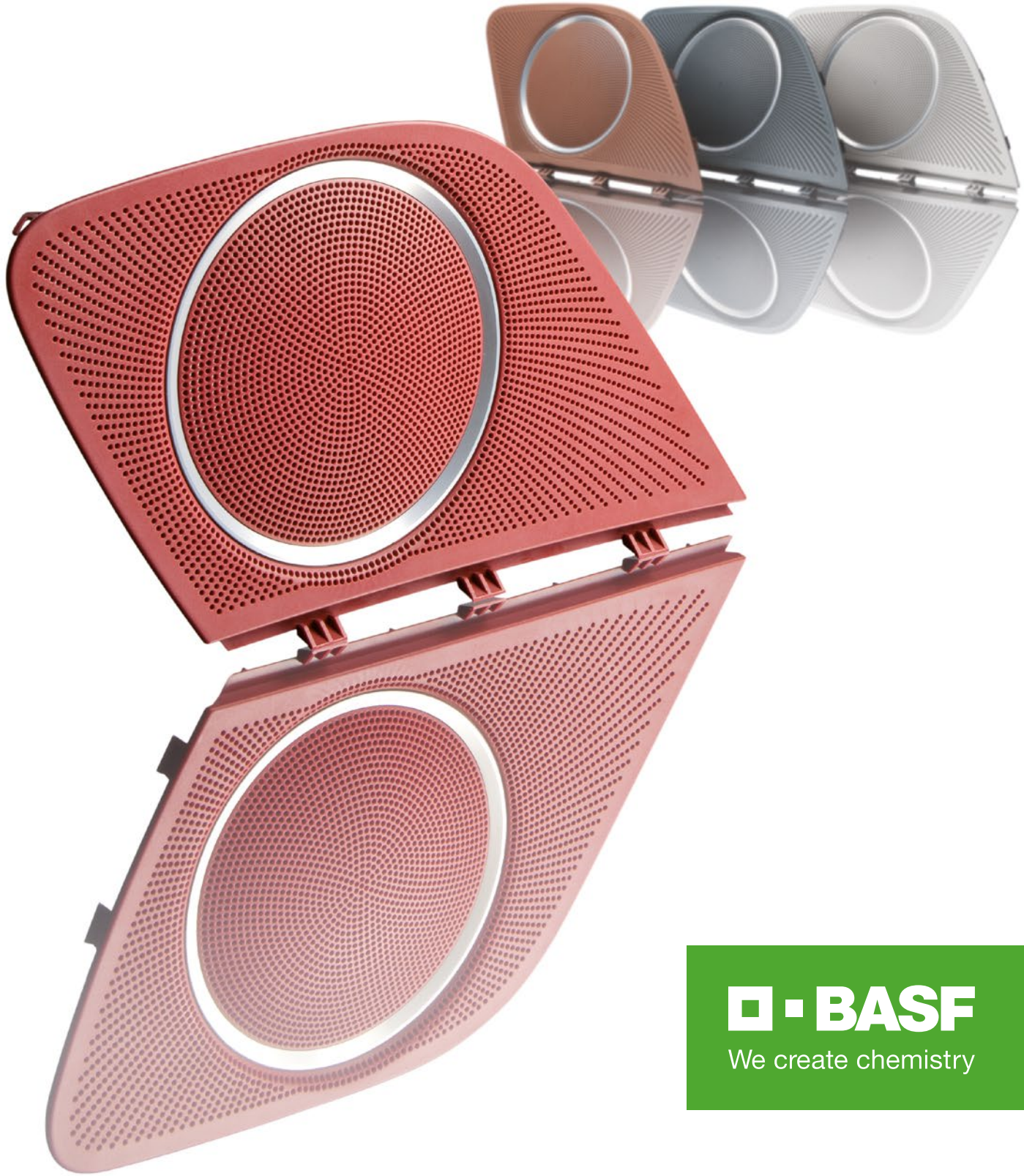
Self-coloring of Ultraform® AT



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Self-coloring of Ultraform® AT

Customer self-coloring of Ultraform® AT has been used very successfully for a considerable time now. Even our most exacting customers value the benefits that self-coloring offers:

- reduced raw material costs because larger, more cost-effective amounts of uncolored product can be purchased
- clearly simplified material logistics because of smaller warehousing needs, centralized raw material stocks and raw material transport from bulk containers or silos
- increased production flexibility due to shorter color changeover times, especially with frequent changes of color

Economic aspects

The major factor underlying a customer's decision to use self colored Ultraform® AT is the long-term economic benefit from lower material costs (uncolored Ultraform® AT + color batch vs. bulk-colored POM). These savings must be balanced against the non-recurring investment costs for metering equipment and, possibly, a mixing element.

Table 1 presents information gathered on four randomly selected color batches from two suppliers:

- color batch costs, classified according to purchased quantity (50/100/250/500 kg)
- metering as per manufacturer's instructions

Ordered batchvolume	50 kg	100 kg	250 kg	500 kg	
Batch	**Batch costs [€/kg]**	**Batch costs [€/kg]**	**Batch costs [€/kg]**	**Batch costs [€/kg]**	**Let down ratio [%]**
A1 (white)	34.00	17.90	9.05	6.60	1.0
A2 (gray)	34.21	18.05	9.15	6.75	1.0
A3 (beige)	35.07	18.76	9.66	7.13	2.0
A4 (red)	37.32	20.40	11.35	8.90	2.0
C1 (red)	19.15	18.66	18.13	16.74	3.5
C2 (blue)	10.05	9.56	9.05	8.56	3.5
C3 (light-blue)	13.80	11.50	10.51	9.51	2.0
C4 (yellow)	19.69	17.38	16.39	15.39	2.0

Table 1: Costs for color batches

In Figure 1 the material costs incurred when color batches are used to manufacture the end product are plotted as a function of yield (i. e. the quantity of end product that can be manufactured). This amount must be set against the price difference of uncolored Ultraform® AT and bulk-colored POM.

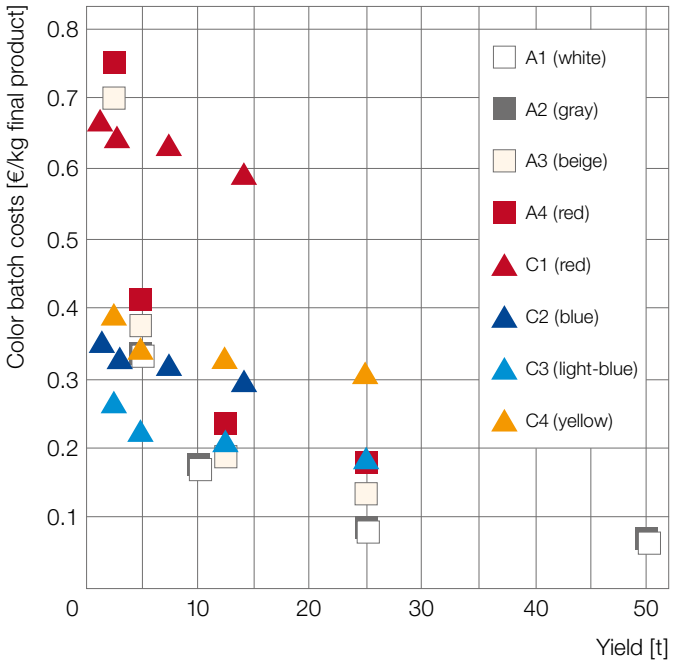


Fig. 1: Raw materials costs by color batches

Example

Uncolored Ultraform® AT is to be colored with A1 white batch. Given that the end product contains 1% of the color batch, purchasing 100 kg of color batch will be sufficient to color 10,000 kg of the end product. The material costs for this self-coloring procedure are 0.18 € per kilogram of end product. This amount must be compared to the difference in the price per kilogram of uncolored and white bulk-colored POM.

This long-term price advantage must be offset against the one-off expenditure on metering and mixing equipment. From this one can calculate the so-called amortization or payback period, i. e. the time it takes for the financial advantage due to lower material costs to compensate for the initial non-recurring investment outlay.

The calculation requires knowledge of the following parameters:

- shot capacity
- cycle time
- available annual machine utilization period
- cost of metering equipment
- cost of mixing equipment
- the specific savings in material costs

Example calculations for two cases of practical relevance are shown in Table 2. Depending upon the actual savings in material costs that can be realized, the amortization periods vary from a few weeks to about a year.

Example 1, assumptions:	**Raw material cost savings specific [€/kg]**	**Raw material cost savings total [€/y]**	**Break even time [weeks]**
▪ shot weight: 50 g/cycle ▪ cycle time: 30 sec ▪ machine usage: 2,000 h/y (= 250 d/y · 8 h/d) ▪ material consumption: 12,000 kg/y ▪ costs for batch feeding unit: 2,000 € ▪ costs for mixing ring: 1,500 €	0.25	3,000	61
	0.50	6,000	30
	0.75	9,000	20
	1.00	12,000	15
	1.25	15,000	12

Example 2, assumptions:	**Raw material cost savings specific [€/kg]**	**Raw material cost savings total [€/y]**	**Break even time [weeks]**
▪ shot weight: 500 g/cycle ▪ cycle time: 120 sec ▪ machine usage: 2,000 h/y (= 250 d/y · 8 h/d) ▪ material consumption: 30,000 kg/y ▪ costs for batch feeding unit: 2,500 € ▪ costs for mixing ring: 2,000 €	0.25	7,500	31
	0.50	15,000	16
	0.75	22,500	10
	1.00	30,000	8
	1.25	37,500	6

Table 2: Two example calculations

Technical aspects

The main self-coloring techniques use:

- liquid or paste-like colorant formulations
- powder pigments or colorants
- thermoplastic-based color batches

Table 3 provides an overview of the advantages and disadvantages of each of these techniques. The use of color batches based on polyacetal copolymer is recommended, particularly Ultraform® AT (e. g. W2320 003 AT). In this case, it probably is safe to assume that only POM compatible colorants will be used.

In many cases, good results can be achieved using a conventionally designed processing machine to which a colorant metering facility has been added. For very demanding applications, the use of the BASF Mixing Ring is recommended (see Fig. 2 and list of suppliers on page 7). This mixing element is being used instead of the conventional tip on the injection molding screw (Fig. 3).

The following methods and test criteria are available for assessing the quality of self colored components:

- visual examination of pigment distribution – either in impinging light or, with more demanding applications, under illumination with transmitted light, limited to thinner parts and lighter colors
- comparison of the melt volume-flow rate (MVR) of the colored molding with that of the uncolored Ultraform® AT granules in accordance with ISO 1133
- testing mechanical properties, especially toughness

Liquid color formulations (e. g. paste)	
easily dispersible	+
pigments / dyes / matrix compatible with POM	-
pellet feeding problems	-
work-place contamination	-
Pigment / dye powder	
work-place contamination	-
pigments / dyes compatible with POM	-
pigment agglomeration / dispersing problems	-
reproducibility / constant color	-
Batches (Ultraform® AT / POM-C based)	
pigments / dyes / matrix compatible with POM	+
easy handling	+
clean	+
reproducible	+

Table 3: Self-coloring options

Selection of suitable batches

If Ultraform® AT coloration with a masterbatch is considered, meaningful trials must be done to verify the compatibility of the selected Ultraform® AT grade and masterbatch. Batches could be incompatible because of insufficient miscibility with the matrix polymer, or by degrading it chemcally. In this case, mechanical performance might be reduced and gaseous formaldehyde may be released. Formaldehyde will be noticed by its pungent odor and irritations of eyes and mucous membrane. This must be avoided reliably under workplace health and safety rules. Long residence times, high temperatures or high shear conditions tend to aggravate these issues.

Fig. 2: BASF Mixing Ring

Fig. 3: Standard screw with conventional tip

Example 1

Ultraform® N2320 003 AT was mixed with 0.5 % of a blue POM-based color batch and processed into box lids with a wall thickness of 2.4 mm on an Engel ES 700 machine (screw diameter 45 mm, clamping force 1,750 kN).

The following equipment was used:
a) standard screw with conventional tip (Fig. 3)
b) standard screw equipped with BASF Mixing Ring (Fig. 2)

The quality of mixing was assessed using pictures taken under illumination with transmitted light (Fig. 4).

Evaluation

- The use of the BASF Mixing Ring yields significantly higher mixing performance than a screw with a conventional tip.

- Under adequate processing conditions, the BASF Mixing Ring allows a production process without degrading the material. The pressure needed to fill the mold with the BASF Mixing Ring corresponds closely to that of the standard screw with conventional tip.

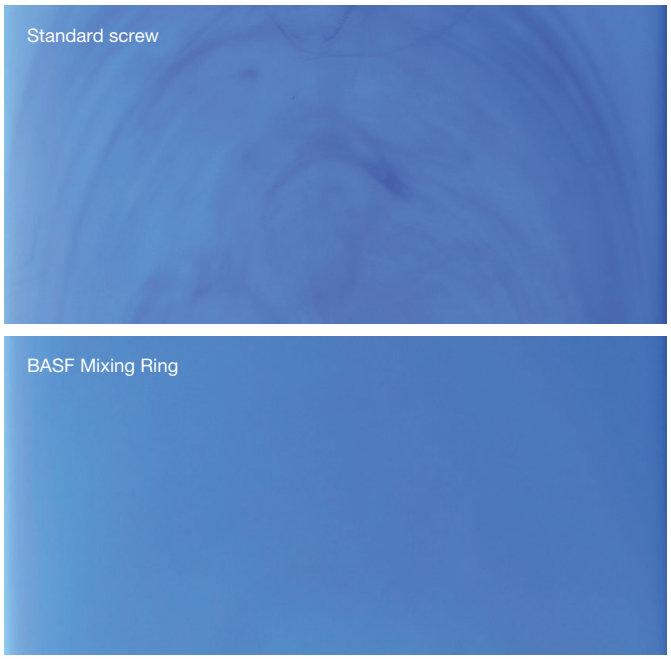


Fig. 4: Lid made of Ultraform® N2320 003 AT and 0.5 % color batch (blue)

Example 2

Ultraform® N2320 003 AT, mixed with red color batch in accordance with the manufacturer's instruction, was processed on an Arburg 320 injection molding machine (25 mm screw diameter) to produce circular disks (diameter: 100 mm, thick-ness: 1.6 mm, gate cross-section: 1.6 x 5 mm). The melt temperature was 200 °C, the surface temperature of the mold was 90 °C.

The test was performed once with a standard screw and once using a mixing ring. When viewed by reflected light, the disks from the two tests show the same homogeneous distribution of pigment; significant differences are not apparent. The situation is different, however, when viewed by transmitted light (Fig. 5 and 6). When the disks are back lit by a powerful light source, one sees that the use of a mixing ring results in a considerably improved pigment distribution.

Fig. 5: Circular disk made of Ultraform® N2320 003 AT and 3.5 % of batch C1 using a standard screw

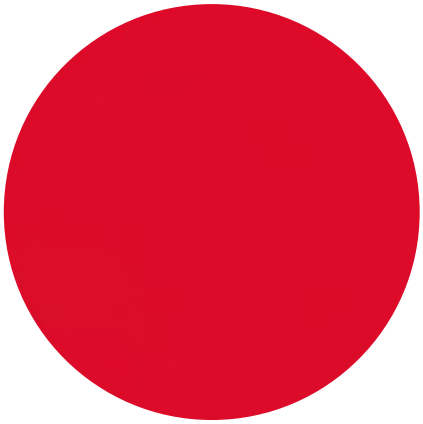


Fig. 6: Circular disk made of Ultraform® N2320 003 AT and 3.5 % of batch C1 using a mixing ring

Example 3

Ultraform® N2320 003 AT that had been mixed with color batch according to manufacturer's instructions, was processed on an Arburg 370 CMD injection molding machine (25 mm screw diameter) without any special mixing element to produce injection-molded tensile test bars (as per ISO 527 type 1A) and impact strength test bars (as per ISO 179/1eU). The color batches used were those listed in Table 1. The test series and the results of the mechanical tests are presented in Table 4. The results were, in all cases, either good or very good, with most values corresponding closely to those of uncolored Ultraform® AT.

Summary

In many cases, self-coloring of Ultraform® AT offers both economic and logistic advantages with unchanged high quality of the end product. The costs of investing in metering and, where necessary, mixing equipment can often be recovered after only a few weeks due to the significant, long-term savings in material costs.

		Tensile modulus [MPa] ISO 527	Tensile stress at yield [MPa] ISO 527	Tensile elong. at yield [MPa] ISO 527	Nominal elong. at break [MPa] ISO 527	Charpy un-notched [kJ/m²] ISO 179/1eU
	uncolored	2,658	64	9.8	28	215
Supplier "A"	with 1 % color batch A1 (white)	2,726	65	9.3	27	209
	with 1 % color batch A2 (gray)	2,721	65	9.3	27	213
	with 2 % color batch A3 (beige)	2,701	65	9.5	28	196
	with 2 % color batch A4 (red)	2,671	64	9.7	27	215
Supplier "C"	with 3.5 % color batch C1 (red)	2,760	65	9.0	26	181
	with 3.5 % color batch C2 (blue)	2,706	65	9.2	25	127
	with 2 % color batch C3 (light-blue)	2,671	64	9.4	27	229
	with 2 % color batch C4 (yellow)	2,747	65	8.9	20	150

Table 4: Ultraform® N2320 003 AT – trials

Color sample plates

BASF Mixing Ring

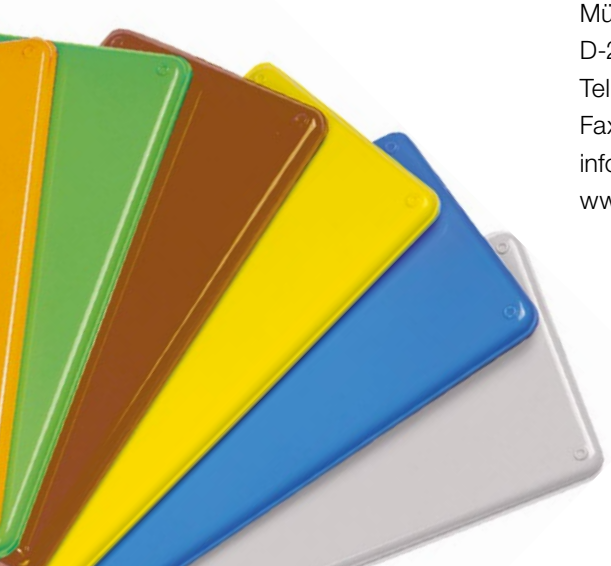
Suppliers
Plasma Kunststofftechnik GmbH
Salzuflener Straße 124
D-32602 Vlotho
Tel.: +49 5733 96130
Fax: +49 5733 961377
s.koch@plasma-kunststofftechnik.de
www.plasma-kunststofftechnik.de

Technical support
BASF SE
Carl-Bosch-Straße 38
D-67056 Ludwigshafen
Tel.: +49 621 60-78780
Fax: +49 621 60-78730
ultraplaste.infopoint@basf.com

Suppliers of color batch feeding units

Werner Koch Maschinentechnik GmbH
Industriestraße 3
D-75228 Pforzheim
Tel.: +49 7231 8009-0
info@koch-technik.com
www.koch-technik.com

AZO GmbH & Co. KG
Rosenberger Str. 28
D-74706 Osterburken
Tel.: +49 6291 92-0
Fax: +49 6291 92-9500
azo-solids@azo.com
www.azo.de



motan-colortronic gmbh
Otto-Hahn-Straße 14
D-61381 Friedrichsdorf
Tel: +49 6175 792 167
Fax: +49 6175 792 284
info@motan-colortronic.de
www.motan-colortronic.com

Labotek Deutschland GmbH
Nöllenhammerweg 10-16
D-42349 Wuppertal
Tel.: +49 202 747585-0
Fax: +49 202 747585-10
info@labotek-de.com
www.labotek-de.com

ProTec Polymer Processing GmbH
Stubenwald-Allee 9
D-64625 Bensheim
Tel.: +49 6251 77061-0
Fax: +49 6251 77061-500
info@sp-protec.com
www.sp-protec.com

Color batch suppliers

BASF Color Solutions GmbH
Clevischer Ring 180
D-51063 Köln
Tel.: +49 221 96498-0
Fax: +49 221 96498-501
info.masterbatch@basf.com
www.basf.com/masterbatch

Albis Plastic GmbH
Mühlenhagen 35
D-20539 Hamburg
Tel.: +49 40 78105-0
Fax: +49 40 78105-361
info@albis.com
www.albis.com

Clariant Plastics & Coatings
(Deutschland) GmbH
Kornkamp 50
D-22926 Ahrensburg
Tel.: +49 4102 487-0
Fax: +49 4102 487-169
kontakt@clariant.com
www.clariant.com

Lifocolor Farben GmbH & Co. KG
Reundorfer Straße 18
D-96215 Lichtenfels
Tel.: +49 9571 789-0
Fax: +49 9571 789-33
zentrale@lifocolor.de
www.lifocolor.de

G.E. HABICH'S SÖHNE GmbH
& Co. KG
Burgstraße 3
D-34359 Reinhardshagen
Tel.: +49 5544 791-362
Fax: +49 5544 8238
matthias.reinsch@habich.de
www.habich.de

Treffert GmbH & Co. KG
In der Weide 17
D-55411 Bingen
Tel.: +49 6721 4030
Fax: +49 6721 40327
info@treffert.org
www.treffert.org

ROWA Masterbatch GmbH
Siemensstr. 1-3
D-25421 Pinneberg
Fon +49 4101 706 01
info@rowa-masterbatch.de
www.rowa-group.com

Selected Product Literature for Ultraform®:

- Ultraform® – Product Brochure
- Ultraform® – Product Range
- Ultramid®, Ultradur® and Ultraform® – Resistance to Chemicals

Note

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Further information on Self-coloring of Ultraform® can be found on the internet:
www.ultraform.basf.com

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