https://doi.org/10.2352/CIC.2025.33.1.43

How color influences gloss and gloss influences sparkle and graininess in metallic coatings

Eric Kirchner; College of Optical Science and Engineering, Zhejiang University; Hangzhou, China

Abstract

Three main aspects of the appearance of metallic coatings are color, gloss and texture (including graininess and sparkle). All three aspects can now be objectively measured using instruments according to ASTM and other international standards. However, there is no reason why these three aspects would be independent from each other. Indeed, it is known for more than a century that variations in color influence the perception of gloss. Here, we present the first systematic investigation on the influence of gloss variations on the occurrence of sparkle and graininess.

We created a new, dedicated set of 462 solid and metallic paint samples, with systematic variations in color and gloss. We measured the multi-angle reflectance properties for all samples. Our results confirm that color strongly influences measured gloss values, especially for metallic coatings. We also show that there is a substantial influence from glossiness to the measured graininess and sparkle properties. For example, by applying a matte clearcoat instead of a more common high-gloss clearcoat on top of a metallic basecoat, the measured graininess reduces by 0.6±0.3 units and the sparkle grade at 15° by 3.3±1.7 units. This is in line with visual assessments on matte car paints: matte metallic paints hardly show sparkle. A physical explanation for these trends is presented.

Introduction

For the visual appearance of materials, several attributes have been identified in earlier work [1]. The most important attributes are color, gloss, texture and translucency. For industrial quality control of products, it is important to be able to objectively measure each of these attributes. For color, gloss (and haze) commercial instruments are being used already for decades. For the visual texture of metallic and pearlescent paints, the first commercial instrument was launched in 2007 by BYK-Gardner, based on the pioneering work of McCamy [2][3] and Kirchner et al. [4][5]. For effect coatings such as metallic paints, it was shown that the most important aspect of visual texture is diffuse coarseness when viewed under diffuse lighting and glint impression when viewed under intense directional light [2]. Clear definitions of these properties are given in Ref.[2], and the roughly similar properties Graininess and Sparkle Grade have been used as well [6]. After the introduction of the BYK-mac i, two more instruments capable of texture measurements have been introduced by competitors, the X-Rite MA-T12 by X-Rite in 2018 and the Aesthetix by Rhopoint in 2024. While the BYK-mac I and MA-T12 use proprietary methods to determine texture values from the images they capture, the Aesthetix instrument uses methods that will be published in recommendations from the CIE [7][8].

These instruments are now routinely used in industries such as automotive and cosmetics, for example for objective Quality Control of products and for finding best matching formulations in databases filled with measurement data. For these applications it is common to assume not only that the measurement values correlate well with visually assessed values for each of the attributes, but also that the various attributes can be measured independently from each other.

But the measured value and observed assessment value of one attribute may influence the measured value and observed assessment value of another. For example, it is already known for at least a century that the visual observation of gloss levels varies with color. It was Hunter who described one aspect of gloss perception which he called contrast gloss, as being “the perceived relative brightness of specularly and diffusely reflected areas”, which on dark surfaces would be much stronger than on light surfaces.

In this investigation we quantify the influence of color on gloss for metallic coatings. We also investigate if the degree of glossiness of a metallic paint influences its degree of texture: graininess and sparkle grade. To the best of our knowledge this is the first systematic investigation to this topic.

Experimental

For this investigation we prepared the following set of paint samples. We selected a total of 22 different colors: 8 non-effect colors, 9 metallic paints, 3 pearlescent paints and 2 combination paints containing both metallic and pearlescent pigments. Each of these 22 colors was applied as a basepaint (paint brand Autobase Plus) on seven different stainless steel panels. For each of the seven panels, we applied a different clearcoat (paint brand Autoclear Mix & Matt) on top of the basecoat. These seven clearcoats were selected by mixing different ratios of High Gloss clearcoat (HG), Semi-Gloss clearcoat (SG) and Low Gloss clearcoat (LG), according to Table 1.

Table 1: Clearcoat mixtures with different glossiness, as used in this investigation.

Gloss class	Clear coat	Gloss 60° (GU, on solid black)
1	LG: 100	10
2	LG: 80 SG: 20	17
3	LG: 60 SG: 40	25
4	LG: 40 SG: 60	34
5	LG: 20 SG: 80	64
6	LG: 0 SG: 100	82
7	HG	91

Table 1 also illustrates how we used the gloss measurement values on these 7 clearcoats as applied on solid black substrate to define seven gloss classes.

In this way we created a series of paints with seven different degrees of glossiness for each of the 22 different basecoat colors. Each series was applied three times, on separate panels, giving a total of 22x7x3=462 paint panels.

The 22 different basecoat colors are listed in Table 2. As a confirmation that with these clearcoats we cover a wide range of glossiness values, Table 1 shows that when applied on seven panels with the same black non-effect paint, the value for glossiness measured at 60° varies from 10 to 91 Gloss Units (GU).

Table 2: Colors selected in this investigation.

Color category	Solid	Metallic	Pearl	Metallic and Pearl
White	X			
Light grey	X	X		
Beige		X		
Mid Grey	X			
Black	X	X	X	
Red	X	X	X	
Orange		X		
Yellow	X			
Green	X	X	X	
Blue	X	X		X
Purple		X		
Brown		X		X

For all panels we measured the Gloss parameters at three different angles (20°, 60° and 85°) using a TriGloss meter (supplier: BYK-Gardner). The measurement was repeated on three different spots on the panel, then averaged over the three spots and also for each of the three identical panels. Reflectance and CIE-Lab color coordinates were measured at 6 different measurement geometries (-15°, 15°, 25°, 45°, 75° and 110° aspecular angles) using the BYK-mac i instrument (supplier: BYK-Gardner). The same instrument was also used to measure texture parameters (Graininess, as well as Sparkle Grade at 15°, 45°, 75° aspecular angle).

Figure 1 shows the example of the red color center for solid paints. Viewed inside a commercial light booth (X-Rite Spectralight QC) which creates a light distribution somewhere intermediate between diffuse and directional, the seven solid paint samples show the same color, whereas glossiness clearly increases from left to right in the photograph. Figure 2 shows the corresponding photograph for the same red color center for metallic paints.

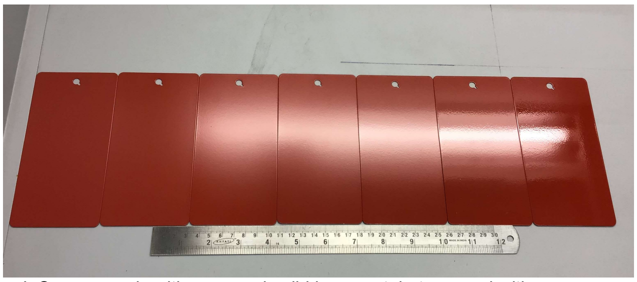

Figure 1. *Seven panels with same red solid basecoat, but covered with different clearcoats varying from matte (left) to high-gloss (right). From left to right, these same clearcoats are referred to as gloss class 1 to 7 in Table 1.*

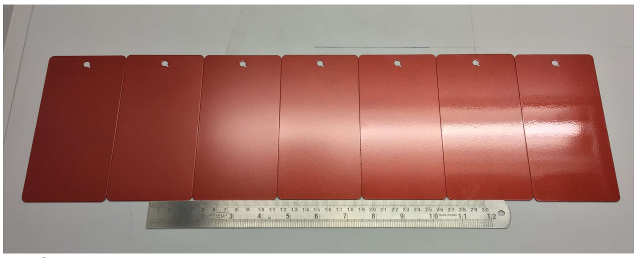

Figure 2. *Seven panels with same red metallic basecoat, but covered with different clearcoats varying from matte (left) to high-gloss (right). From left to right, these same clearcoats are referred to as gloss class 1 to 7 in Table 1.*

Results

Gloss variation for solid colors

After applying the same clearcoat on differently colored basecoats, gloss measurements show that for solid colors the average value of measured gloss values strongly depends on the clearcoat, just as expected. This is clearly shown in Figure 3. In this Figure, the error bar refers to the standard deviation found because of using differently colored basecoats. In general, we find that on light basecoat colors the measured glossiness value is slightly higher than the average, whereas on dark basecoats it is slightly lower. Table 3 shows that for the white color center this difference for Gloss at 60° is +1.3 GU, whereas for the black color center it is -1.0 GU. Because of this large difference for differently colored paints, it is not useful to discuss the average deviation.

Note that for perceived glossiness, due to contrast perception one expects the opposite trend, i.e. to find perceived glossiness values on light basecoat colors that are slightly smaller than the average, and on dark basecoats to be slightly larger.

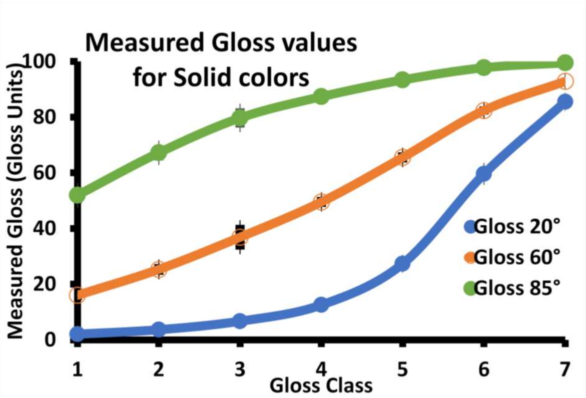

Figure 3. *Gloss measurement data for solid colors for each of the seven gloss classes defined in Table 1.*

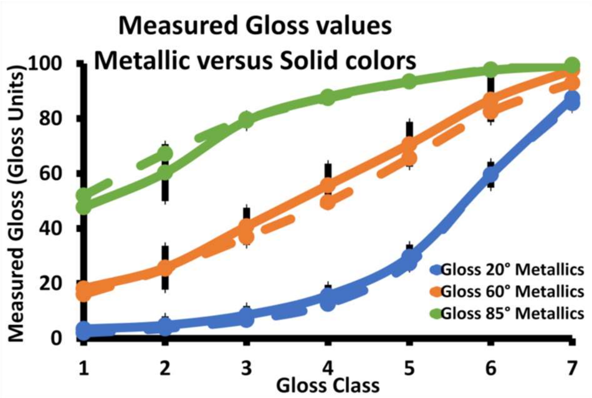

Figure 4. *Gloss measurement data for metallic colors (solid lines) vs solid colors (dashed lines) for each of the seven gloss classes defined in Table 1.*

Table 3: For solid colors, difference between gloss measurements for each color center, as compared to overall average. These values are averages over 3 spots per panel, 3 panels per color center, and 7 gloss classes per color center.

Color category	Gloss 20° (GU)	Gloss 60° (GU)	Gloss 85° (GU)
White	1.0	1.3	0.4
Light grey	0.6	1.2	1.4
Mid Grey	0.2	-1.2	-1.5
Black	0.6	-1.0	-0.7
Red	-0.4	0.7	1.3
Yellow	-0.5	0.1	-0.8
Green	-0.1	0.3	0.2
Dark Blue	-1.4	-1.4	-0.3

Gloss variation for metallic colors

We repeated the previous analysis for metallic rather than solid colors. The results are shown in Figure 4. It is clear that the measured gloss values are very similar to the values found for solid colors (Figure 3). The main difference is that for metallic samples the variation in measured glossiness is much larger than for solid paint samples.

Similar to what we found for solid colors, also for metallic paints the deviation in measured glossiness from the average value shown in Figure 4 strongly depends on the color center. This is quantified in Table 4. Also for metallic coatings on light basecoat colors the measured glossiness value is higher than the average, whereas on dark basecoats it is lower. The deviations are larger than for solid colors. For example, Table 4 shows that for the light grey color center this difference for Gloss at 60° is +18.6 GU, whereas for the black color center it is -4.2 GU. The deviations are probably larger for metallic coatings than for solid coatings because due to the presence of aluminum flakes the reflectance values of the metallic paints obtain larger values for bright paint colors and smaller values for black paint colors.

Table 4: For metallic colors, difference between gloss measurements for each color center, as compared to overall average. These values are averages over 3 spots per panel, 3 panels per color center, and 7 gloss classes per color center.

Color category	Gloss 20° (GU)	Gloss 60° (GU)	Gloss 85° (GU)
Light grey	9.0	18.6	1.7
Beige	2.7	4.9	1.9
Black	-2.0	-4.2	2.1
Red	-0.9	-2.7	-2.2
Orange	-2.8	-4.1	0.2
Green	-0.9	-1.4	0.7
Dark Blue	-2.7	-5.1	-0.1
Purple	-2.0	-5.1	-6.6
Brown	-0.4	-0.9	2.2

Influence of gloss level on sparkle and graininess

In most industries where effect coatings such as metallic paints are used, high-gloss clearcoats are used. In order to investigate how glossiness influences texture parameters sparkle and graininess we will use the measured values for the corresponding high gloss panel as a reference.

The results of this analysis are shown in Table 5.

Based on these results, we conclude that after applying a clearcoat that is not high-gloss, the resulting paint will look less coarse. This effect is quite small, being 0.6 ± 0.3 units on the Graininess scale. However, since in several industries databases are searched using color coordinates and graininess (or coarseness) as search criteria, this finding may be significant for color matching software and other applications.

Table 5 also shows that there is a much larger influence from glossiness on the sparkle grade, especially at 15°. This can be understood by realizing that most sparkles occur close to the mirror angle, and therefore any effect on sparkle will have the largest impact at the 15° measurement geometry. From the point of view of physics and optics, it is also clear why reducing the glossiness of the clearcoat negatively impacts the occurrence of sparkle. The reason is that for sparkle to be fully visible or detectable by an instrument, the intense narrow beam of light reflected by individual metallic flakes needs to be able to travel undistorted through the interface between the clearcoat and the air. For a matte clearcoat, this interface is much less plane and uniform than for a high gloss clearcoat. This explains why strong sparkle effects are not observed in matte clearcoats. The sparkle effect is washed away and diluted by the matte clearcoat. For the graininess parameter this optical dilution is also relevant but at a smaller magnitude, because of the inherently lower angular resolution at which this effect is detected.

Table 5: Influence of gloss level on the measured texture values (graininess, sparkle grade) for metallic colors. In all cases, we use the corresponding high-gloss panel (gloss class 7) as a reference. For example, a matte paint (gloss class 1) on average has 0.6 units smaller Graininess than the corresponding high-gloss (gloss class 7) paint, with a standard deviation of 0.3 units.

Gloss class	Graini-ness	Sparkle Grade 15°	Sparkle Grade 45°	Sparkle Grade 75°
1	0.6 ± 0.3	3.3 ± 1.7	0.3 ± 0.4	0.0 ± 0.2
2	0.5 ± 0.5	2.8 ± 1.7	0.2 ± 0.4	0.0 ± 0.3
3	0.3 ± 0.4	1.9 ± 1.2	0.2 ± 0.4	0.0 ± 0.2
4	0.3 ± 0.3	1.2 ± 1.1	0.2 ± 0.3	0.0 ± 0.2
5	0.3 ± 0.5	0.8 ± 0.7	0.2 ± 0.4	0.0 ± 0.3
6	0.2 ± 0.2	0.3 ± 0.4	0.1 ± 0.3	0.0 ± 0.2

Discussion

The results just shown confirm what is known from visual assessments: the perceived glossiness of paint samples correlates with the color of the paint, even if paint surfaces have equal roughness and chemical composition. This is understood by noting that the color of the paint can make the visual clues that are needed to recognize the level of glossiness less visible for an observer. Similarly, when measuring glossiness the measured gloss value correlates with the color of the paint, because the physical method to measure glossiness is affected by the reflectance level of the paint. It is these correlations which are referred to in this paper when we describe certain parameters as “influencing” other parameters, either when visually assessed or when measured (without obviously implying that measurement values influence each other in the sense of quantum mechanics).

Our results show that the same type of “influence” also holds between measured glossiness and measured visual texture (graininess and sparkle) values.

Conclusions

In this work, we evaluated the influence of various appearance attributes on each other. We designed and created a set of 462 paint samples to investigate this topic. We measured three of the most important appearance attributes for each of these panels: their multi-angle reflectance (color under six measurement geometries), texture (graininess and sparkle grade under three measurement geometries) and glossiness (under three measurement geometries). The results show that measured gloss values depend on color, and for metallic coatings this is a strong dependence. The results also show that glossiness has a large effect on sparkle grade, especially for small aspecular angles, and on graininess.

These results may be useful for Quality Control systems as used in various industries, and also for color matching applications where closest matches are searched for in databases filled with measurement data.

Acknowledgements

The author would like to thank paint company AkzoNobel for making the creation of the paint samples possible.

References

[1] CIE 175:2006 A framework for the measurement of visual appearance, International Commission on Illumination, 2006.

[2] C.S. McCamy, “Observation and measurement of the appearance of metallic materials. I. Macro appearance,” Color Res. Appl. 21, 292–304, 1996.

[3] C.S. McCamy, “Observation and measurement of the appearance of metallic materials. II. Micro appearance,” Color Res. Appl. 23, 362–373, 1998.

[4] E.J.J. Kirchner, G.J. van den Kieboom, S.L. Njo, R. Supèr and R. Gottenbos, “Observation of visual texture of metallic and pearlescent materials,“ Color Res. Appl. 32, 256-266, 2007.

[5] N. Dekker, E.J.J. Kirchner , R. Supèr, G.J. van den Kieboom and R. Gottenbos , “Total appearance differences for metallic and pearlescent materials: contributions from color and texture,” Color Res. Appl. 36, 4-14, 2011.

[6] G.A. Klein, Industrial Color Physics. New York: Springer; 2010.

[7] N.D. Slembrouck, A. Ferrero, E. Perales, N. Basic, J. Audenaert, F.B. Leloup, “Psychophysical experiment towards a measurement scale of

sparkle," in CIE Vienna Scientific Conference, Book of Abstracts, ID 267, 2025.

[8] A. Ferrero, E. Perales, N. Basic, M. Pastuschek, G. Porrovecchio, A. Schirmacher, J.L. Velázquez, J. Campos, F.M. Martínez-Verdú, M. Smid, P. Linduska, T. Dauser, P. Blattner, "Preliminary measurement scales for sparkle and graininess," Opt. Exp. 29, 7589-7600, 2021.

Author Biography

Eric Kirchner received his MSc and PhD in Theoretical Physics and Chemistry from the Free University of Amsterdam, the Netherlands, in 1994. He worked from 2000 until 2025 as senior color scientist at paint company AkzoNobel, authoring 70+ papers on color science. Currently he is affiliated with the College of Optical Science and Engineering of Zhejiang University in Hangzhou, China, as well as working as consultant in color science for multiple industries (www.colorsai.nl).