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Publication date:
2017

Document Version
Publisher's PDF, also known as Version of record

Citation (APA):
Regi, F., Li, D., Nielsen, J. B., Zhang, Y., Tosello, G., Madsen, M. H., ... Aanæs, H. (2017). A comparison of reflectance properties on polymer micro-structured functional surface. Poster session presented at 17th euspen International Conference & Exhibition, Hannover, Germany.

A comparison of reflectance properties on polymer micro-structured functional surface

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Abstract

In this study, a functional micro-structure surface [1] has been developed as a combination of arrays of micro ridges. The scope of the surface is to achieve specific directional optical properties: that is, under constrained lighting, maximizing the reflectance from a certain viewing direction, and minimizing it from the corresponding horizontally orthogonal position, i.e. maximize the contrast between two horizontally orthogonal view positions at the same inclination (Figure 1). The sample is composed of 12 different anisotropic surfaces, that are designed as a combination of ridges defined by their pitch distance and their angle in respect to the surface (Figure 2). The geometry was obtained by precision milling of a tool steel bar and replicated through silicone replica technology [2], and by hot embossing using Acrylonitrile Butadiene Styrene (ABS). A digital microscope has been used as a gonioreflectometer to determine the directional surface reflectance of each surface to varying light and camera positions. The presented results show that the replication processes and the polymeric material have a strong impact on the contrast under constrained lightening. More specifically, the reflectance properties are strongly influenced by the geometry of the structure and by the colour.

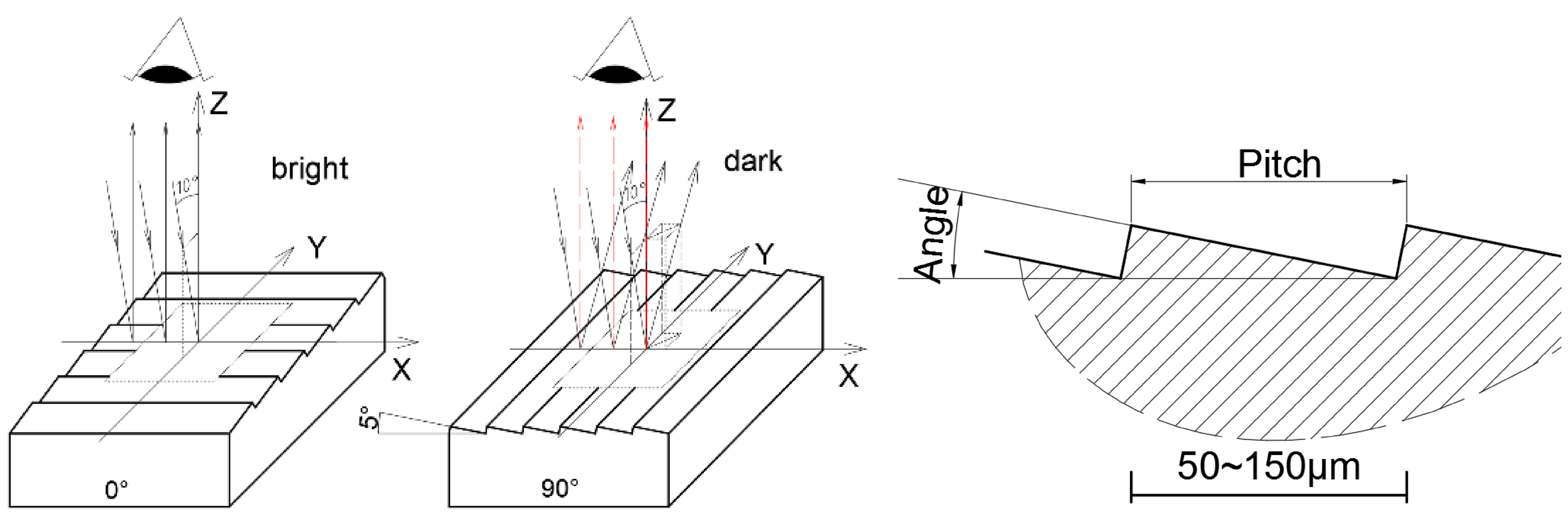

Figure 1. Contrast generation and structure of the surface.

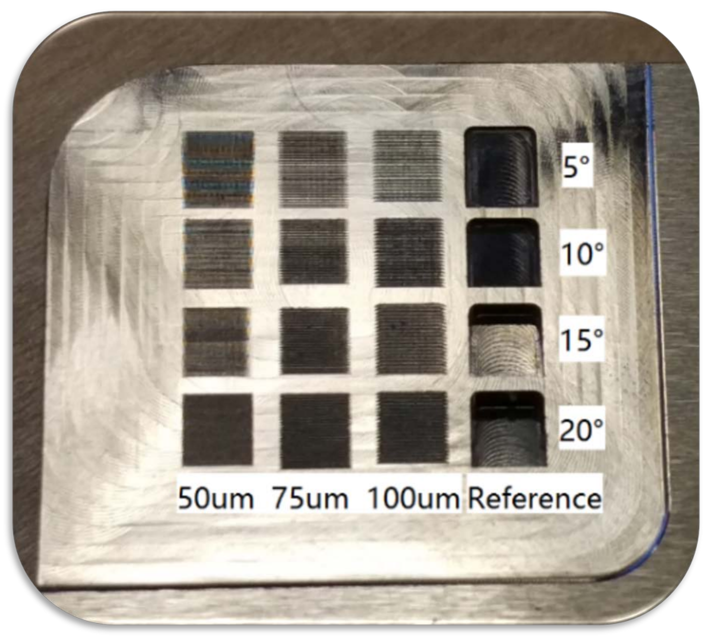

Figure 2. Milled Surfaces.

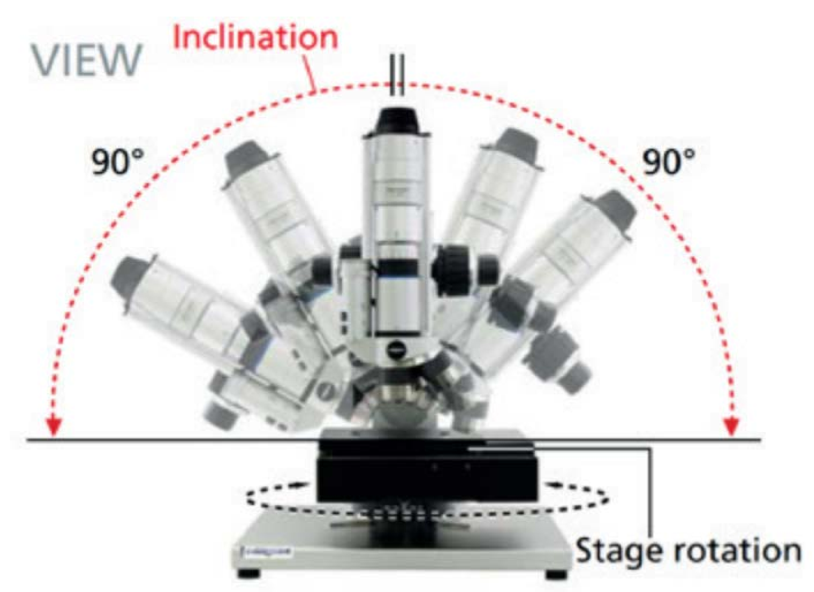

Figure 3. Hirox RH-2000 digital microscope.

Measurement Instrument and Strategy

The radiometric measurements were carried out using a Hirox RH-2000 digital microscope operated as a gonioreflectometer.

The microscope was modified to hold a constant LED based light source at a fixed baseline relative to the optics, ensuring a constant camera-light source angle. Calibrated High Dynamic Range imaging, based on the approach of Debevec and Malik [3], was utilized to convert observations into physical units of radiant exposure.

Data Collection

Several samples in the two different materials and exhibiting diverse colours have been produced (Table 1).

Pitch distance between the ridges was kept constant at 50 µm, while the four ridge angles were varied (Figure 2). θ is the tilting angle of the microscope and it ranges $\pm 20^\circ$, inclination in Figure 2. ϕ refers to the azimuthal rotation of the structure, stage rotation in Figure 3; radiant exposure has been measured at phi = {0, 90,180}.

The main output, radiant exposure $\left[\frac{kJ}{m^2}\right]$, is measured up to an unknown scale k, and under constant lightning conditions, i.e. intensity and distance to surface, it is proportional to the reflectance of the surface.

The contrast is evaluated as the difference between the radiant exposure obtained for the sample at positions 0˚ and 90˚, and between 90˚ and 180˚ of the ϕ parameter, keeping constant the other parameters.

Sample	Material	Colour	Sa [nm]	Sq [nm]
S5	ABS	Dark Green	171	223
S6	ABS	Blue	135	188
S9	Silicone	Light Green	118	161
S11	Silicone	Brown	102	147

Table 1. Summary of the colours and materials of the samples.

Results and analysis

The analysis of the collected data was focused on the determination of:

- Preferable ridge angle that maximizes the contrast between perpendicular structures;
- Colour and material that maximize the contrast;
- Colour and material that give the highest reflectance.

The vertical direction of the microscope (θ = 0) produces the highest average reflectance, while the tilting strongly reduces it (Figure 4). For what concerns the ridges choice, smaller ridge angles are preferred: the 10-degree ridge gives the best solution also in terms of contrast (Figure 5). Finally, blue and light green have the highest absolute reflectance (Figure 4), but perform poorly in terms of contrast (Figure 5), and although the difference is small, ABS guarantees a better contrast. The directionality of the geometry makes the contrast 0° - 90° stronger than the 90° - 180°.

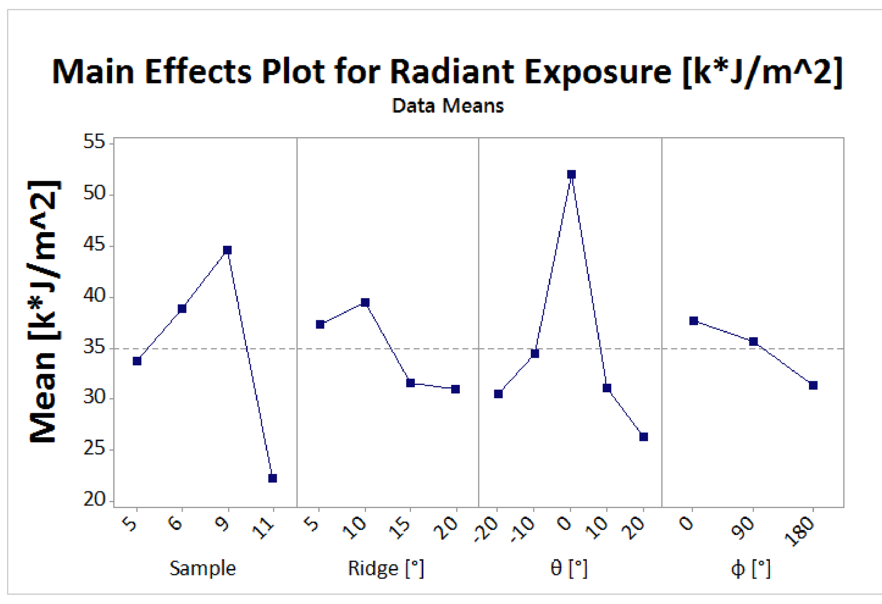

Figure 4. Absolute Reflectance results.

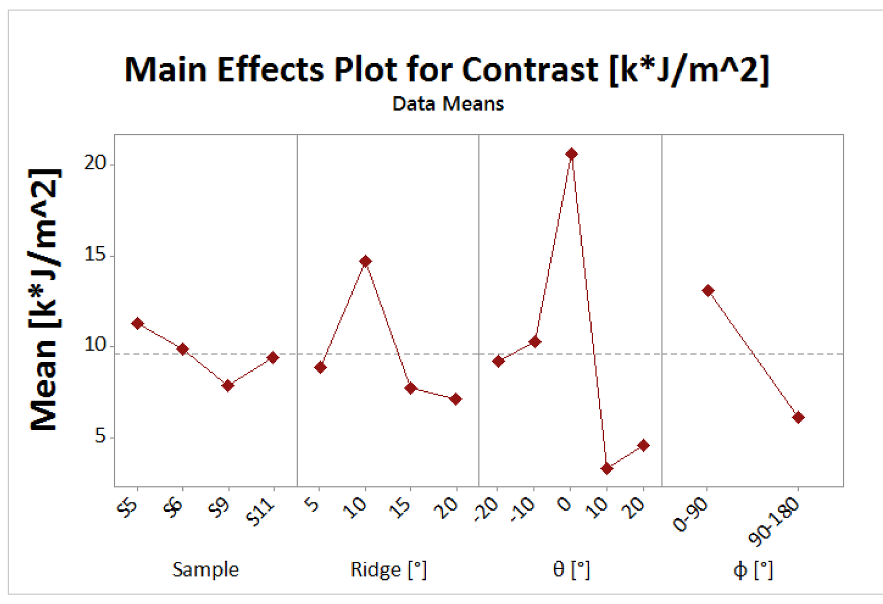

Figure 5. Contrast results.

Conclusions

An evaluation of the reflectance performance of an anisotropic surface for different colours and materials has been conducted. The structure with a 10-degree ridge angle has given an orthogonal contrast 50% higher with respect to the other angles. Furthermore, darker colours minimize the absolute reflectance and maximize the contrast.

Acknowledgements

This paper reports work undertaken in the context of project 5163-00001B funded by Innovation Fund Denmark

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