

ARTICLE

February 2017

COMPOSING “PIANO BLACK MUSIC” WITH INEOS STYROLUTION SHINY STARS

by

Erik Fetter

M. Sc., Business
Development Manager
Styrenics Specialties,
INEOS Styrolution



Dr. Fabian Beckert

Technical Product
Manager Novodur &
Terblend EMEA



Dipl. Ing. (FH) Felix Rattay

Global Color Project
Manager



Introduction

Surface quality and appearance of an injection molded article made of styrenic copolymers are of great importance for manifold applications. Besides the tool quality and the processing conditions, especially the choice of the used material and color recipe is crucial to achieve a perfect result according to the designer expectations. One big trend nowadays among industries such as household, electronics and packaging is to strive for high gloss in combination with a rich deep-black (“piano-black”) impression for visible parts in order to confer a high value premium looking surface appearance. The following data will guide you, to pick the high gloss material fitting your requirements.

Piano Black and high color depth

The term “piano black” denotes the sensory impression of a very deep (jet) black and a highly lustrous appearance like in the black body of a grand piano (see **Figure 1**). For this publication, color depth is associated with the darkness (lack of brightness) and the perceived intensity of the color impression relative to comparable objects. The deeper the black color appearance, the darker the part aspect and the perception that we can look even beyond the surface. For plastic parts this depth effect can be achieved by using additional clear coat layers (i.e. via lacquering /painting or bi-injection) and/or by using specialized color formulations that reduce the amount of colorant reflection on the surface.

FIG.1: PIANO BLACK LOOKING

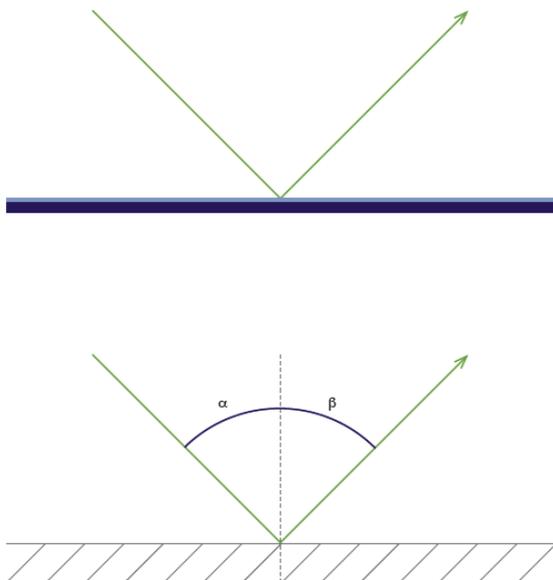


Gloss

Gloss is in simple terms the visual impression by an observer of the shiny appearance of a surface. It indicates how well a light source reflects in a specular (mirror-like) direction unattenuated and without scattering. For a high gloss mirror-like surface all of the incident light source will be reflected from the surface and the angle of the reflected light beam (β) will correspond to the angle of the incident light beam (α) as shown in **Figure 2**. The surface reflected light (associated with the shiny appearance of an object) is the attribute called gloss. In this way a high gloss surface highlights a perception of high brilliance, maximizing the final product appeal. On the opposite to a high gloss surface, a high degree of light scattering within the surface will lead to a less intense reflection in the main direction resulting in a matt appearance. This is for instance the case when having rough or texturized structures that aim this kind of surface finish.

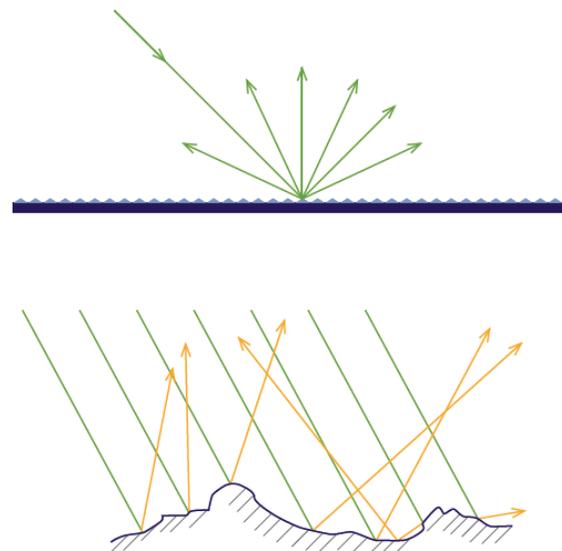
FIG. 2: LIGHT DISTRIBUTION FROM HIGH GLOSS SURFACE

High gloss (mirror-like surface): All of the incident light is reflected directly on the surface at the same angle ($\alpha=\beta$).



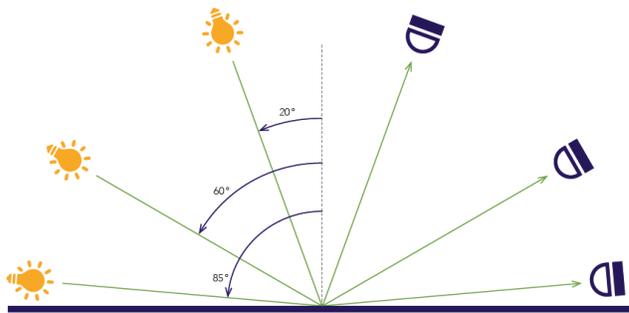
LIGHT DISTRIBUTION FROM MATT SURFACE

Matt surface (e.g. rough texturized surface): The light is scattered diffusely at many different angles, instead of only the mirror angle.



Besides the color, the gloss level of a product will directly influence the final customer's decision making behavior. For this reason and in order to ensure the quality of their products, many industries measure and closely monitor the specular gloss level of a product. This is done by means of a glossmeter (see **Figure 3**). The measurement result is related to a given standard (highly polished plain black glass with a fixed refractive index) for which an upper point calibration value of 100 gloss units (GU) has been assigned. For high gloss plastic appliances specular gloss measurements with an illumination angle of 20° are recommended, while the 85° measurement geometry is rather suitable for matt and low gloss surfaces. Values that are close or above 100 GU show very high gloss (e.g. this would be the case for shiny metals), whereas values in the lower range (close to 0 GU) refer to matt surface appearance and a high degree of light scattering.

FIG. 3: GLOSS MEASUREMENT SPECULAR REFLECTION AT DIFFERENT ANGLES
(LIGHT SOURCE POSITION AND DETECTOR POSITION)



Color

An important and key attribute for every development is related to the right color tone. The perception of the color relies on the human visual sense (observer), the sample itself and the light source. For this reason, it is important to consider the expected light sources where the part will be observed already during the development stage. For color evaluation purposes a measuring device (spectrophotometer) is used which contains different light sources being the daylight standard D65, 10° Obs. (standard daylight illuminant, 10 degrees field of standard observer) one of the most commonly employed conditions for color evaluation purposes. As an output of the analysis, the International Commission on Illumination (CIE, standing for “Commission Internationale de l’Éclairage”) has defined a set of a system based on three coordinates that correspond to the interpretations of what the human eye sees. Briefly explained, the coordinates are L* (Lightness/darkness, scale 0 = Black; 100 = White), a* (red/green shade) and b* (yellow/blue shade).

When it comes to consumer products, designers have the task to carefully select and agree on the color appearance and chromaticity of a new product. Over the years, INEOS Styrolution has developed plenty of tailor made color solutions and can provide assistance regarding color developments (see **Figure 4A**). INEOS Styrolution experts at the Color Excellence Center (CEC) in Cologne support and assist customers with specific color requests (e.g. based on ideas defined in the RAL or Pantone color schemes) resulting in the development of a new color in the desired polymer.

FIG. 4A: EVERY COLOR YOU CAN IMAGINE

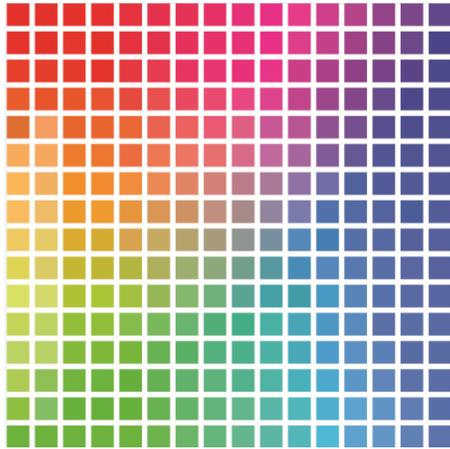
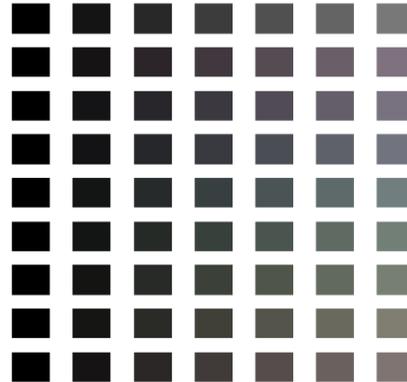


FIG. 4B: BLACK COLOR GRADIENT



A particular color cluster like “black” can be offered from an aesthetic perspective in a wide selection of shades. “Black is not just black” and there are many different designations for dark color impressions like charcoal, onyx, smoke, obsidian and deep (jet) black (see **Figure 4B**).

INEOS Styrolution offers material solutions for perfect gloss in combination with customized colored packages and tailored mechanical and thermal properties. The gloss will depend on the material selected, but also on the processing conditions and tool design.

INEOS Styrolution black precolored selected grades

INEOS Styrolution selected for this investigation black precolored styrenic copolymers (impact and non-impact modified) given their well-known high aesthetic surface quality. In particular, this study focuses on Terluran® (ABS), Novodur® (ABS, ABS blends) and Luran® (SAN) product families. The Terluran and Novodur product families are both elastomer impact modified SAN grades but with inherent differences regarding the production process and consequently the core/ shell structure of the grafted latex particles and its size and distribution. These differences between the rubber morphology will feature a distinction on the surface appearance. Terluran is a standard ABS grade while the Novodur product family belongs to the specialty ABS product range targeting precolored high gloss applications. The ABS grades that were particularly chosen were the standard Terluran GP-22 and the specialty Novodur P2H-AT. Furthermore, Luran HH-120 (SAN) and Novodur HG-36 (an advanced PMMA/ABS polymer blend) were considered for this study given their excellent colorability (leading to high color depths) and surface appearance. Because the color recipe will strongly influence the gloss and color depth appearance, different color recipes were employed.

A brief overview of the INEOS Styrolution black colored grades (standard and deep black color recipes) that were evaluated during this study is provided in **Table 1**:

TAB. 1: INEOS STYROLUTION BLACK COLORED GRADES

Grades	Color package	Description
Terluran GP-22 BK10009	Standard black	Easy-flow ABS, commodity injection molding grade
Novodur P2H-AT BK901510	Standard black	Specialty high flow, high gloss injection molding ABS grade featuring an antistatic package
Novodur HG-36 BK901510	Standard black	PMMA/ABS blend with high surface quality, enhanced scratch resistance and high gloss appearance
Novodur HG-36 BK10437	Deep black	PMMA/ABS blend with specially selected colorants in order to achieve a deep color and multi-dimensional appearance
Luran HH-120 BK37133	Deep black	AMSAN grade with high heat resistance and improved mechanical strength. The 'piano black' version delivers a high-gloss and jet black tone

Standard black refers to a color recipe that considers predominantly the use of a standard carbon black pigment to impart high color strength. A deep black color package is a more advanced coloration recipe for a pronounced deep black featuring the use of customized tuning colorants.

Processing Conditions

End-users continuously design and develop different housings for new eye-catching devices where high gloss and good color depth are in the foreground. Given the different complex geometry designs, a good material processability within a broad processing range is key. INEOS Styrolution carried out a comparative study testing standardized sample plaques (on a high polished surface tool) among different processing conditions. The effect of the mold temperature, different injection speed, and melt temperature on the part's final gloss was assessed on a high polished surface tool (Europlaque: 200*140*4 mm).

The experimental set-up can be summarized as follows:

TAB. 2: EXPERIMENTAL SET-UP (PROCESSING CONDITIONS)

Variable	Range
Melt temperature	240 – 260°C
Mold temperature	30 – 70°C
Injection speed	20, 50 and 100 mm/s
Color package	Standard black, deep black

Results overview: For each of the set-up conditions, the gloss (20°) and the CIELAB color space values were measured on the respective Europlaques.

Gloss results:

A comparison of the gloss measurement results between the selected grades is shown in **Figures 5 and 6**. The measurement of Novodur HG-36 in BK1009 (standard black) and a mold temperature of 30 °C was left out on purpose as the intention was to show the influence of and compare the gloss between standard and the deep black coloration of this grade at optimum mold temperature conditions (70 °C).

FIG.5: GLOSS MEASUREMENT OVERVIEW, MELT TEMPERATURE 260 °C

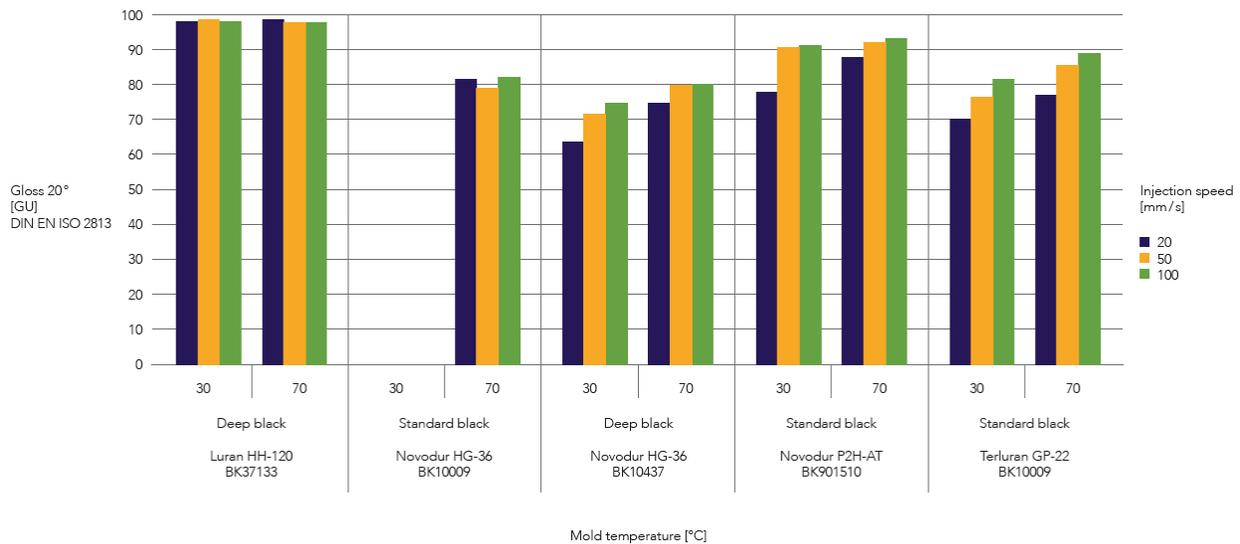
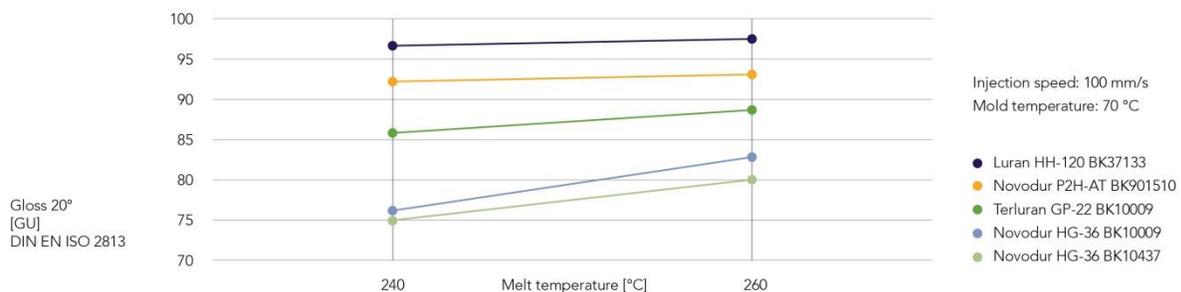


FIG.6: GLOSS MEASUREMENT OVERVIEW, MELT TEMPERATURE 240 – 260 °C



The results show the broad range of material solutions that INEOS Styrolution can provide targeting high gloss and color depth. Luran HH-120 excels in terms of high gloss and piano black. For impact modified grades, high gloss results were achieved with Novodur P2H-AT and Terluran GP-22. Novodur P2H-AT showed the best results and a very consistent high gloss level over a broad range of processing conditions among the ABS portfolio. This explains also why this grade is widely used for high demanding applications requiring high aesthetic levels. For the manufacturing of for instance vacuum cleaner housing it is key to use a material that provides easy processing and high gloss consistency within different processing considerations. Vacuum cleaner housings are typically complex shaped parts with long flow paths and featuring ribs and bosses elements, wall thickness differences and holes and depressions. This leads at the end to flow diversion and weld and meld line formation and requires typically adjusting the processing conditions like the injection speed in order to maximize the part optical appearance. Thus, a high gloss consistency is here of special interest. For applications requiring a high color depth combined with good scratch resistance and good gloss INEOS Styrolution offers Novodur HG-36 which is a PMMA/ABS blend.

It can be concluded from this study that the mold temperature and injection speed have a considerable impact on the final gloss. In general, higher mold and injection speeds lead to greater gloss levels. This is in line with the fact that those two processing parameters enable a better replication of the tool surface. The melt temperature has an influence as well, but it was not as significant as with the first two mentioned variables. Within the recommended processing conditions it plays a less significant role.

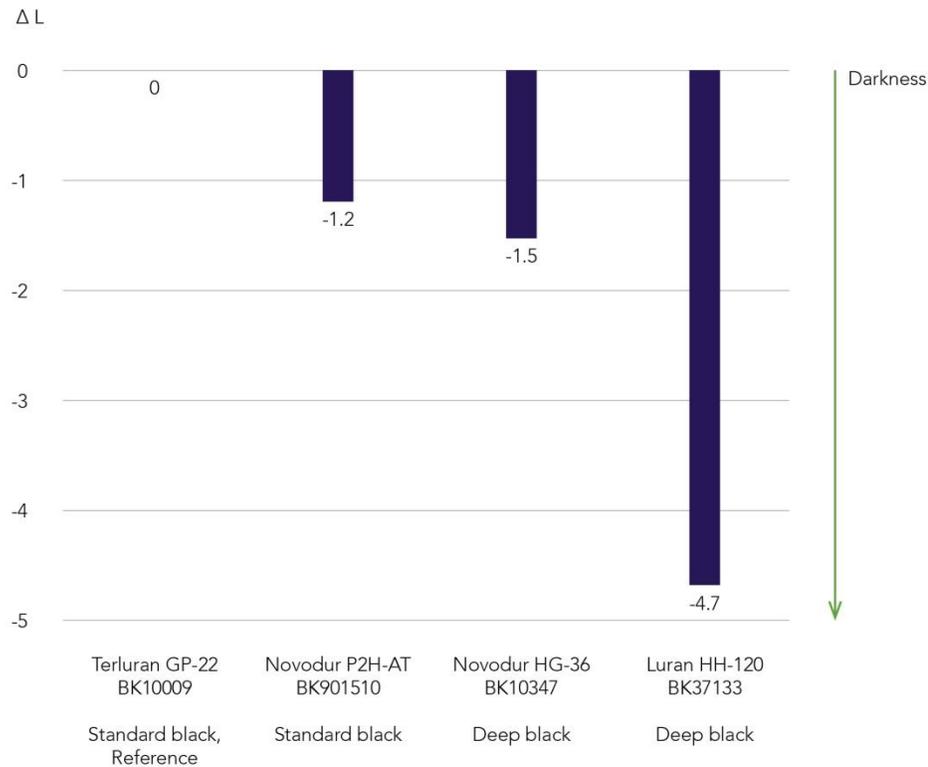
The effect of the color recipe (standard or deep black formulation) is noticeable when comparing the results of Novodur HG-36 in both standard and deep black coloration. The tendency is that the standard package leads to a slight higher gloss at the expense of the less pronounced color depth. The explanation of this result is the consequence that the standard black recipe brings on a higher reflection of the pigments on the surface increasing the gloss level and at the same time creating a higher brightness and lower color depth. The special colorants used in the deep black recipe on the contrary are situated deeper and don't allow the light to reflect on them that easily generating a higher color depth and jetness impression.

Color depth (ΔL^*)

A comparison was performed among the products in terms of their difference in lightness and darkness (CIE ΔL^*) under a daylight standard source (D65, 10° Obs.). To allow an easy comparison of the results, the lightness difference was measured against Terluran GP-22 BK10009. In this way, a lower value means an increase in the darkness of the samples compared to the reference one.

FIG. 7: CIELAB ΔL^* COMPARISON (D65, 10° Obs.).

COMPARISON PROPERTY PROFILE OF GLOSS AND COLOR DARKNESS
(RELATIVE VALUES) FOR MOLDED PLAQUES

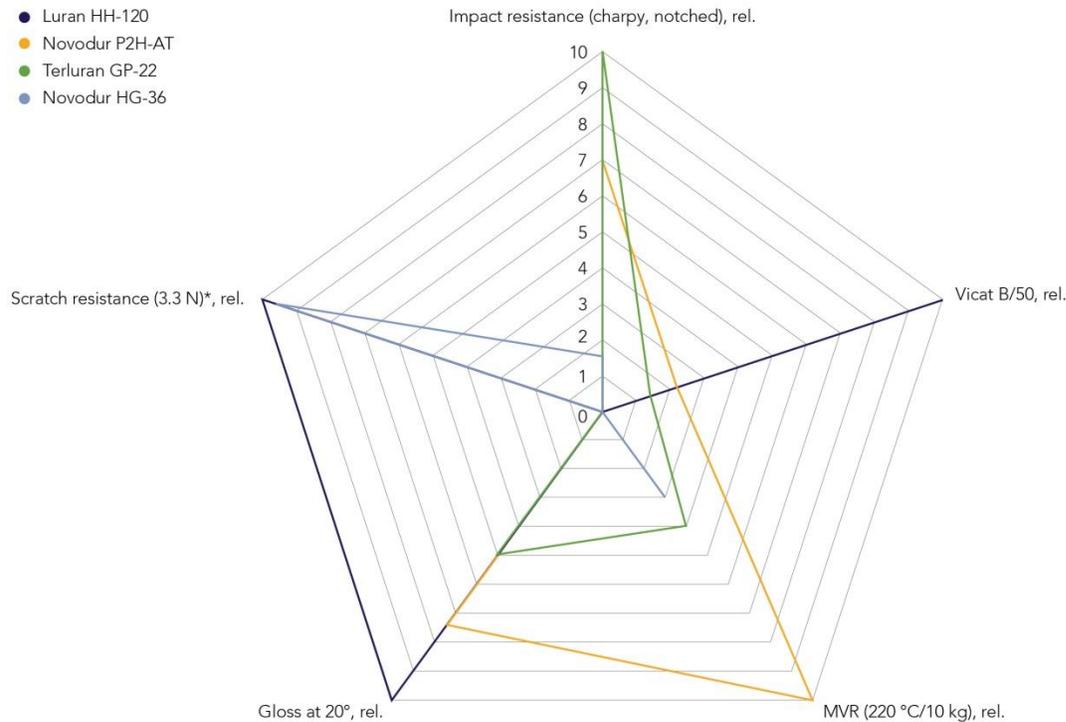


From the chart it is easy to distinguish the superior and higher darkness of Novodur P2H-AT BK901510 compared to the standard ABS. Furthermore, the advanced deep black products Luran HH-120 BK37133 and Novodur HG-36 BK10347 feature a remarkable “piano black” darkness compared to the two reference standard black grades. Particularly Luran HH-120 BK37133 outclasses in terms of high color depth.

Property profile

For the selection of the material it is not only the aesthetic considerations that are important but also the overall material properties. Of particular interest are properties such as the material flowability, the impact performance, the heat resistance, the material stiffness and the scratch performance. For a quick material profile overview, the following spider chart (**Figure 8**) was prepared providing a relative comparison among the grades presented in this study.

FIG. 8: SPIDER CHART, PROPERTY PROFILE (RELATIVE VALUES)



* Scratch test performed on the basis of DIN EN ISO 1518, diamond scratch head (pointed angle: 120°/radius: 0.2 mm)

Applications like electric shaver housings or vacuum cleaner housings require a material offering a certain heat resistance and impact modification. A coffee machine blend will focus more attention to high gloss and good scratch resistance and for cosmetic packaging and applications featuring decorative covers, the piano black look will be on the top of customers' interest. The following table lists the typical mechanical properties of the resins that were studied.

TAB. 3: OVERVIEW OF THE TYPICAL MECHANICAL PROPERTIES

Type	Grade	MVR (220 °C/10 kg) [cm ³ /10 min] ISO 1133	Impact (Charpy notched) [kJ/m ²] ISO 179	Vicat VST/B/50 [°C] ISO 306	Stiffness (E-Modulus) [MPa] ISO 527
Impact modified	Novodur P2H-AT	37	16	98	2500
Impact modified	Teluran GP-22	19	22	96	2300
Impact modified	Novodur HG-36	16	5	92	2600
Non modified	Luran HH-120	7	2	120	3900

INEOS Styrolution's specialty ABS in black color, Novodur P2H-AT BK901510 offers a good combination of appearance, flow (easy processing) and impact and heat resistance features. This property profile fits the requirements of the packaging, the household and the electronics-industries. The gloss properties of the finished part exceed clearly the commodity ABS appearance and are even close to the surface of the state-of-the-art "piano-black" product, INEOS Styrolution's Luran HH-120 BK37133. Highest surface gloss is obtained applying high mold-temperatures in combination with medium and high injection speeds.

Luran HH-120 BK37133 and Novodur HG-36 BK10437 were developed for high brilliance and deep black impression. At the same time, both grades offer a very good scratch resistance. Novodur is recommended for applications requiring impact resistance while Luran for aesthetical parts with excellent surface appearance.

Summary & Material Recommendation

The grade to select will highly depend on the mechanical, thermal and aesthetical requirements for the target application. In a nutshell, this study provided the benefits of the following products for deep colored and high gloss applications:

- Terluran GP-22 commodity ABS injection molding grade with good property balance
- Novodur P2H-AT showing best gloss and darkness among the ABS portfolio for applications demanding high gloss, gloss consistency and high impact resistance (e.g. drop tests). Ideal as well for complex parts (e.g. complex design with snap fits, ribs, bosses) requiring good processability within a broad window.
- Luran HH-120 BK37133 giving true "deep-black" impression, high gloss and very good scratch resistance
- Novodur HG-36 for high color depth, medium-impact applications and very good scratch resistance

Application examples



Courtesy of: Groupe SEB (ROWENTA)



Courtesy of: De'Longhi



About the authors

Erik Fetter started his career at Dow Chemical, where he was responsible for Technical Service and Development within Dow Automotive located in the Netherlands and afterwards in Switzerland. In 2011 he relocated to Germany and became responsible for business development at INEOS Styrolution within the Packaging, Electronics and Household industries. With more than 10 years of experience, Fetter has actively supported several customer developments covering a broad portfolio range (thermoplastics, thermosets and elastomers). Fetter holds a Chemical Engineering degree and subsequently completed a Master of Science in Polymer Technology degree at the Aalen University of Applied Sciences.

Fabian Beckert is TPM for Novodur and Terblend at INEOS Styrolution since 2015. He studied chemistry with a focus on polymer chemistry at the Albert-Ludwigs-University in Freiburg, Germany, and he holds a Ph.D. from that university.

Felix Rattay started his colorful career at Albis Plastics in Hamburg, Germany, where he led the color development within the R&D department. He then took the opportunity to build a new color lab from scratch in Tarragona, Spain, after joining Lanxess in 2006. Three years later, in 2009, he moved to Cologne, Germany, continuing to lead the color lab. Today, he builds on his experience in color guiding the global color labs in all three regions for INEOS Styrolution. Rattay graduated in chemistry from the Technische Hochschule Berlin in 1993.