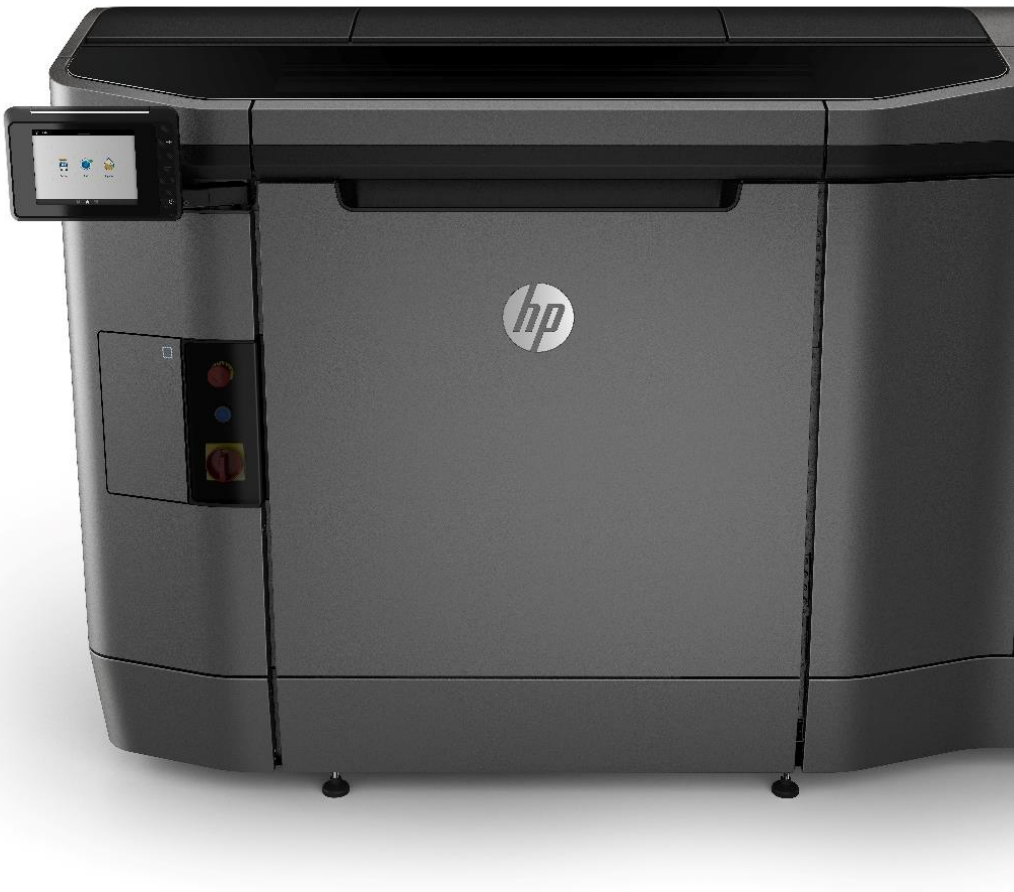
Accelerated Weathering Test: Color Resistance

Author: ATC TEAM

October 2018



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Executive summary

The purpose of this test is to characterize the outdoor durability of MJF parts (with or without post-processing) with PA12, PA12GB and PA11 materials. The first part of the study focuses on the sample appearance (color and gloss only) and the next step will be focused on the changes in mechanical properties. All the post-processes tested (unless none was used) were produced by third parties and the final parts were black. The following table shows the combination of material and post process tested.

Post Process/Material	PA12	PA11	PA12GB	SLS PA2200
Natural	Tested	Tested	Tested	Tested
RIT	Tested	Tested	Tested	Not Tested
Dyemansion	Tested	Tested	Tested	Not Tested
AMT (chemical polishing)	Tested	Tested	Tested	Not Tested

An HP outdoor weathering method, with a daylight filter, aligned with SAE J2527/ASTM D2565 was used. This test was adopted from the automotive industry. The method involves spurring on fading using high intensity Xe-Arc lamps combined with water sprayed in controlled conditions inside an ATLAS weatherometer.

The Blue Wool Scale was used to characterize fading. It is a widely used method used to characterize the permanence of colorant dyes. Cards made from eight blue strips of colored textiles, from a very durable dye (BW8) to a very non-enduring/unstable (BW1) dye were exposed along with the samples. If the sample underwent a similar color change, it got the appropriate ranking, from 1 to 8. Delta E is the metric used to quantify the change in color as observed by a human. In this study, we used the simplest version of Delta E—the Euclidian Delta E—which is the distance between the two points in an L*a*b* color space. Additionally, gloss was also measured, at an 85 degree inclination, because for plastics the amount of reflected light increases with a greater angle of illumination. Summarizing:

- All the coatings and materials tested showed excellent durability in outdoor weathering tests and resulted in Blue Wool Scale scores of 7 or 8.
- Only the AMT finish provided any gloss to the sample. Some moderate decreases in glossiness were observed, however, for this finish, as time left to fade increased.

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About the Test

The ability of a plastic material to resist deterioration of its mechanical and optical properties caused by exposure to light, heat and water can be very important for many applications. The purpose of this test is to characterize the outdoor durability of MJF parts, both w/o coating and with third party coatings intended for outdoor durability (under exposure to UV light and sprayed water). All the post-processes tested (unless none) were produced by third parties and the final parts were black. The following table shows the combination of materials and post processes tested. In Annex 2, more information about the post processes can be found.

Post Process/Material	PA12	PA11	PA12GB
Not Post-processed	Tested	Tested	Tested
RIT	Tested	Tested	Tested
Dyemansion	Tested	Tested	Tested
AMT (chemical polishing)	Tested	Tested	Tested

Figure 1: DoE

Basically, RIT and Dyemansion were applied by dipping the parts in them, with the only difference being that for Dyemansion, a machine with an automated process was used and with RIT it was done in a more manual way. For more information about manual dying processes, see the "Manual Dyeing-MJF applications" [1] whitepaper. On the other hand, chemical polishing is a process in which the surface is chemically treated. This process is also used for reducing surface roughness.

An HP outdoor weathering method, with a daylight filter, aligned with SAE J2527/ASTM D2565 was used. This test was adopted from the automotive industry. The method involves inducing fading using high intensity Xe-Arc lamps along with sprayed water in controlled conditions inside an ATLAS weatherometer. Figure 2 shows the cycle's characteristics.

Program	Segment	Event	Time (min)	BPT (°C)	Air T (°C)	RH (%)	Irradiance (W/m^2)	Filters
Outdoor (SAE J2527)	1	Dark+Spray	60	38±3	38±3	95±5	0	**Atlas Weather-Ometer:** Quartz / Borosilicate Type S
	2	Light	40	70±3	47±3	50±5	0.55 @ 340 nm	
	3	Light+Spray	20	70±3	47±3	50±5	0.55 @ 340 nm	
	4	Light	60	70±3	47±3	50±5	0.55 @ 340 nm	

Figure 2: Cycle for weathering test

Above: RH is relative humidity and BPT is the uninsulated black panel's temperature, a parameter which represents the temperature of the samples.

In these type of tests, there is no threshold defined that says whether a part is UV resistant or not. It usually depends on the application's requirements. The exposure time used was 1000 machine hours, with an intermediate measurement at 600 hours. The Blue Wool Scale was used to characterize fading, as it is a widely method used to characterize the permanence of colorant dyes. Cards made from eight blue strips of colored

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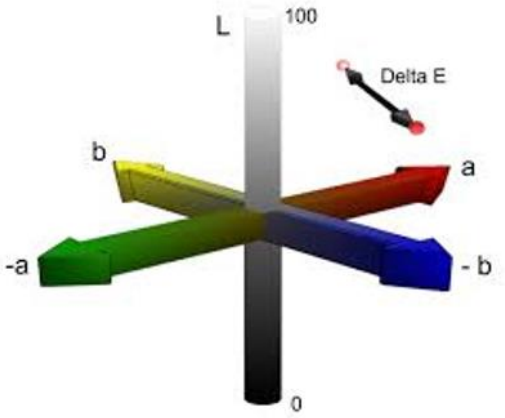
textiles, from a very durable (BW8) dyes to very non-enduring/unstable (BW1) dyes were exposed along with the samples. If the sample underwent a similar color change, it was ranked accordingly (from 1 to 8).

Figure 3: Blue wool scale

To quantify the color change, the CIELAB color space was used. It expresses color as three numerical values—*L** for lightness and *a** and *b** for green–red and blue–yellow color components. CIELAB was designed to be perceptually uniform with human color sight, meaning that the same amount of numerical change in these values correspond to about the same amount one would visually perceive [2]. In this study, the simplest version of Delta E was used, which is the distance between two points in an L*a*b* color space. Color coordinate values (L*, a*, b*) were measured with an X-Rite D65 at 2 degrees, each measurement tripled, as they were taken at three various locations of the sample.



$$\Delta E = \sqrt{(L_2^* - L_1^*)^2 + (a_2^* - a_1^*)^2 + (b_2^* - b_1^*)^2}$$

Figure 4: Delta E

Additionally, gloss was also measured. It is determined by projecting a beam of light at a fixed intensity and angle onto a surface and measuring the amount of reflected light at an equal but opposite angle. For non-metals such as coatings and plastics the amount of reflected light increases with a greater angle of illumination, as some of the light penetrates the surface material and is absorbed into it or diffusely scattered from it depending on its color [3]. For this reason, the gloss was measured at 85º (G85). A BYK Micro Trigloss was used, each measurement tripled (at three various locations of the sample).

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Test Results

The observed Delta E values were small and all of them supported a score between BW7 - BW8. Note that Delta E can be caused by the surface variability of samples themselves rather than fading-induced changes. Thus, the very low Delta E for Dyemansion coatings can be interpreted as a very high color consistency for this post process.

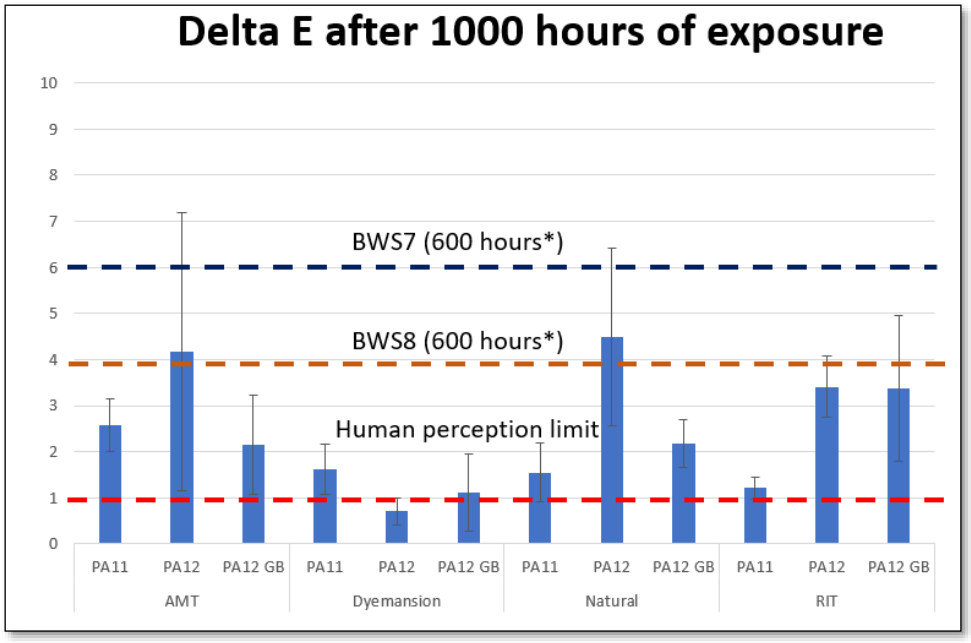

Figure 5: Delta E average results with +- std

The next picture shows the Dyemansion-plate samples (right) and the AMT samples (left) for PA12 after 1000 hours of exposure. In Annex 1 there is a complete set of pictures.

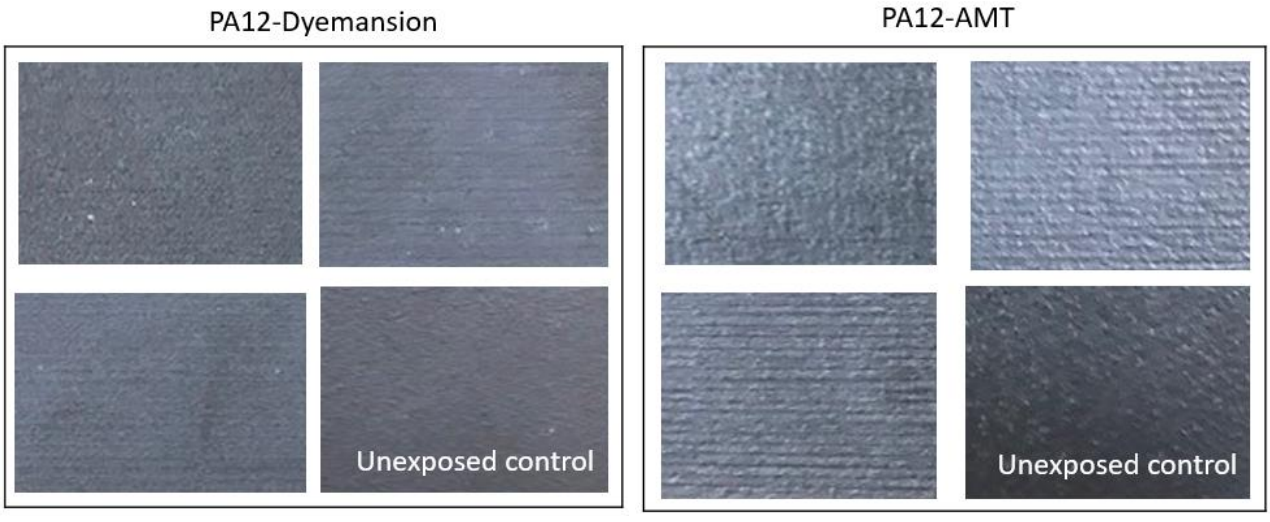

Figure 6: Dyemansion and AMT samples

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Only AMT finishes provided any gloss to the samples. Some moderate decreases in glossiness were observed for this finish as the fading time increased.

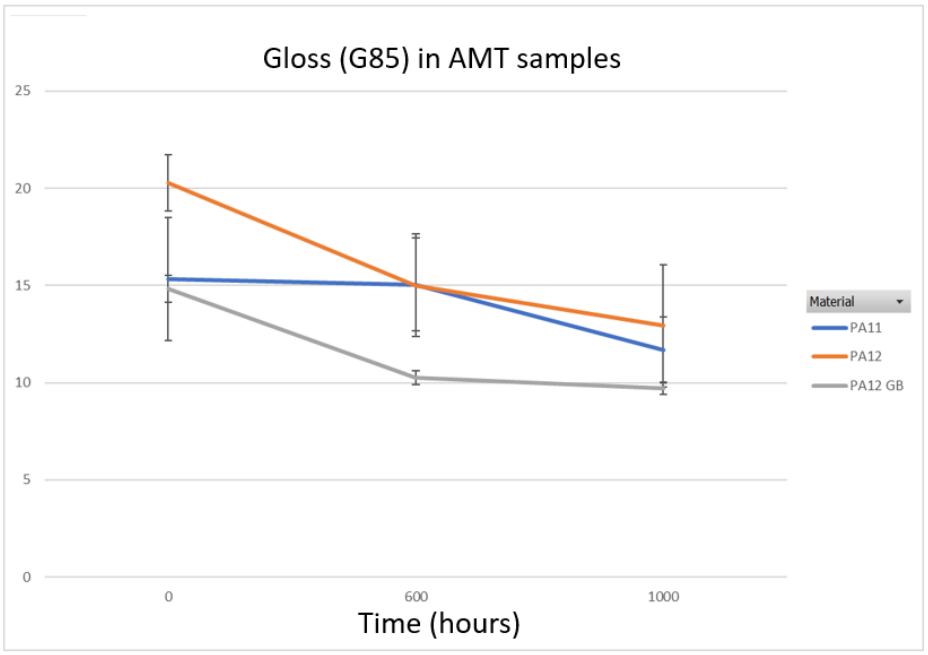

Figure 7: Glossiness average results +- std

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Future Accelerated Weathering Study

The next round of results will include an analysis of the change in mechanical properties of a set of of HP PA12, HP PA11, HP PA12 GB and SLS PA220 tensile materials exposed to different numbers of hours (200,400,600,800,1000) of weathering conditions following the same cycle as the plates. Strength tests will be performed on the samples following the ASTM D638 standards. Their tensile strengths, young moduli, elongations at breakpoints and elongation at yield-points will be measured.

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References

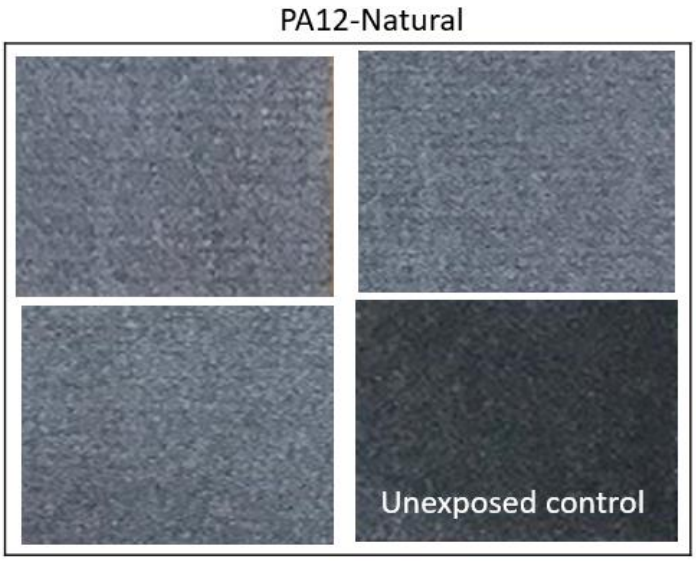
[1] HP ATC team, "Manual Dyeing-MJF applications," 2017. [Online]. Available: https://myknowledge.blob.core.windows.net/documents/Manual%20Dyeing%20-%20MJF%20Applications.pdf?sv=2015-04-05&sr=c&sig=WwDq2xzTAK4%2FGZus6GiUGDPcQfAIsUI5x6isYI%2BQUqE%3D&st=2018-07-17T07%3A51%3A48Z&se=2018-07-17T08%3A21%3A48Z&sp=r.

[2] Hoffmann, Gernot, [Online]. Available: http://docs-hoffmann.de/cielab03022003.pdf. [Accessed May 2018].

[3] BYK, [Online]. Available: https://www.byk.com/fileadmin/byk/support/instruments/theory/appearance/en/Intro_Gloss.pdf. [Accessed May 2018].

ANNEX 1: Pictures

The following pictures show a comparison between the samples that have been exposed and the ones that not.



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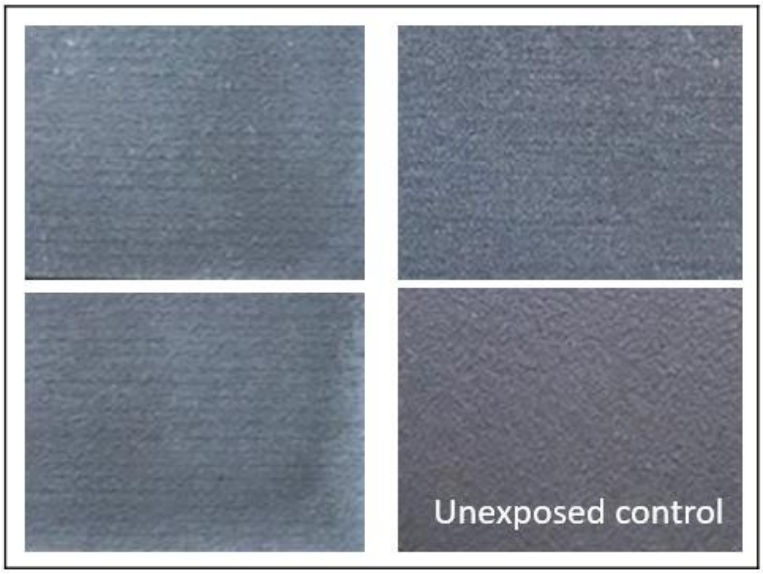
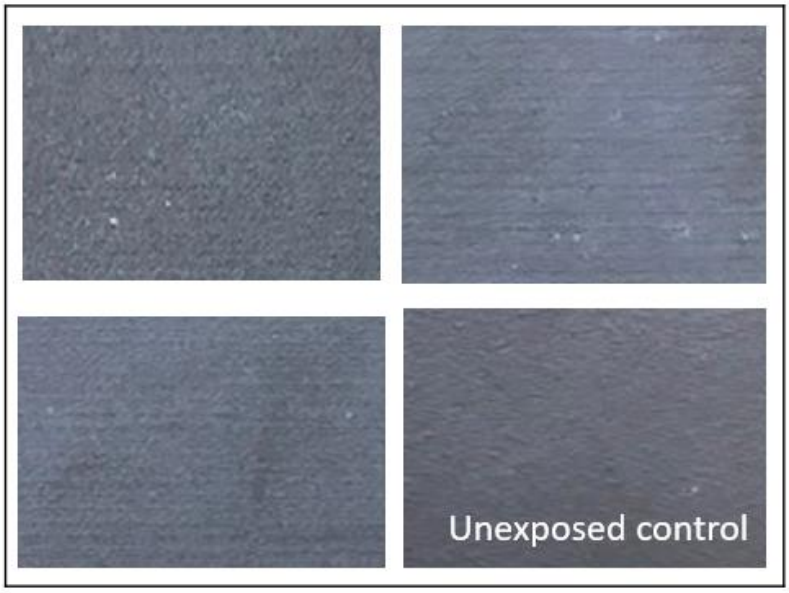
PA12-RIT



PA12-Dyemansion



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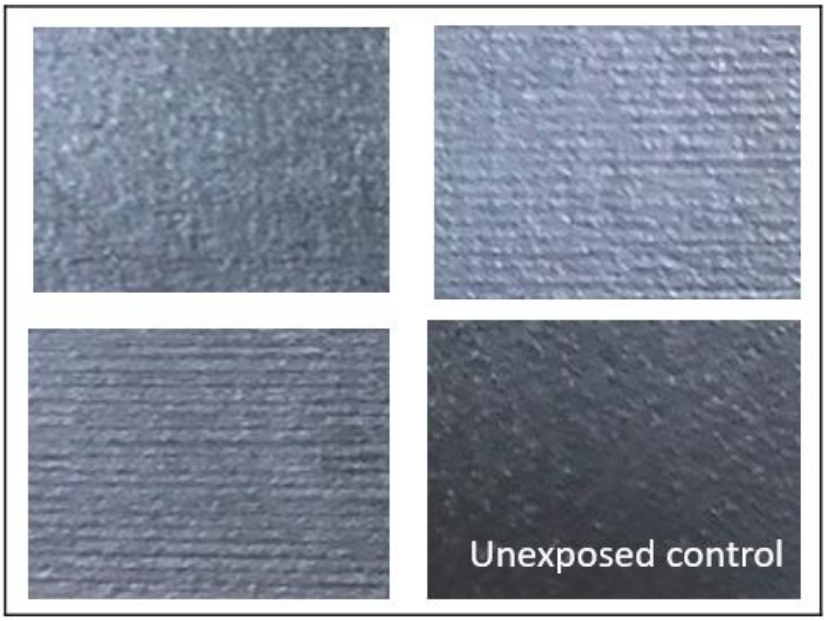
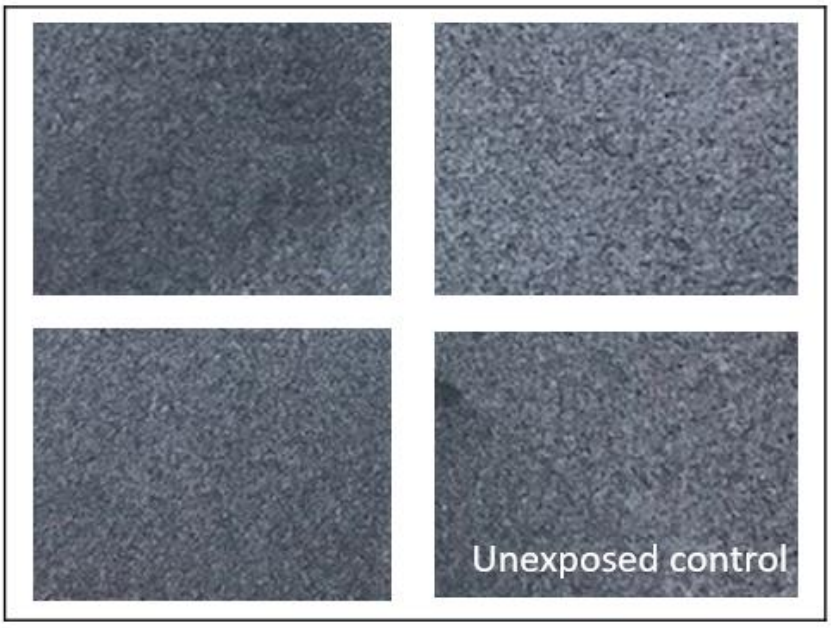
PA12-AMT



PA12 GB-Natural



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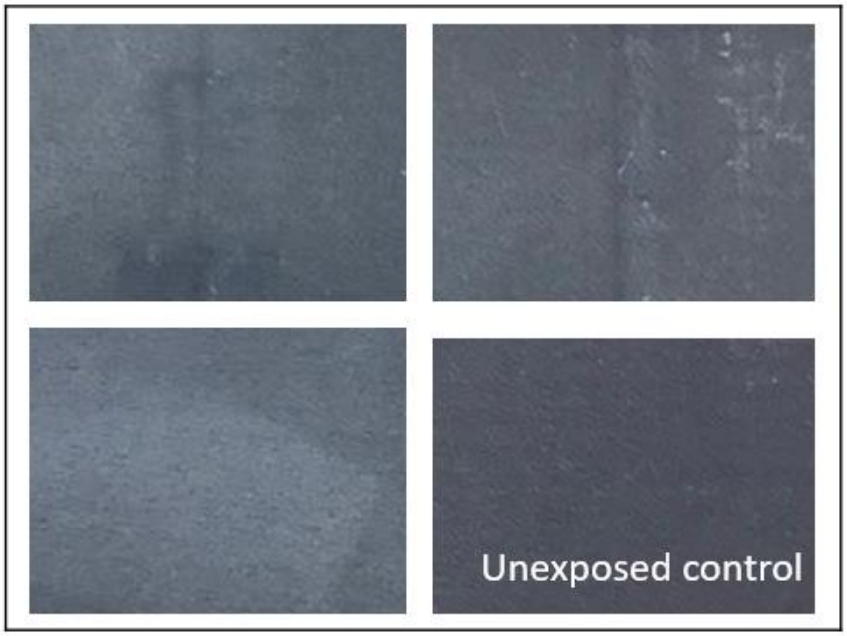
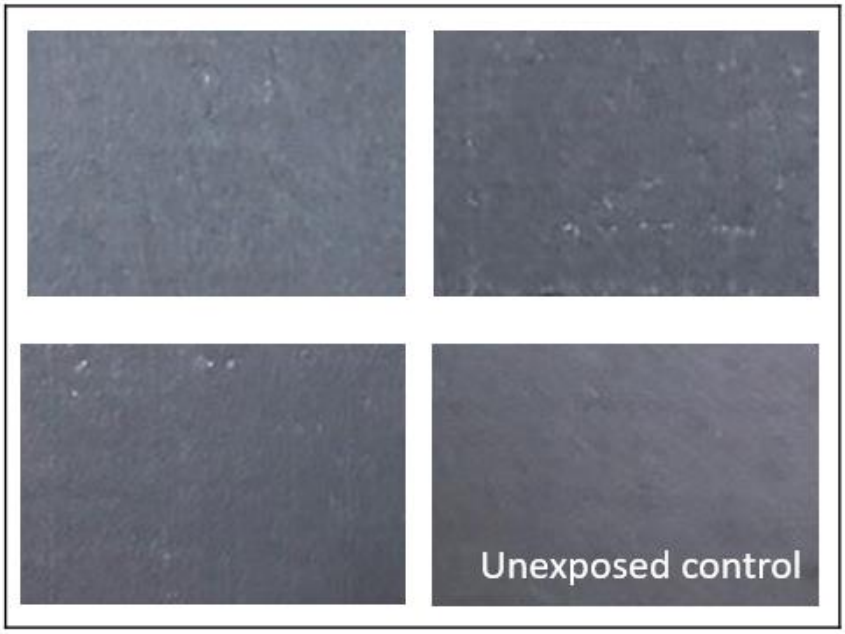
PA12GB-RIT



PA12 GB-Dyemansion



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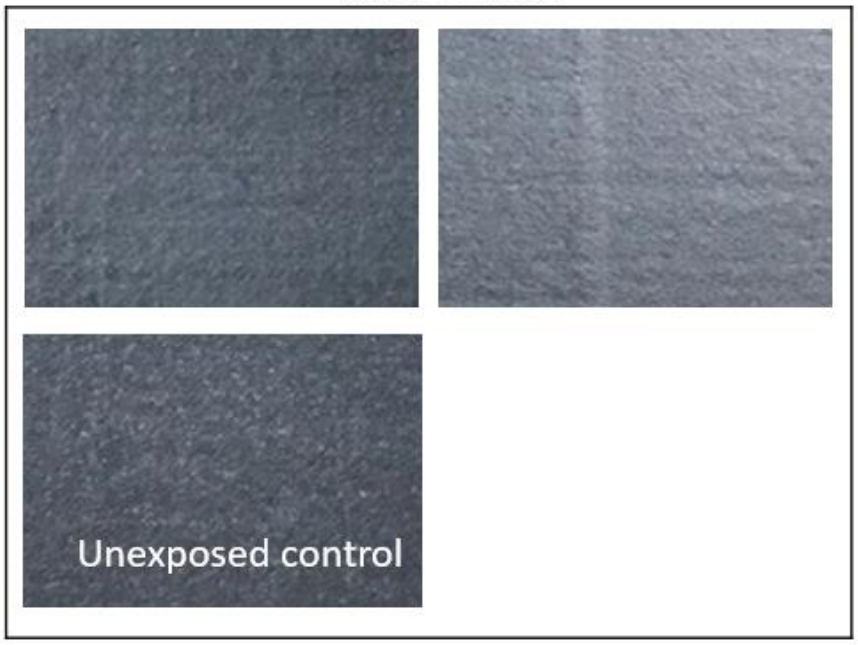
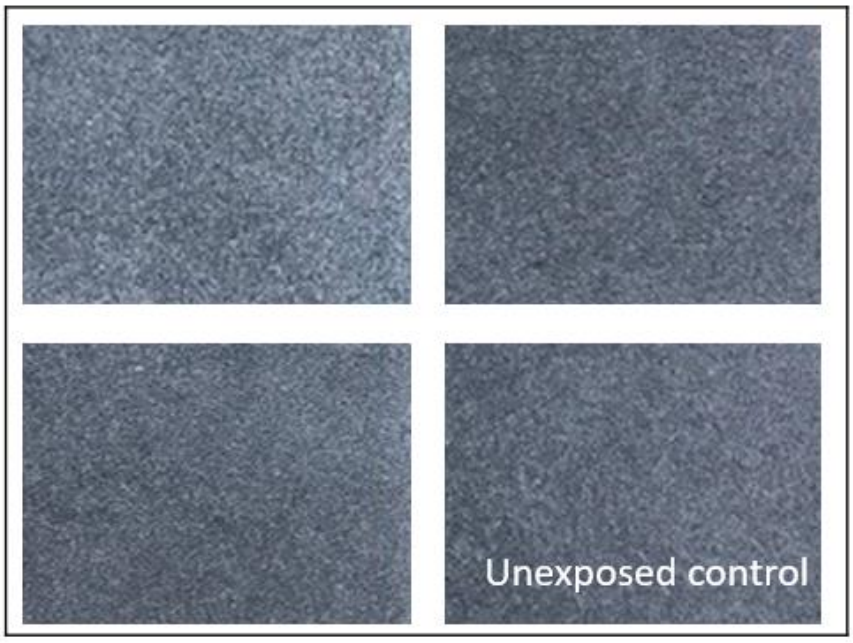
PA12GB-AMT



PA11-Natural



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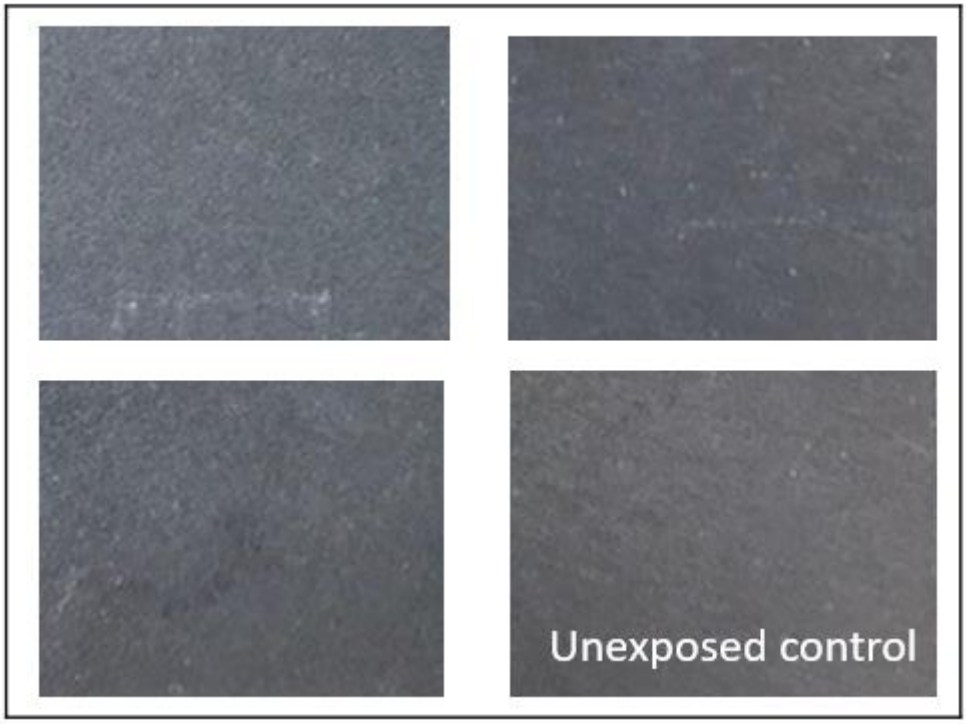
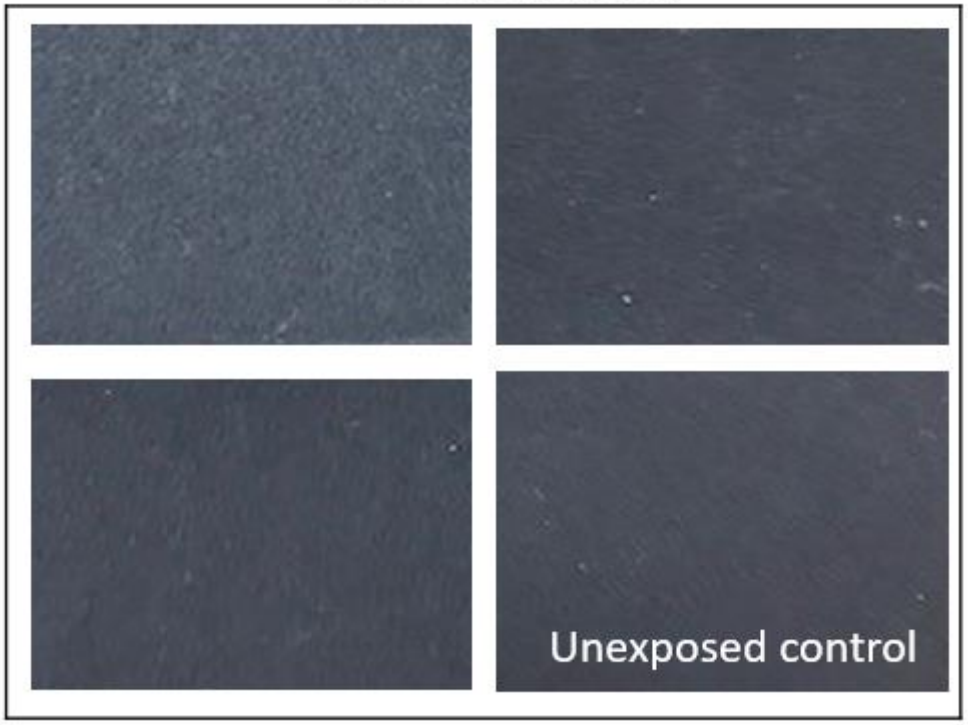
PA11-RIT



PA11-Dyemansion



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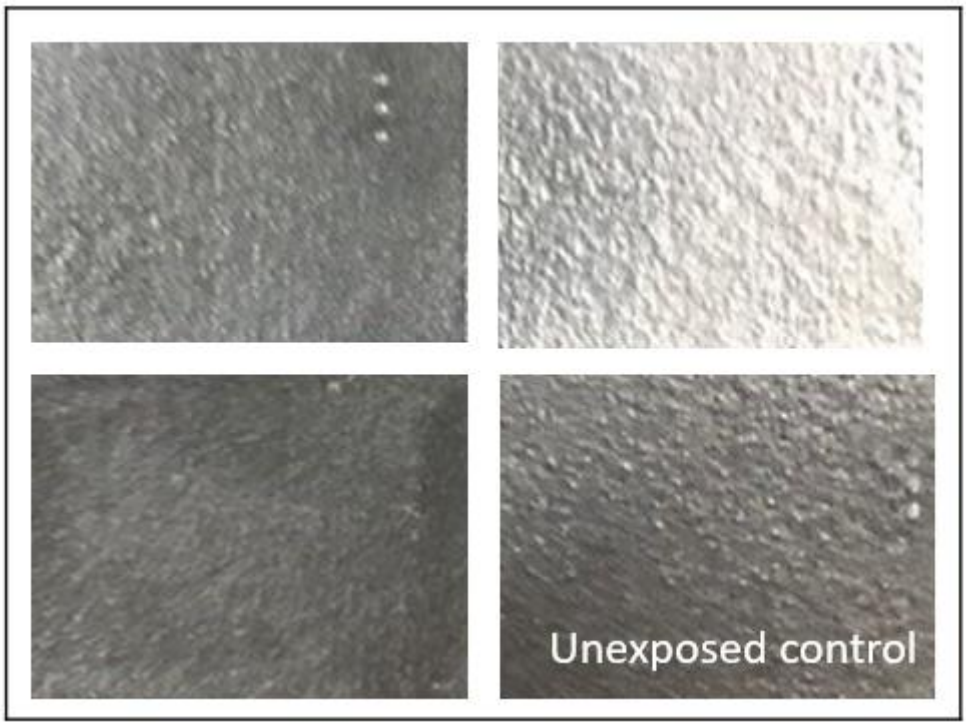
PA11-AMT



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ANNEX 2: Post-Process Links

Dyemansion: https://dyemansion.de/en/

RIT: https://store.ritdye.com/5-pound-dye/black-proline-dye-5-lb/

AMT: https://www.pushprocess.technology/

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