parts are painted. With the Renault Trafic, for example, the side panel under the loading area is made of coextruded, thermoformed ABS/PMMA sheets (Senosan AM 50 Solar New EG sheets) in white, with the colour shade matched to the painted cab (Fig. 5). Increasing use is being made of directly coextruded sheets of ABS/PMMA composite (grade: Senosan AM 50 Solar Neu EG) or ABS/PC/PMMA composite (grade: Senosan VP CM 60 Solar). Suitable "study objects" for develop-

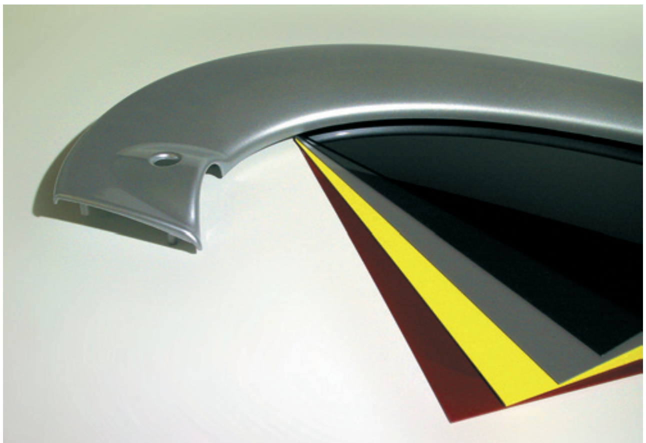

Fig. 4. Coextruded film based on (PC+ASA) and PMMA as examples of colour matching for the automotive industry

Fig. 5. The side panel below the loading area of the Renault Trafic consists of coextruded and thermoformed ABS/PMMA sheets

ments of this nature are wind-deflection systems for trucks. A variety of material grades have been tested, e.g.

- thermoformed parts of ABS/PMMA multi-layer composites of the grade Senosan AM 50 Solar Neu,
- thermoformed paintable parts of ABS/PC composite of the grade Senosan C60 EG and
- thermoformed ABS/PC/PMMA multi-layer composites.

Whereas the ABS/PMMA-based composites cover a broad field of application [7], backing layers based on (PC+ABS) blend come into their own particularly where maximum demands are made on the impact strength and where long-term service temperatures above 80 °C are specified.

With regard to the impact strength and surface properties, it was found that painted parts based on (PC-ABS) films can be replaced by coextruded films of the same substrate having a facing layer of coloured PMMA. This saves the complicated painting process without sacrificing any of the optical or mechanical properties. Fig. 6 compares the impact strength and penetration energy of painted and coextruded ABS/PC composites.

Outlook

The study shows that, based on the mounting interest being shown by OEMs in concepts for paint substitution for the bodywork, a number of companies have taken up the subject and are working on it. A variety of systems are already in series production or approaching maturity. The range of application extends from car exterior parts to the utility vehicle segment. Because of the number of project inquiries, it seems that this topic will become ever more important in future. ■

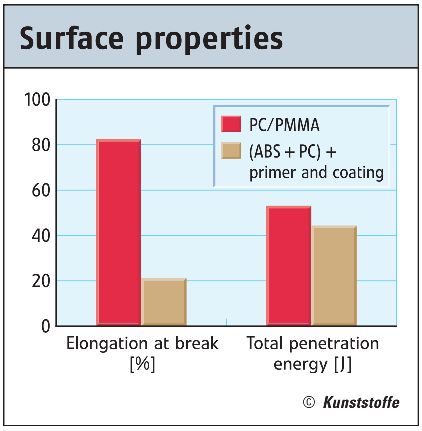

Fig. 6. Comparison of toughness and resistance characteristics of the PC-PMMA composites with painted systems

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