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The Influence of Pearlescent Pigments Printed on Plastic Packaging on the Print Gloss

Mirica Karlovits, Blaž Likozar, Uroš Novak
National Institute of Chemistry, Ljubljana, Slovenia
mirica.karlovits@ki.si, blaz.likozar@ki.si, uros.novak@ki.si

This study investigates the influence of pearlescent pigments printed on polypropylene (PP) packaging on print gloss, focusing on different viewing angles and background colors. Pearlescent pigments, known for their special luster and interference properties, are increasingly used in the packaging industry to increase visual appeal and differentiate products on the shelf. Five different pearlescent pigments (gold, polar white, green, blue and lilac) with the same particle size were used in the study. All pigments consist of thin platelets of the natural material mica, which are coated with a wafer-thin layer of metal oxide. The pigments were overprinted on black background color on printing material (Yupo) using the offset printing process. The print gloss was measured at three different angles (20°, 60°, 85°) using a multi-angle glossmeter, and the pigments were also examined using a scanning electron microscope (SEM). The results show that the background color significantly affects the final appearance of pearlescent pigments, with gloss being higher when printed on a black background than on a white background.

Keywords:
pearlescent pigment,
print gloss,
optical effect,
luster,
packaging

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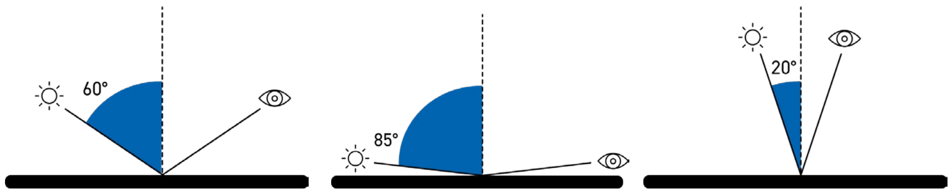
1 Introduction

The special effect pigments are used in various areas, e.g. in security applications to protect against counterfeiting and in aesthetic applications such as printing, coating, painting, cosmetic formulations, etc. (Chen, 2019). They are divided into two primary categories: metal effect pigments and pearlescent pigments, also known as nacreous or interference pigments (Buxbaum, 2005). The pearlescent pigments, which are either natural or synthetic, are distinguished by their iridescent color effect, brilliance, and shine, which are based on optically thin layers. Pearlescent pigments simulate the lustre of natural pearls and give the materials additional colour effects, such as the angular dependence of the colour. The light is reflected and scattered across tiny layers to create this optical appearance (Pfaff, 2008). All of these pigments consist of small, thin platelets which, when aligned in parallel in application systems (e.g. in coatings, plastics, printing inks, cosmetic formulations), exhibit strong lustrous effects (Klein, 2010). Most pearlescent pigments consist of at least three layers of two different materials with different refractive indices. The pearlescent effect is created by the specular reflection of light on the many surfaces of the platelets at different depths of the coating film. Light that hits the platelet is partly reflected and partly transmitted through the platelet; the pearlescent effect is created by the dependence of the reflection on the viewing angle. Alumina-based pigments have a strong pearlescent effect compared to mica-based pigments because they are easy to produce, have a very narrow thickness distribution and very smooth surfaces. Alumina-based pigments have the well-known advantages of mica pigments and, thanks to their controlled thickness and chemical purity, offer the possibility of achieving unique optical effects (Rossi, 2020).

Gloss is one of the basic elements of our visual appearance, both in terms of colour and texture. The geometry-dependent characteristics of a surface are described by the gloss perception.

The visual appearance attribute known as specular gloss describes the perceived luminance created by specular reflection on the surface. A typical example of a surface with a high gloss level is a mirror (Kehren, 2013).

Four optical processes can take place when light strikes a pigmented ink layer. These include light scattering and absorption within the ink film as well as light reflection and refraction at the film's surface. All four processes occur to a greater or lesser extent. If the surface of the ink film is smooth and mirror-like, the incident light is reflected in a specular manner, which obeys the small laws of reflection. The film then appears glossy. If the surface is rough, the light is reflected diffusely in all directions and the gloss decreases (Thompson, 2004).



Universal Measurement: Angle 60°	**Low Gloss: Angle 85°**	**High Gloss: Angle 20°**
All gloss levels can be measured using the standard measurement angle of 60°. This is used as the reference angle with the complimentary angles of 85° and 20° often used for low and high gloss levels respectively.	For improved resolution of low gloss a grazing angle of 85° is used to measure the surface. This angle is recommended for surfaces which measure less than 10 GU when measured at 60°. This angle also has a larger measurement spot which will average out differences in the gloss of textured or slightly uneven surfaces.	The acute measurement angle of 20° gives improved resolution for high gloss surfaces. Surfaces that measure 70 GU and above at the standard angle of 60° are often measured with this geometry. The 20° angle is more sensitive to haze effects that affect the appearance of a surface.

Figure 1: Gloss measurements
(Rhopoint Instruments, 2024).

2 Methods and Materials

Five different commercially available pearlescent pigments from Merck (gold, polar white, green, blue and lilac) with the same particle size were used in the study. The pigments were overprinted on black background color on printing material (Yupo) using the offset printing process. The print gloss was measured at three different angles (20°, 60°, 85°) using the QIP GlossMaster multi-angle gloss meter. The measurements comply with the ASTM D523 standard measurement protocol for specular gloss measurements. Gloss is measured in gloss units (GU).

Table 1: Properties of printing material (Yupo).

Properties	Grammage	Thickness	Specific volume	ISO Whitness
Values	160 g/m^2	200 µm	1.3 cm^3/g	95 %

In this study we used a scanning electron microscope (JSM–5610JOEL) to evaluate the pigment particles and the surface of the printing material. The synthetic paper Yupo was used as the printing material. It consists mainly of polypropylene film, to which inorganic fillers and small amounts of additives (CaCO3) are added, and is also used for packaging (Yupo, 2024).

Table 2: Properties of pearlescent pigments.

Pigment name / Properties	Iriodin 325 Solar Gold Satin	Iriodin 119 Polar White	Iriodin 231 Rutile Fine Green	Iriodin 221 Rutile Fine Blue	Iriodin 223 Rutile Fine Lilac
Pigment color	gold	silver	green	blue	lilac
Foam	powder	powder	powder	powder	powder
Substrate	natural mica	natural mica	natural mica	natural mica	natural mica
Effects & properties	masstone, improved chroma, silky	interference, silky	interference, reference chroma, silky	interference, reference chroma, silky	interference, reference chroma, silky
TiO_2 modification	rutile	rutile	rutile	rutile	rutile
Particle size	5-25 ηm	5-25 ηm	5-25 ηm	5-25 ηm	5-25 ηm

With increasing TiO_2 layer thickness on the mica, an interference color develops, varying from silver to green (Figure 2).

Figure 2: Interference colors
(Pfaff, 2008).

3 Results and Discussion

The SEM analysis was carried out in the first part of the study. All five pigments are based on natural mica, have the same particle size and, as can be seen in the figures, they all have a "cornflake" shape. In Figure 5 (right) we see the unprinted surface of the printing material (Yupo). The surface is very smooth.

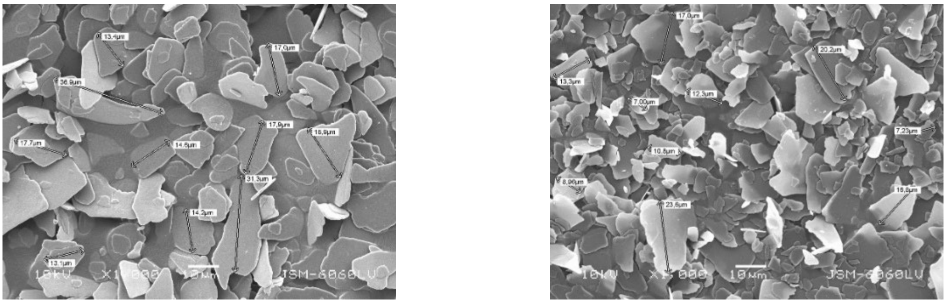


Figure 3: SEM micrograph*: gold pigments (left), silver pigments (right).*

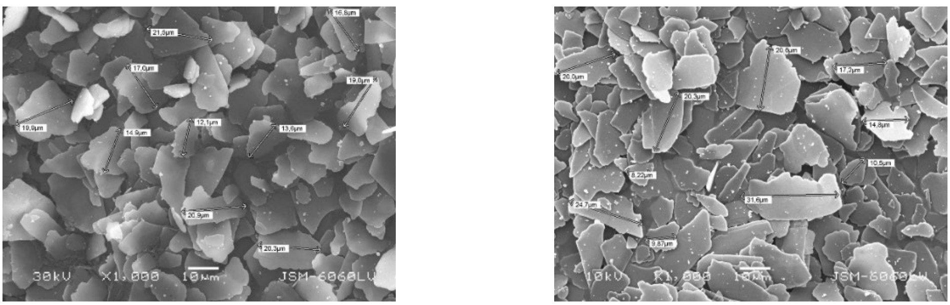


Figure 4: SEM micrograph: *green pigments (left), blue pigments (right).*

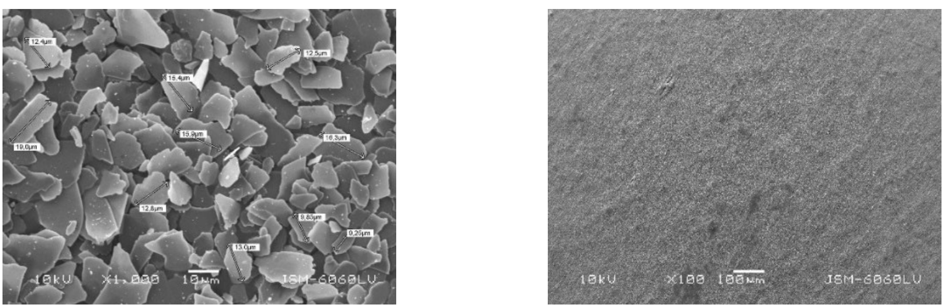


Figure 5: SEM micrograph of *lilac pigments (left) and printing material (right).*

The percepcion of the gloss is usually correlated to the way objects reflect light from their surfaces and is usually perceived indenpedently from the color appearance; but the underlying color of the object can influence the perception of the gloss and vice versa. Most often the gloss appearance is excluded from the total visual stimulus as it is separated from the color appearance. To determin precisselly the gloss values it is important to quantify them by an appropriate measurement device. The classical glossmeters are measuring the intensity of the specular reflection of the sample (I_{sample}) relative to some smooth reference standard ($I_{reference}$) for the appropriate measurement angle. The average value of the specular gloss G can be defined by the following equation:

$$\mathbf{G_S = 100 \times I_{sample} / I_{reference}}$$

The total appearance of any object is the combination of its chromatic attributes (color defined through hue, saturation, lightness) and it's geometrical attributes (gloss, translucency, texture, shape) inside an surrounding where is the object observed (Karlović, 2010).

Table 3 shows the print gloss of printed pigments on a white and black background.

As we can see from Table 3, all pigments printed on white background obtained lower print gloss compared to black background. The blue pigments printed on both background colors achieved the highest print gloss, where the gloss range from 55.33 for the white background to 66.33 for the black background. The standard deviation on white background was σ=0.21, while on black background was σ=1.10. On the other hand, the silver pigments printed on both background colors achieved the smallest print gloss, where the gloss range from 31.30 for the white background to 39.80 for the black background.

The incident light on the printed surface undergoes through several processes of scattering, absorbtion and reflection depending on the surface topography and structure of the material. The specular part of the surface reflection is commonly attributed as the geometric component of the reflection, and when measured is associated with specular gloss (Karlović, 2010).

Table 3: Print gloss of printed pigments on white and black background.

Gold pigments		
	White background	Black background
Print gloss	38.60	45.17
Std. Dev.	0.45	0.47
Silver pigments		
	White background	Black background
Print gloss	31.30	39.80
Std. Dev.	0.29	1.51
Green pigments		
	White background	Black background
Print gloss	50.40	66.20
Std. Dev.	0.57	0.29
Blue pigments		
	White background	Black background
Print gloss	55.33	66.33
Std. Dev.	0.21	1.10
Lilac pigments		
	White background	Black background
Print gloss	46.00	59.60
Std. Dev.	0.36	0.42

In Figure 6 the influence of background color is presented.

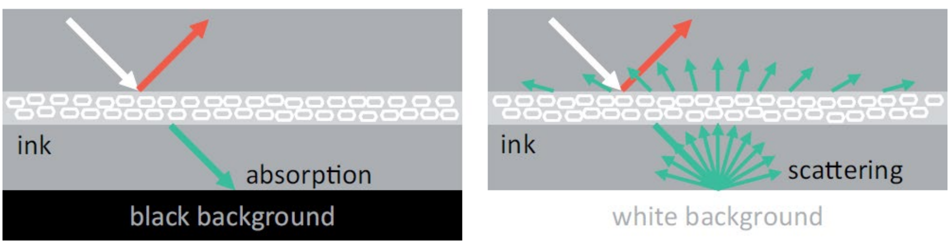


Figure 6: Influence of background color: ***black background (left), white background (white).***

In the colored layer, the effect of thin-film interference amplifies and attenuates the incident light, which is symbolized by a white arrow at certain wavelengths. In the specular direction, the reflected light has a specific interference color, which is symbolized by a red arrow. The transmitted light is colored in the complementary color, which is symbolized by a green arrow. The complementary colored light that passes through the color layer hits the background. In the case of a black background, as shown on the left in Figure 6, most of the transmitted light is absorbed. This means that the complementary color (green arrow) no longer has any influence on the resulting color impression. The perceived color corresponds to the interference effect color of the reflected light (red arrow). In contrast, a white background scatters the transmitted light, as shown in Figure 6 on the right. The intense interference effect color (red arrow) in the direction of reflection is overlaid by a pale complementary color (green arrows) in the entire half-space above the sample.

In the case of gloss and texture, the manipulation concerns the appearance of contrast. The gloss of any light surface is a locally bright reflection of light. The perceived gloss correlates with the difference in lightness of the bright reflection relative to the surroundings. The texture of a surface is based on a pattern of differently colored areas. The difference in color of the brightly shining pigments on the background of some kind determines the perceived texture. For example, gloss and texture are perceived more strongly on the black printed background (Kehren, 2013).

4 Conclusions

The study of printed pearlescent pigments and their effects on visual appearance, such as print gloss, emphasises the crucial role of surface texture in enhancing aesthetic appeal. Gloss, a measure of surface reflectivity, significantly influences how pearlescent pigments interact with light, affecting their perceived vibrancy, depth and shimmer. The print gloss measurements showed that all five pigments had a lower print gloss on a white background than on a black background. When comparing the print gloss of the individual pigments, we found that the highest print gloss was achieved with the blue pigment and the lowest gloss with the silver pigment. Finally, the relationship between printing material and pearlescent pigments influences the significance of the final appearance of the printed packaging. A strong visual appeal is particularly important for high-quality or luxury packaging.

Acknowledgments

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