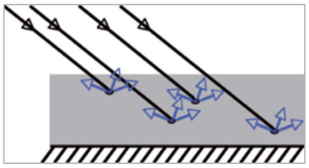
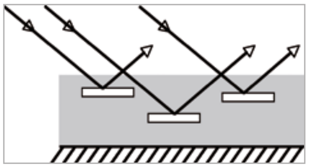
Introduction

Metallic Coatings

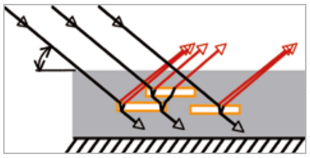
Today effect finishes play a dominant role in many applications as they make an object distinctively appealing.
In contrast to conventional solid colors, effect finishes change their appearance with viewing angle and lighting conditions. Interference finishes show not only a lightness change with different viewing angle, but also a change in chroma and hue. The latest developments are special effect pigments, which create sparkling effects when lighting conditions change from sunlight to cloudy sky.



Absorption pigments



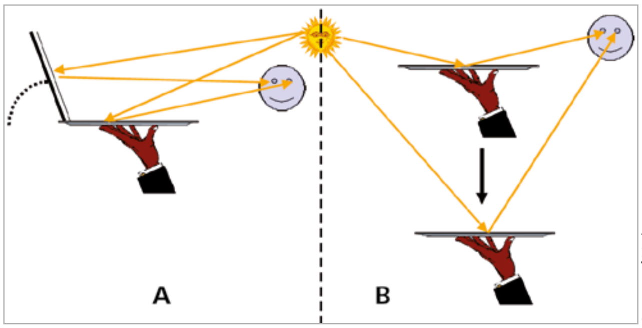
Metallic pigments



Interference pigments

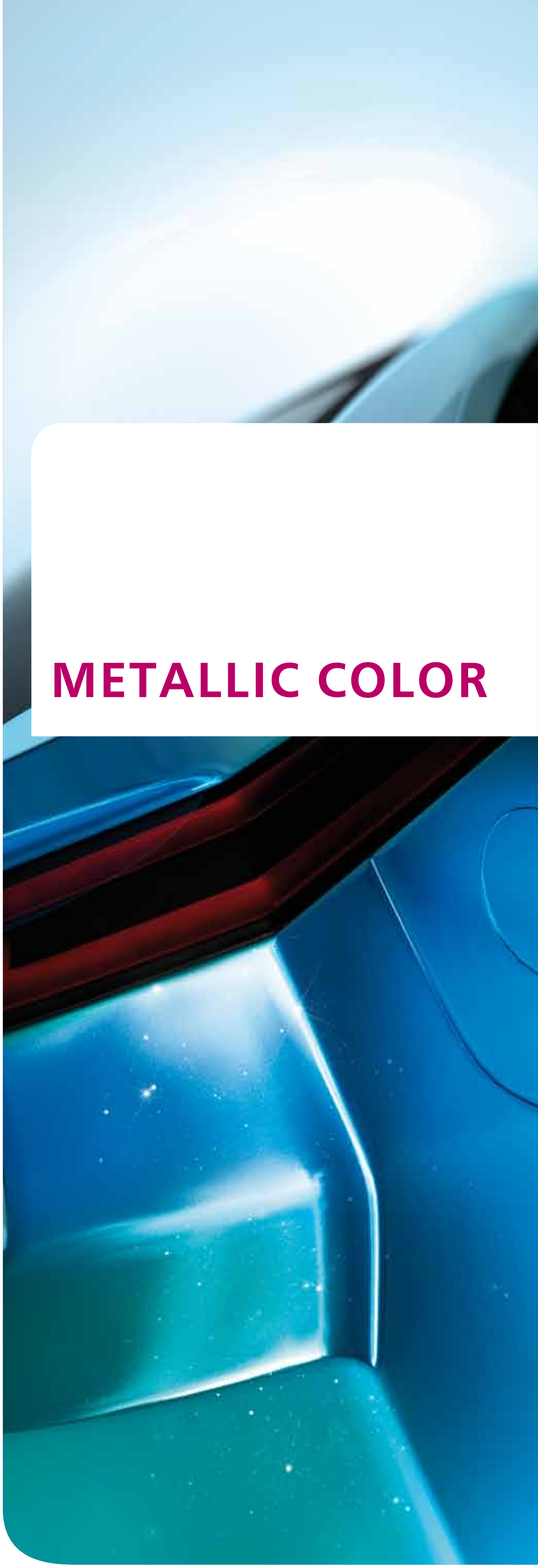
Visual Evaluation of Effect Coatings

As metallic finishes show a lightness change with different viewing angles, the sample needs to be tilted to create the same effect during visual evaluation. This effect is also referred to as "light-dark flop". The bigger the lightness changes between the angles of view are, the more the contours of an object will be accentuated. In order to observe color travel of interference finishes, the panel should be moved to allow increasing or decreasing the angle to the light source.



Visual evaluations of traditional metallic finishes

Visual evaluation of effect coatings with color flop

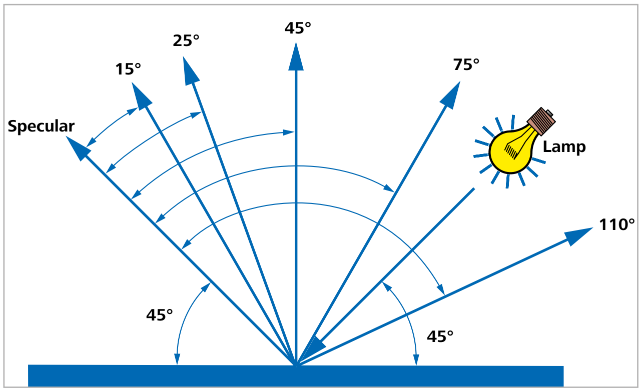


METALLIC COLOR

Instrumental Color Measurement of Effect Coatings

Multi-angle color measurement

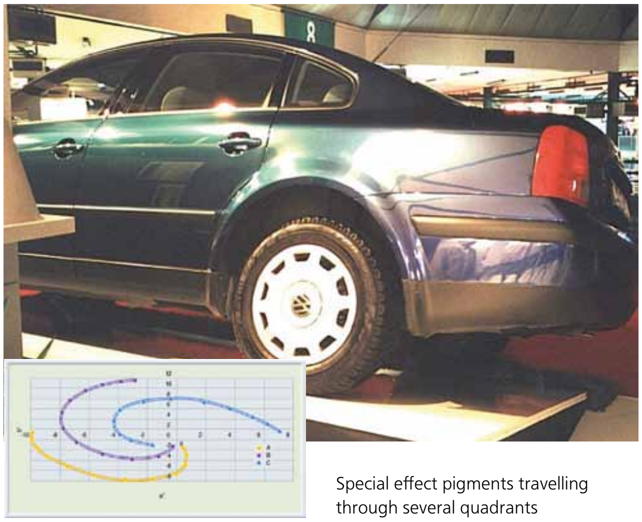
ASTM, DIN and ISO standards define multi-angle color measurement to objectively describe the color of metallic finishes. Research studies show that a minimum of three, and optimally five viewing angles are needed. The measurement geometry for multi-angle color measurement is specified by aspecular angles. The aspecular angle is the viewing angle measured from the specular direction in the illuminator plane. The angle is positive when measured from the specular direction towards the normal direction.



Directional illumination is used versus circumferential illumination because circumferential illumination minimizes the contribution from directional effects such as the Venetian blind effect and surface irregularities.Thus, averaging of the circumferential illumination would cause the measured color values of two specimens to be the same, while visually the two specimens would not match.

For color QC, the colorimetric data L*, a*, b* (or L*, C*, h°) and delta E* can be used. The tolerances are usually higher for the near specular (15°, 25°) and the flop angle (75°, 110°) than the 45° tolerance. In order to have a unique tolerance parameter independent of color, weighted factors have to be used. Therefore, automotive companies often have set specifications on delta E CMC or delta E' based on DIN 6175-2 using 3 or 5 angle instrumentation. Another useful index is the flop index, a measure of the change in lightness of a metallic color as it is tilted through the entire range of viewing angles.

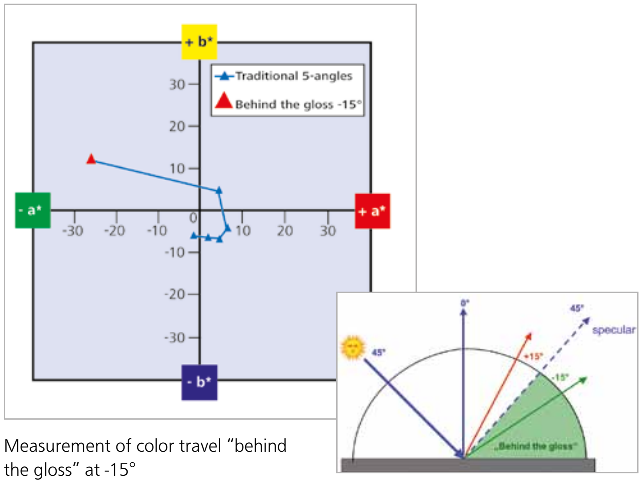
In the last years a new generation of special effect pigments has become more and more popular. For some of these new pigments the color travels over a wide range.



Special effect pigments travelling through several quadrants

Courtesy of Merk

In order to fully capture the color travel of these interference pigments it is necessary to add viewing and illumination angles. To keep the whole procedure practical for industrial use with a portable spectrophotometer it was determined that an additional angle behind the gloss e.g. -15° is of benefit.



Measurement of color travel "behind the gloss" at -15°

Courtesy of Merk

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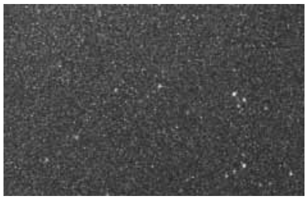
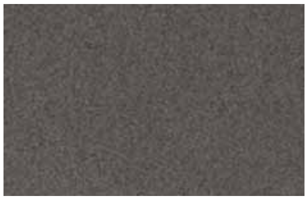
Flake Characterization

In addition to color changes our total perception is also influenced by the effect of the metallic flakes or other sparkling pigments. This effect changes with the lighting conditions, for example direct sunlight versus cloudy sky.



Direct sunlight: Sparkle effect



Cloudy sky: Graininess

Sparkle

A sparkling or glitter impression can be observed under direct sunlight. This effect is often described with different words such as sparkle, micro brilliance or glint and is generated by the reflectivity of the individual effect pigment. Therefore, it is influenced by the

- flake type and size
- concentration level of the effect pigment
- orientation of the effect pigment
- application method

The sparkle impression changes depending on the illumination angle.

Graininess

Apart from the sparkle effect under direct sunlight, another effect can be observed under cloudy conditions, which is described as coarseness or salt and pepper appearance. This visual graininess can be influenced by the flake diameter or the orientation of the flakes resulting in a non-uniform and irregular pattern. The observation angle is of low relevance when evaluating graininess.

Multi-angle color and effect measurement with the BYK-mac

Traditional 5-angle color measurement calculates color values by averaging the spectral reflection over the entire illuminated spot and therefore can not differentiate between the color of the basecoat and the reflection of the aluminum flakes. As a consequence, two effect finishes can have the same color values with a 5-angle spectrophotometer, but visually appear very different. The visual difference is a result of the flake effects.

Sample 1

Sample 2

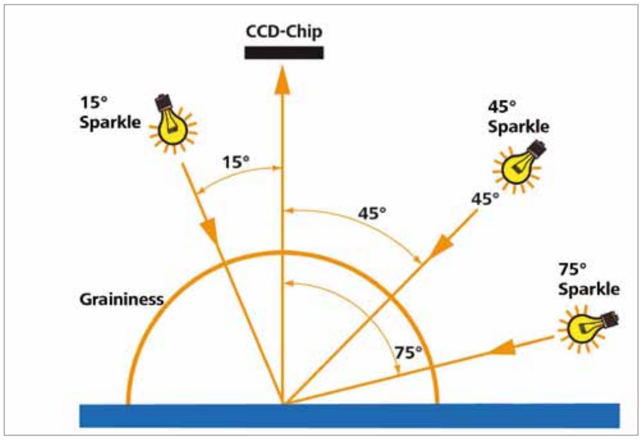
Same color but visual difference

	ΔL*	Δa*	Δb*
-15°	-0.35	0.25	0.42
15°	0.16	0.19	0.43
25°	-0.65	0.20	0.48
45°	-0.10	0.05	0.00
75°	0.46	-0.11	-0.60
110°	0.69	-0.11	-0.89

	ΔSparkle	ΔGraininess
15°	7.85	
45°	4.17	
75°	1.48	
Diffused		3.81

To characterize the impression of effect finishes under different viewing angles and illumination conditions, the BYK-mac spectrophotometer objectively measures the total color impression:

- Multi-angle color measurement (6-angles) clearly defines the light-dark as well as color flop behavior of effect finishes
- Sparkling and Graininess control with a high resolution CCD camera simulates effect changes under direct and diffuse lighting conditions

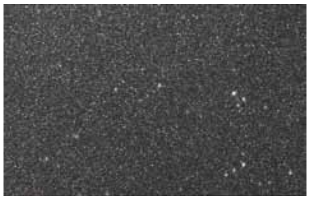


BYK-mac effect measurement geometries

Sparkle measurement under direct illumination at three angles

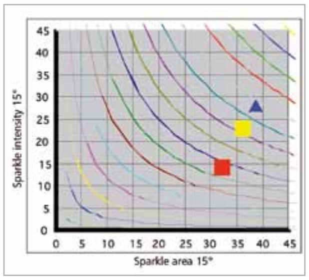
The sparkle impression changes with the angle of illumination. Therefore, the BYK-mac spectrophotometer illuminates the sample under three different angles 15°/45°/75° with very bright LEDs and takes a picture with the CCD camera located at the perpendicular.

Low sparkle (glint)

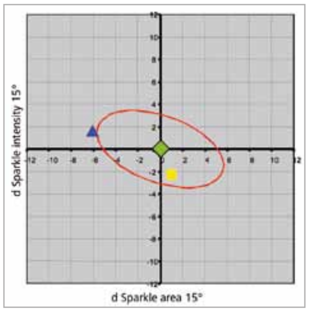


High sparkle (glint)

The pictures are analyzed by image analyzing algorithms using the histogram of lightness levels as the basis for calculating sparkle parameters.
To allow better differentiation, the impression of sparkle is described by a two dimensional system: sparkle area and sparkle intensity for each angle.



For simplicity sparkle area and intensity are summarized in one value: sparkle grade. Sparkle grade is represented by the colored lines in the diagram.
The sparkle evaluation is done by comparing a sample to a defined standard – like color measurement. Therefore, the sparkle data are also displayed in a difference graph.



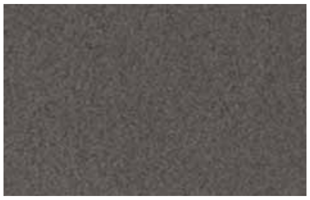
In order to set visually acceptable limits a new sparkle tolerance model was developed together with several partners from the automotive, pigment and paint industry. As a guideline the weighted total color difference equations were used resulting in an elliptical tolerance model.

The human eye is less critical to a change within a sparkle grade than it is to a change from grade to grade. Therefore, the longer axis of the ellipse is towards the sparkle grade lines.
To use the model as a Pass/Fail tool for paint batch or part QC, the total sparkle difference between sample and standard is calculated: ΔSparkle.

Graininess measurement under diffused illumination

Graininess is evaluated by taking a picture with the CCD camera under diffused lighting conditions, created by a white coated hemisphere. The picture is analyzed using the histogram of lightness levels whereby the uniformity of light and dark areas is summarized in one graininess value.

Low graininess (coarseness)

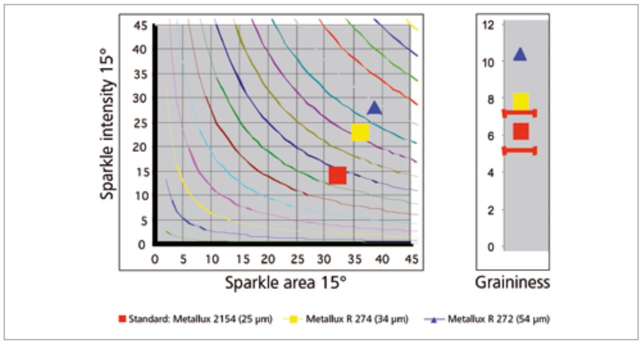


High graininess (coarseness)

A graininess value of zero would indicate a solid color, the higher the value the grainier or coarser the sample will look under diffused light.

Influence of flake size on sparkle and graininess

Sparkle and graininess data give information on flake size and concentration levels. The sample below shows a silver finish with three different flake sizes (25 µm – 34 µm – 54 µm).
Visually, the silver finish with the coarser aluminum pigments appears more sparkling under direct illumination and more “grainy” under diffused lighting.



The BYK-mac measurement correlates with the visual judgment: sparkle area, sparkle intensity and graininess increase with flake size.

Influence of flake Orientation on total color impression

Besides flake types and concentration levels, the comparison of sparkle area at 15° and 75° illumination gives information about flake orientation.

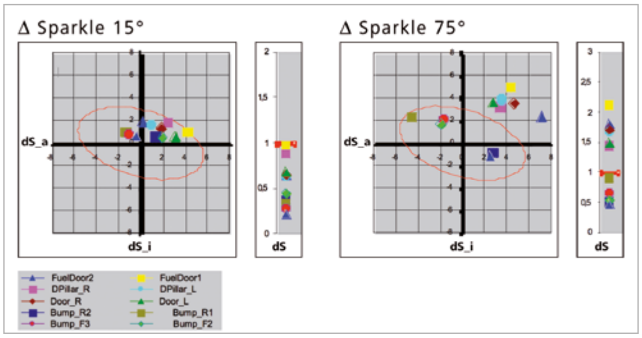
Different application method

In order to increase paint efficiency the basecoat application is changing to 100% electrostatic application. Metallic finishes containing coarser aluminum flakes will show more non-parallel oriented flakes. The result will be a lower light-dark flop and more sparkling at a low grazing illumination angle. In the following example the basecoat of the car body was applied 100% electrostatically and the bumpers were painted with a bell / pneumatic application. The total color difference using the mean ΔEDIN was acceptable.

	ΔE DIN avg.
FuelDoor2	0.59
FuelDoor1	0.88
DPillar_R	0.63
DPillar_L	0.56
Door_R	0.53
Door_L	0.62
Bumper_R2	0.56
Bumper_R1	0.40
Bumper_F3	0.89
Bumper_F1	0.87
Bumper_F2	0.90

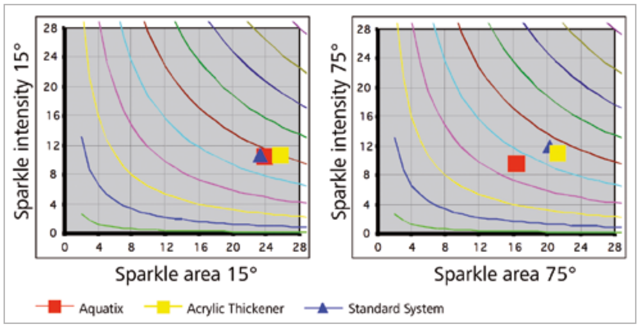
ΔEDIN is well below one for all measurement points

Yet, visually, the car body was sparkling considerably more than the bumper. The BYK-mac measurement data reflects the visual impression clearly evaluating the Sparkle 75° data. The Sparkle 75° measurement evaluates the aluminum flakes which are non-parallel oriented; therefore the main changes can be seen in an increasing sparkle area.



Different rheology additives

Flake orientation can also be influenced by the paint formulation, e.g. the rheology additive. As fine aluminum flakes have more edges and consequently more light is scattered, the orientation is more important for coarser pigments. The use of an optimized rheology additive will result in a better light-dark flop and less sparkling at lower grazing angles.
In the following example a waterborne system was evaluated using three different rheology additives: a standard system, an acrylic thickener and the BYK-Chemie wax additive AQUATIX®. Visually, the three panels look the same under direct illumination at a steep angle. When comparing at a lower grazing angle, the system using the BYK-Chemie wax additive shows less sparkling.



BYK-mac measurement data correlates with a visual judgment. The sparkle area for the system with wax additive at 75° is smaller than for the two other systems. As Sparkle 75° evaluates flakes which are non-parallel oriented, this clearly shows that by using the BYK-Chemie wax additive AQUATIX® the orientation of the aluminum flakes is improved.

BYK-mac measures total color impression

Info! For more information on visual evaluation of effect finishes see byko-spectra *effect* page