DYE MANSION

AUTOMOTIVE COLORS^{X}

MEETING LIGHT & HEAT RESISTANCE STANDARDS FOR AUTOMOTIVE INTERIOR PARTS

EXECUTIVE SUMMARY

In recent years, Additive Manufacturing (AM) has evolved from prototype to seri- al production for end-use parts. This development leads to increased demands on the final components.

Especially in the Automotive sector, reproducibility and improved fastness are particularly important. If 3D-printed parts are in operation in the interior of cars, they must withstand numerous external influences. The resistance to heat and light, good scratch resistance and good rub fastness regarding both, distortion and bleeding are particularly worth mentioning here.

In order to meet these demands, DyeMansion has developed a new color range within the extended Colors^{X} series, which is characterised by significantly improved light and heat resistance.

This paper presents how the new and strong Automotive Black^{X} enables lightfast dyeing for various polyamide materials. With this solution the criteria of the ISO EN 105-106 standard used by Automotive companies can be fulfilled

PROBLEM

PHOTOFADING OF 3D-PRINTED AND DYED POLYMER PARTS

In colored materials, there are dyes that absorb part of the light while the rest of the solar spectrum is reflected. This ratio of absorbed and reflected light makes dyed objects appear colorful. If some of the dyes are destroyed, e.g., by the influence of light, less light of the corresponding wavelength can be absorbed. Consequently, the colored object fades. The light induced mechanism of the dye destruction is exemplarily shown in Fig. 1 for an acidic dye.

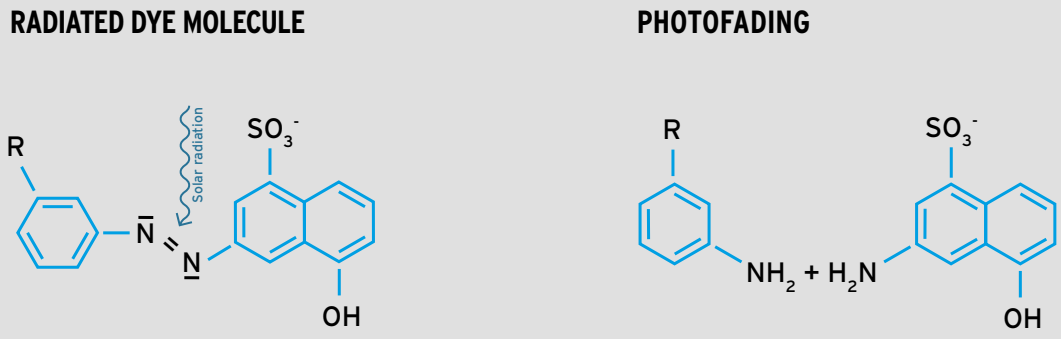

Figure 1: **Mechanism of light induced reduction of an azo-dye.**

The central weakness of organic materials originates from the relatively weak binding forces in their macromolecular structure. Thus, the application of plastics and other organic compounds is limited by certain external factors, such as heat, oxygen and light, accelerating the unpreventable ageing process. As this effect applies for all organic materials it also affects the properties of 3D-printed and dyed polymer parts.

Thermal and photooxidative degradation are two common types of deterioration reactions. Thermal degradation of polymers is a chemical and physical degradation process as a result of high temperatures. Consequently, the chain backbone of the polymer can begin to break down and react with one another leading to great changes in the materials properties. Photooxidation refers to the chemical and physical changes in polymers initiated by solar radiation. Free radicals, formed by photon absorption, react with oxygen leading to a chain propagation of radical formation. Both effects alter the properties of polymer. As a result, 3D-printed polyamide parts yellow with time due to sunlight.

In case of dyed polyamide parts, color fading initiated by solar radiation can be observed. After absorbing the radiation, the dye molecule converts the absorbed energy into heat, but more importantly the dye molecule gets excited into a higher energetic state. Subsequently, the excited dye molecule can undergo reactions with oxygen. Consequently, chemical bonds within the dye molecule are destroyed, altering the molecular structure so that light can no longer be absorbed. Thus, the 3D-printed and dyed parts appear brighter.

SOLUTION

LIGHT & HEAT RESISTANT DYEING WITH AUTOMOTIVE COLORS^{X}

In order to delay the aging process, DyeMansion has developed a new color range, which offers a higher UV absorbance and anti-oxidative properties, called Automotive Colors^{X}. These Automotive Colors^{X} enable unprecedented possibilities for the use of 3D-printed polyamide components as automotive interior parts.

To prolong the ageing process, additives can be added and thus increase the resistance to solar radiation. One can differ two types of additives: UV absorbers and light stabilizers.

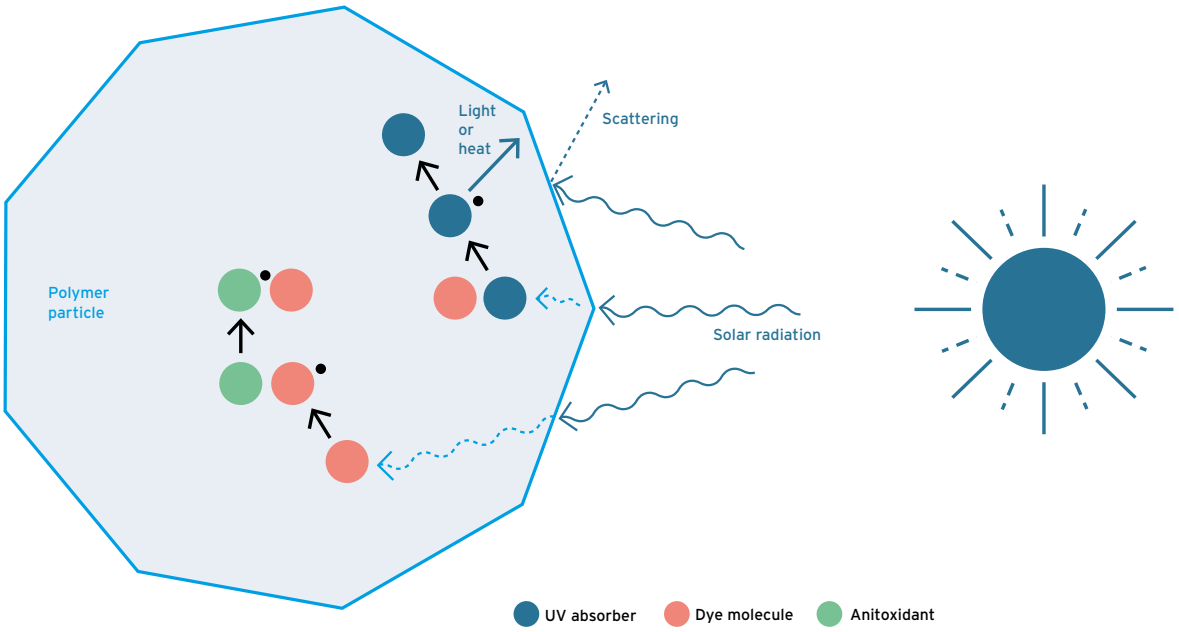

Figure 2: **Working principle of different additives that can prevent dyed parts from photofading: UV-absorbers and antioxidative light stabilizers.**

UV absorbers are additives, which absorb the UV light and convert it into thermal energy.

Light stabilizers, also known as antioxidants, act as so-called radical scavengers. Antioxidants are inhibitors of oxidation reactions, which produce free radicals. Light stabilizers can terminate the oxidation process by trapping the free radicals.

EXPERIMENTAL SETUP

DEEPDYE COLORING (DDC) PROCESS IN THE DYEMANSION DM60

As photofading is not only determined by the used dyeing solution but also by the interaction between the dyes and the material of the 3D-printed part, three most commonly used materials EOS PA 2200, HP 3D HR PA 12 and EOS PA 1101 were tested.

The 3D-printed parts of the three materials were firstly depowdered with the PolyShot Cleaning (PSC) process using PC4 blasting media. The parts were processed in two different finishes e.g., homogenized by the PolyShot Surfacing (PSS) process or smoothed by the VaporFuse Surfacing (VFS) process. The surfacing processes reduce surface unevenness and increase the gloss of the part. All parts were dyed with the regular DM Black 01 as well as the lightfast Automotive Black^X in the DM60. An overview of the tested materials applied colors and finishes can be seen in Table 1.

MATERIALS	TECHNOLOGY	COLOR	FINISH
EOS PA 2200	Selective Laser Sintering (SLS)	DM Black 01 vs. Automotive Black^X	PolyShot Surfacing (PSS)
			VaporFuse Surfacing (VFS)
HP 3D HR PA 12	Multi Jet Fusion (MJF)	DM Black 01 vs. Automotive Black^X	PolyShot Surfacing (PSS)
			VaporFuse Surfacing (VFS)
EOS PA 1101	Selective Laser Sintering (SLS)	DM Black 01 vs. Automotive Black^X	PolyShot Surfacing (PSS)
			VaporFuse Surfacing (VFS)

Table 1: Overview of tested materials, used printing technologies and applied DyeMansion Finish.

ACCELERATED LIGHTFASTNESS TESTING:

The material parts, colored with the DeepDye Coloring (DDC) process in DM Black 01 and Automotive Black^X, respectively were exposed to solar radiation in a lightfastness testing device (Q-Lab Xe3-HBS) according to the hot irradiation standards of ISO EN 105-B06 method 3. Table 2 lists the chosen parameters of the performed test.

The performed lightfastness test, according to ISO EN 105-B06, comprises a constant heating at a chamber air temperature of 65 °C and a relative humidity of 30. The 3D-printed and dyed parts were exposed to three Xenon lamps, each with an irradiance intensity of 60 W/m^2. Three cycles, with a duration of 45 hours per cycle, were performed.

INSULATED BLACK PANEL TEMPERATURE	100 °C
CHAMBER AIR TEMPERATURE	65 °C
RELATIVE HUMIDITY	30
IRRADIANCE (TUV SENSOR 300-400 NM)	60 W/m^2
CYCLE TIME	45 h
NUMBER OF CYCLES	3

Table 2: Used lightfastness testing parameters in accordance with ISO EN 105-B06

The color deviation as well as the change in brightness before and after weathering was visually inspected using a grey scale.

RESULTS

The results of the lightfastness testing on three different materials (EOS PA 2200, HP 3D HR PA 12 and EOS PA 1101) dyed in DM Black 01 and Automotive Black^{X} respectively are shown in the following figures. The influence of solar radiation along with the difference between DM Black 01 and Automotive Black^{X} on the three materials is depicted.

EOS PA 2200

As shown in Fig. 3, the regular DM Black 01 color does not fulfill the criteria of the ISO EN 105-B06 standard as one sees that the color faded. In contrast, Fig. 4 & 5 depict the results of the Automotive Black^{X} color. Compared to the parts dyed in DM Black 01 with the PolyShot Surfacing (PSS) finish, which has a grey scale value of 3 – 3.5, the parts coloredin Automotive Black^{X} shows an improvement in the lightfastness: With the PolyShot Surfacing (PSS) a grey scale value of 3.5 – 4 can be achieved. Treated with the VaporFuse Surfacing (VFS) a grey scale value of 4 – 4.5 is accessible.

Figure 3: **DM Black 01 with PSS finish on EOS PA 2200 (before vs. after lightfastness testing).**

Figure 4: **Automotive Black^{X} with PSS finish on EOS PA 2200 (before vs. after lightfastness testing).**

Figure 5: **Automotive Black^{X} with VFS finish on EOS PA 2200 (before vs. after lightfastness testing).**

HP 3D HR PA12

Next to EOS PA 2200, a commonly used material is HP 3D HR PA 12. Although this material is already greyish after the printing process, it has the need of lightfast black dyeing, too. Parts surfaced with the PolyShot Surfacing (PSS) finish and colored in DM Black 01 show a grey scale value of 3 – 3.5 (Fig. 6). When using the Automative Black^{X}, the lightfastness will increase to a grey scale value of 4 (PSS) or even 4.5 – 5 if the parts are surfaced with the VaporFuse Surfacing (VFS) finish (Fig. 7 & 8).

Figure 6: **DM 01 with PSS finish on HP 3D HR PA 12 (before vs. after lightfastness testing).**

Figure 7: **Automotive Black^{X} with PSS finish on HP 3D HR PA 12 (before vs. after lightfastness testing).**

Figure 8: **Automotive Black^{X} with VFS finish on HP 3D HR PA 12 (before vs. after lightfastness testing).**

EOS PA 1101

Especially for automotive interior applications, PA 11 plays an important role due to the increased fracture toughness. In order to prove the increased lightfastness not only for PA 12 materials but also for PA 11, identical tests were performed on EOS PA 1101. The results of the parts surfaced with PolyShot Surfacing (PSS), colored in DM Black 01 (Fig. 9) and in Automative Black^{X} (Fig. 10) as well as the results of parts with a VaporFuse Surfacing and Automotive Black^{X} coloring (Fig. 11), are shown below. As for PA 12, improved lightfastness could be achieved for PA 11 through the new coloring solution of DyeMansion. On the grey scale, PA 1101 colored in DM Black 01 with the PolyShot Surfacing (PSS) finish has a grey scale value of 3, colored in Automotive Black^{X} it achieves a 3.5 – 4. When using the Automative Black^{X} with the VaporFuse Surfacing (VFS), the lightfastness will increase even to a grey scale value of 4 – 4.5.

Figure 9: **DM Black 01 with PSS finish on PA 1101 (before vs. after lightfastness testing).**

Figure 10: **Automotive Black^{X} with PSS finish on PA 1101 (before vs. after lightfastness testing).**

Figure 11: **Automotive Black^{X} with VFS finish on PA 1101 (before vs. after lightfastness testing).**

MATERIALS	COLOR	GREY SCALE WITH PSS FINISH	GREY SCALE WITH VFS FINISH
EOS PA 2200	DM Black 01	3 – 3.5	–
	Automotive Black^{X}	3.5 – 4	4 – 4.5
HP 3D HR PA 12	DM Black 01	3 – 3.5	–
	Automotive Black^{X}	4	4 – 4.5
EOS PA 1101	DM Black 01	3	–
	Automotive Black^{X}	3.5 – 4	4 – 4.5

DM BLACK 01 VS. AUTOMOTIVE BLACK^{X}

Depending on the requirements and application, DyeMansion now offers two different black colors for the DeepDye Coloring technology. With DM Black 01 a deep black coloring is achieved, which bleaches somewhat faster. However, it still offers a reasonable lightfastness which is by far sufficient for most applications. In contrast, the new Automotive Black^{X} offers a slightly less saturated black tone, which is characterized by its excellent resistance to light and heat.

HOW TO USE AUTOMOTIVE COLORS^{X} WITH DEEPDYE COLORING (DDC) IN THE DYEMANSION DM60

Since 2015, DyeMansion offers an automated, high-through- put coloring solution for 3D-printed industrial and consumer products. This world leading coloring solution for AM plastics is called DeeyDye Coloring (DDC) and can be used with the DyeMansion DM60.

The DM60 is a user-friendly coloring system and achieves consistant coloring results to meet the requirements for high-value, end-use products. Simply insert parts, choose a color cartridge (e.g. Automotive Black^{X}) and press start. DyeMansion color cartridges provide a contact-free and clean dyeing process without any manual pigment handling. In order to satisfy any demands with respect to the number of dyed parts, the cartridges are available in different sizes. The DyeMansion coloring solution is optimized for powder-based materials and ensures the best color quality on the market today. The colored plastic parts are reproducible in color, long-lasting, scratch resistant, not washable and thanks to the new Automotive Black^{X} even more lightfast than before.

The lightfast Automotive Black^{X} dyeing can be easily integrated in the regular DeepDye Coloring process without any hardware changes. In addition, the advantages of the DM60 DeepDye Coloring process apply also for Automotive Black^{X}. Using heat and pressure, the dye penetrates the 3D-printed part. Thus, no additional layer of material is added at the surface, allowing a geometry independent coloring of 3D-printed parts. Even finest textures, such as leather patterns, can be colored in Automotive Black^{X} by the DDC process without losing any details.

As black is one of the most important colors for automotive interiors, Automotive Black^{X} was chosen to represent the new color range of Automotive Colors^{X}. However, this does not imply that the positive effects achieved for this color are limited to black. As for our other colors, DyeMansion also offers its customers an individual color development for Automotive Colors^{X}.

CONCLUSION

AUTOMOTIVE COLORS^{X} AS THE SOLUTION FOR LIGHT & HEAT RESISTANT DYEING OF AUTOMOTIVE INTERIOR PARTS

From now on, 3D-printed, black colored parts are also a serious alternative for Automotive (spare) parts. These applications are made possible by the fact that the strict criteria of the Automotive industry can be met for the first time with the new Automotive Colors^{X}. More colors can be developed individually on request.

LIGHTFAST DYEING IN THE DM60

For Automotive Black^{X} the customer can enjoy the advantages of the DeepDye Coloring technology as well. Like any other DyeMansion color, Automotive Black^{X} can be colored by the contactless cartridge system in the DM60. There is no need for any hardware or software update.

GEOMETRY INDEPENDENT

As usual, dyeing with Automotive Black^{X} is also geometry-independent and suitable for different amounts of parts.

COMPATIBLE WITH PA 11 AND PA 12

The increased lightfastness of the Automotive Black^{X} can be achieved on 3D-printed parts of different powder bed fusion technologies (MJF and SLS) and on different polyamide-based materials like PA 12 and PA 11.

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