BYK
Additives & Instruments

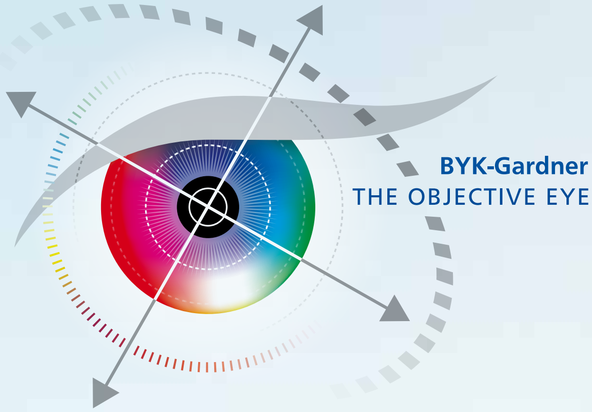
QC SOLUTION FOR PLASTIC PARTS

Contents

The Objective Eye for Consistent Color and Appearance

Plastics revolutionized our world! Suitcases are durable and flexible at the same time; window frames never need repainting; breathable and water-resistant sneakers support runners in their performance. Our purchasing decision is dependent on functional criteria and equally important is its design including color and gloss!

A successful example of “Color sells” is the company Apple. Apple was continuously losing market share until they revolutionized the look of their iMac computers. The iMac was the first “stylish” PC in regards to design and color. Meanwhile, Macs and all other Apple products have a reputation of being hipster accessories. Color and appearance are central factors in most people’s decision-making process. Whether buying a car or simply shopping at the grocery store: 85 % of shoppers place color as a primary reason for why they buy a particular product.



The use of distinctive colors to identify products can be seen everywhere. "Coca-Cola red" is the best known example for a corporate identity color. There is no need to say, that certain quality standards are associated with the brand color. Consistent color and appearance are crucial before as well as after sale. As important is reliable product performance over time, which is reflection of customer satisfaction and hence the number of repeat purchases.

The quality of a multi-component product is the result of the cooperation of many partners along the entire value chain. But in the end the assembled product should be uniform in color. Color harmony has a major influence on the impact of perceptual quality on a product and thus, plays a key role in purchasing decision.

Visual color perception is influenced by our individual color preferences, which are dependent on personal factors (mood, age, gender etc.), environment (lighting, surrounding etc.) as well as our ability to communicate color and color differences. A color looks different in the department store (cool white fluorescent lighting) than at home (warm, incandescent lighting). Effect colors will even change their appearance depending on the type of daylight conditions being sunny or cloudy. In order to guarantee consistent color and appearance under all possible situations, it is essential to define numerical parameters with customer relevant tolerances, which can be controlled in daily production and communicated among the entire supply chain of raw material and final product suppliers. A high quality production process should only be based on figures and facts and not emotions.

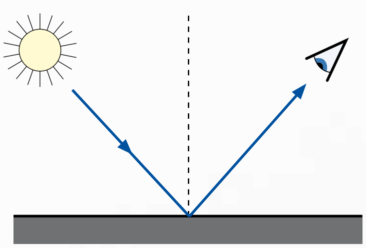
Consistent color and appearance needs an OBJECTIVE EYE!

BYK-Gardner offers complete quality control solutions for your application in plastics.

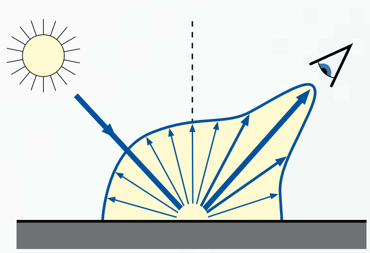
Gloss Measurement

Until recently, high gloss surfaces were directly linked with superior quality. For some time now, a new trend is apparent, which points in the completely opposite direction: matte, velvet-like surfaces. Will this trend continue? You never know! What counts in either case is the consistent quality and appearance of the customer's favorite product.

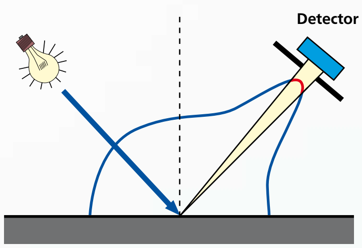
Gloss measurement
Gloss is a visual impression dependent on the surface condition. The more direct light is reflected, the more obvious the impression of gloss will be. A high gloss finish will make the product appear darker and having a very smooth surface. The incident light is directly reflected on the surface, i.e. only in the main direction of reflection. The angle of reflection is equal to the angle of incidence.



A matte finish includes matting agents, which produce a micro roughness scattering the light diffusely in all directions. The more uniform the light is scattered, the less intense the reflection will be in the main direction. The surface will appear more and more matte.



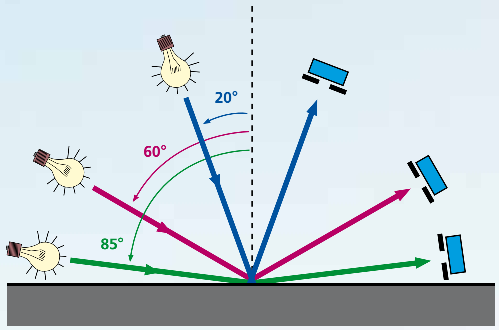
Gloss meter
International standards define the measurement of specular reflection with a gloss meter. The light intensity is measured over a small range of the reflection angle.



A light source, simulating CIE illuminant C, is placed at the focal point of a collimating lens. A receptor lens with an aperture in the focal plane followed by an illumination detector completes the basic optical design.

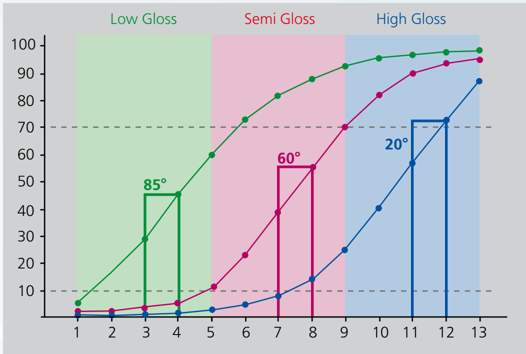
The intensity is dependent on the material and the angle of illumination. The measurement results are related to the amount of reflected light from a black gloss standard with a defined refractive index. The measurement value for this defined standard is equal to 100 gloss units. Materials with a higher refractive index can have a measurement value above 100 gloss units (GU).

The angle of illumination is of high influence. In order to obtain a clear differentiation over the complete measurement range from high gloss to matte, three geometries, i.e. three different ranges, are standardized:



Gloss level	60° value	Recommended geometry
Semi gloss	10 to 70 units	60° geometry
High gloss	> 70 units	20° geometry
Low gloss	< 10 units	85° geometry

In a case study 13 samples were visually ranked from matte to high gloss and measured with the three specified geometries. In the steep slope of the curves, the differences between the samples can be clearly measured, while in the flat part the measurement geometry no longer correlates with the visual perception.



Why three different gloss ranges?

A single measurement geometry, such as 60°, may not provide instrument readings of gloss that correlate well with visual observations when comparing different gloss levels. This is why international standards provide for measurement at three different angles of incidence, namely 20°, 60°, and 85°. Each of the three geometries uses the same source aperture, but a different receptor aperture. The choice of geometry depends on whether one is making a general evaluation of gloss, comparing high gloss finishes or evaluating low gloss specimens for sheen. The 60° geometry is used for comparing most specimens and for determining when the 20° or 85° geometry may be more applicable. The 20° geometry is advantageous for comparing specimens having 60° gloss values higher than 70. The 85° geometry is used for comparing specimens for sheen or near grazing shininess. It is most frequently applied when specimens have 60° gloss values lower than 10.

References

ISO 2813	Determination of Specular Gloss of Non-Metallic Paint Films at 20°, 60°, 85°
ASTM D523	Standard Test Method for Specular Gloss

micro-gloss

The new intelligence in gloss measurement

- Unsurpassed industry standard in gloss measurement
- 1- angle and 3-angle gloss meters for high gloss to matte finishes
- Automatic calibration check in holder
- Measurement modes for any task: Statistics – Difference – Pass/Fail
- Continuous mode for uniformity check of large surface areas
- Wireless data transfer

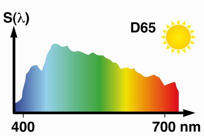
Color Measurement of Solid Colors

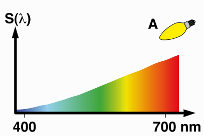
"You can have any color as long as it's black". Those days are long gone! We like to have a choice and thus, the world is getting more and more colorful. The variety of colors requires us to make daily decisions: which color is best for a special occasion, an outfit or a room decoration. Therefore, manufacturers have to clearly differentiate the different color shades and guarantee consistent color over time.

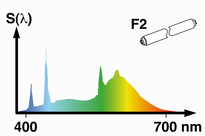
Our color perception is dependent on our individual "taste", which is influenced by our mood, gender, age, but also the light source used, the viewing environment being light or dark, neutral or colorful as well as our deficiency to exactly remember and communicate one specific color.

Standardized viewing conditions

For controlled visual and instrumental evaluation the light source, the surrounding and the observer are to be defined. Colors may match under one light source (daylight), but not under another (fluorescent light). Thus, the match needs to be verified with the kind of light likely to be found where the product is sold or used. The CIE (Commission Internationale de l'Éclairage) standardized commonly used **light sources**.

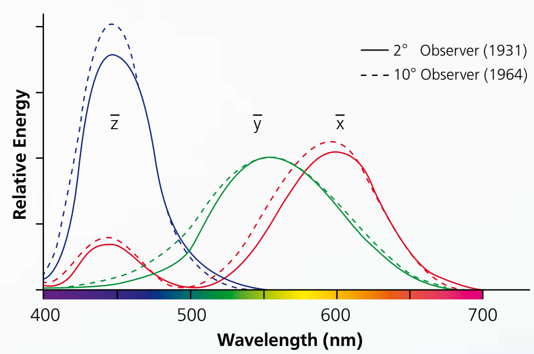






ISO and ASTM standards define the **surroundings** as portion of the visual field immediately surrounding the specimens as well as the ambient visual field, when the observes glances away from the specimen, such as the interior surfaces of the light booth. It shall have the color with Munsell notation N5-N7 and a 60° gloss not greater than 15 GU.

The **observer for visual appraisal** should have normal color vision and be trained in observing and classifying colors. Visual tests are recommended to check an observer's color vision periodically as it can change over time (see Guide ASTM E1499). The **observer for instrumental color control** was standardized with two different viewing fields: 2° standard observer and 10° standard observer. Today mainly the 10° observer functions are used as the eye integrates over a larger area.



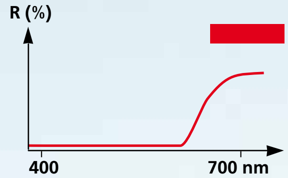
byko-spectra light booth

Standardized visual color appraisal

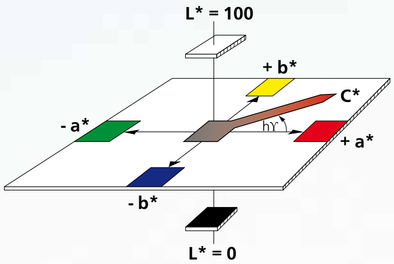
- Color neutral surround and ambient field
- Several light sources: D65 – A – CWF/TL84 – UV
- UV light to detect fluorescence
- Timer to track daylight lamp usage
- Compact design

Standardized measurement parameters

For instrumental color measurement the optical properties of the product need to be measured. A spectrophotometer measures the amount of light that is reflected by the object at different wavelengths in the visible range (400 – 700 nm). The reflectance curve shows the spectral data and acts as a "finger print" for the object color.



Internationally standardized **color systems**, like the widely used CIELab system, combine data of standardized illuminant, standardized observer and spectral reflection data in three color components describing the lightness, hue and chromaticity of a color.



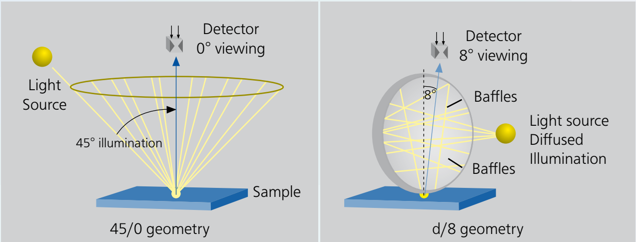
Tolerances are established either on each color component or on the total color difference ΔE*.

$$\Delta E^* = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2}$$

Over the years new color systems and equations (ΔECMC – ΔE94 – ΔE99 – ΔE2000) were developed based on visual comparison studies for solid colors to improve the visual correlation, which shows elliptical tolerance behavior.

Standardized instrument geometries

International standards define the geometric conditions of spectrophotometers:



45/0 – Control color as you see it

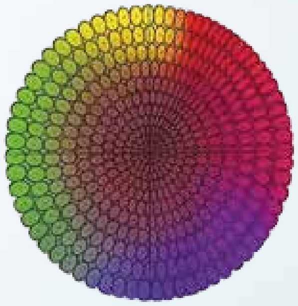
For final QC of solid colors a 45° circumferential illumination is defined to achieve repeatable results on unstructured and structured surfaces.

d/8 – Control the hue of a color

If the color without influence of surface gloss or texture is to be controlled, diffused illumination is required.

References

CIE 15	Colorimetry
ISO 3668	Visual Comparison of the Color of Paints
ASTM D1729	Visual Appraisal of Color Differences



CMC Tolerance Ellipsoids in CIELab Color Space

spectro-guide
Portable color control

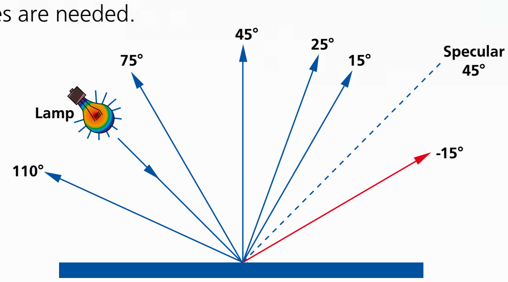
- Simultaneous color and 60° gloss measurement
- Innovative LED technology
  → Excellent repeatability and inter-instrument agreement
  → Long-term and temperature stable results
  → Low maintenance with 10 years warranty on LEDs

Color Measurement of Metallic Colors

Metallics, whether it is silver or gold, lends a shimmering richness to classic colors and introduces a timeless luxury to any product. Depending on the lighting conditions, the product will appear differently – sparkle like diamonds or fascinate with a sleek, luminous finish.

Multi-angle color evaluation
In contrast to solid colors, effect finishes change their color and appearance with viewing angle and lighting conditions. Metallic finishes will show a lightness travel depending on the viewing angle. Pearl colors with special interference pigments can not only show a lightness change with different viewing angle, but also a change in chroma and hue (color travel).

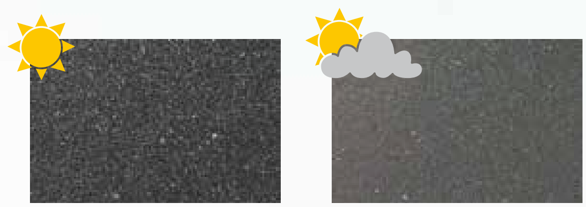
International standards define measurement geometries for multi-angle color measurement to objectively describe the color of metallic finishes. Research studies show that a minimum of three, and depending on the effect finish up to six viewing angles are needed.



As the color perception of effect finishes is changing by viewing angle, it is necessary to define different tolerances for each viewing angle. Therefore, new color equations based on visual correlation studies were developed:

- ΔE94 with lightness travel (Rodrigues, 2004)
- ΔE_{eff} (DIN 6175-2, 2001)
- ΔEAudi2000 (Dauser, 2012)

Visual effect evaluation
The latest developments are special effect pigments, which create high sparkling effects under direct illumination. Viewed under diffused lighting conditions, the sparkling effect will disappear as the light intensity is equal from all directions. Therefore, metallic pigments will look more or less grainy depending on the flake size and pearlescent pigments will look more like a solid color. Under direct illumination, i.e. the light intensity comes from mainly one direction (sunny sky), the same metallic or effect finish will look completely different showing small light flashes with low to high intensity. In contrast to graininess, the sparkle effect is depending on the illumination angle resulting in a sparkle travel.



References

DIN 6175-2	Tolerances for Automotive Paints – Part 2: Goniochromatic Colors
ASTM E2194	Multiangle Color Measurement of Metal Flake Pigmented Materials

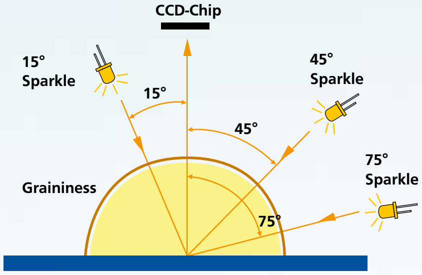
byko-spectra *effect* light booth
Standardized visual evaluation of effect finishes

Multi-angle color evaluation
- Daylight illumination at 45°
- Tiltable sample table with six viewing angles (-15°, 15°, 25°, 45°, 75°, 110°)
- Timer to track daylight lamp usage

Sparkle evaluation
- Illumination at three angles (15°, 45°, 75°)
- Very bright LEDs to simulate direct sunlight
- 10 year warranty on LEDs

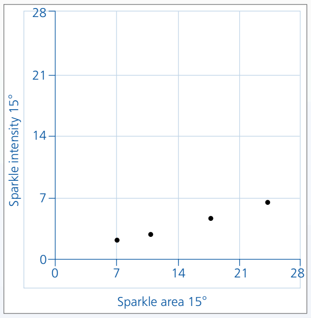
Instrumental effect measurement
In order to objectively measure effect characteristics, the new BYK-mac i combines a multi-angle spectrophotometer (6-angle color measurement) with a second measurement set-up for sparkle and graininess evaluation. A CCD camera takes pictures under various lighting conditions:

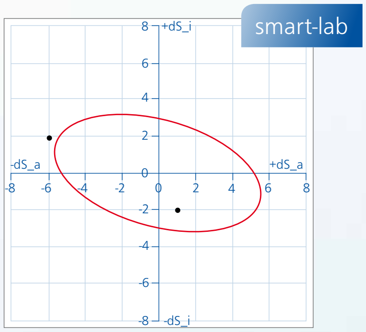
- Diffused illumination with two white LEDs built-into a white coated hemisphere
- Direct illumination at three angles with three white super bright LEDs



The pictures are analyzed using the histogram of lightness levels of the individual pixels as the base information. The uniformity of light and dark areas is summarized in one graininess value. 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.

In case of sparkling, a threshold is set and only the very bright pixels above the threshold are evaluated. To allow a better differentiation, the impression of sparkle is described by a two dimensional system: sparkle area and sparkle intensity for each angle.





A sparkle tolerance model was developed, which allows setting a maximum limit value for "Delta Sparkle" similar to a weighted total color difference equation.

$$dS = \sqrt{\left(\frac{f_1(Sa_{Std}, dSa, Si_{Std}, dSi)}{Tol\_Gr}\right)^2 + \left(\frac{f_2(Sa_{Std}, dSa, Si_{Std}, dSi)}{Tol\_Gr \times Tol\_GF}\right)^2}$$

BYK-mac i
Portable multi-angle color & effect control

- 6-angle color measurement for light-dark and color flop
- Sparkling and graininess analysis
- Detection of fluorescent light excited in the visible range
- Unique LED technology
  → Excellent technical performance
  → No need for lamp exchange
  → The key to a global QC system using digital standards

Measurement of Raw Materials

The range of raw materials includes many different material types and forms such as pellets, pigment pastes and powders, from opaque to translucent or transparent. The requirements on color measurement and sample preparation are particularly challenging because of the extreme diversity. Lot-to-lot color consistency is an important indicator of quality and can only be achieved, if the measurement results are repeatable and reproducible.

Consistent Quality of Raw Materials

The ultimate manufacturing objective is to consistently and confidently sell their end product to a customer. Therefore, the product needs to be checked prior to shipping, to ensure it meets the agreed upon color and appearance tolerances. If the color is off specification, it will have to be reprocessed and potentially be sold at a lower price or even needs to be discarded. Therefore, incoming quality control of the raw materials is essential. Tight lot-to-lot variation is a pre-requisite for minimizing rejects.

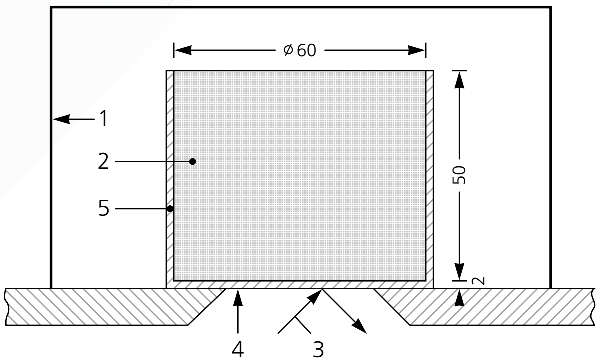
Resins

Plastic raw materials such as PP which is often used for colored end-use applications must be controlled for degree of yellowness. If the resin is not "white", the final color will be off specification. The degree of yellowness is influenced by contamination or impurities of the raw materials as well as process variations. For a very quick quality control, the pellets can be measured according to ISO 17223 using a glass sample cup and a light trap (see details in following schematic). To guarantee repeatable positioning, the spectro-guide can be placed on a mask which fits the aperture. Averaging several readings is essential for reproducible results.

BYK-Gardner Solution

Solid Color & Gloss
spectro-guide S

Objective Visual Evaluation
byko-spectra



1 = light trap
2 = specimen
3 = incident light
4 = measured surface
5 = specimen container

For stable quality control, creating reliable and repeatable results, it is necessary to mold the plastic pellets into plaques with a homogenous surface and defined thickness. The plaques can then be measured in reflection mode by the spectro-guide, a portable color spectrophotometer, which automatically calculates the yellowness index according to international standards.

As the yellowness index is just a one-dimensional number it sometimes does not completely describe the visual perception. Often samples show an additional significant difference in hue and lightness. Therefore, a three dimensional description of color using the CIELab color coordinates is recommended. Within this system, the b* value can be used as an indicator for yellowness. The molded plaques are usually not completely opaque. Thus, when taking color readings the background has a crucial impact on the measurement results. To achieve the best discrimination between different products a white backing material is recommended. The material should be long-term stable and agreed upon between the involved parties.

Granulate

Plastic pellets are typically translucent, non-uniform in size and inhomogeneous in color. The inhomogeneity in color of cylindrical pellets is due to different surface properties of the cut and the lateral surfaces or as a result of stress whitening. Thus, only under significantly increased efforts using special accessories and sample preparation techniques reproducible results can be achieved. Therefore, the process of pressing a color chip for the purpose of color measurement is common in plastic processing and is the recommended procedure to create reliable and repeatable measurement results.

Glass Sample Cup
Granulate

Template-C
Aperture mask for spectro-guide

Molded Color Chips

Molded color chips are thermoplastic materials that are compression molded from material suppliers into test specimens for the purpose of color measurement. These color chips often have areas with increased thicknesses and therefore range from opaque to translucent. Thus, they require different measurement techniques depending whether the color chip is opaque or translucent.

Opaque color chips are impermeable by light and are best measured using a 45°/0° or a d/8° reflectance instrument. A 45°/0° instrument is used in situations where we want to measure color the way our eyes see color. A practical use for a 45/0 color instrument is to check color consistency of consumer products when appearance is a deciding factor in a product purchase. A d/8° geometry eliminates the influence of gloss and surface texture on the object's color. A raw material supplier of pigments or resins would normally use the d/8° geometry to check lot-to-lot consistency.

Translucent color chips allow light to pass through, but only diffusely, so that objects on the other side cannot be clearly distinguished. The choice of instrumental measurement depends upon how a visual judgment is made. When measuring the diffuse reflection of these materials, the thickness of the specimen and the color of the material behind the specimen during the measurement process can significantly affect the measurement data. Therefore, thickness and backing must always be specified and held constant. To achieve the best discrimination between different products a white backing material is recommended. The use of byko-chart drawdown cards, as backing for the color chip guarantees consistent color and gloss ensuring that the measured color difference only comes from product variations.

A color chip provided by the material supplier poses a certain risk. Its material composition may slightly differ to the finally delivered material. The production processing parameters are usually unknown and it often does not have the exact same texture as the final product. To ensure comparable results the standard should be made from the same material and with the same grain as the final product.

BYK-Gardner Solution

Solid Color & Gloss
spectro-guide S

Gloss
micro-gloss S

Color consistency under different illuminants

As multi-component products are utilized under different lighting conditions, color consistency needs to be controlled under multiple light sources. Otherwise parts molded from different batches have the potential risk to appear the same under daylight but show an apparent mismatch under indoor room lighting. This phenomenon is known as metamerism.

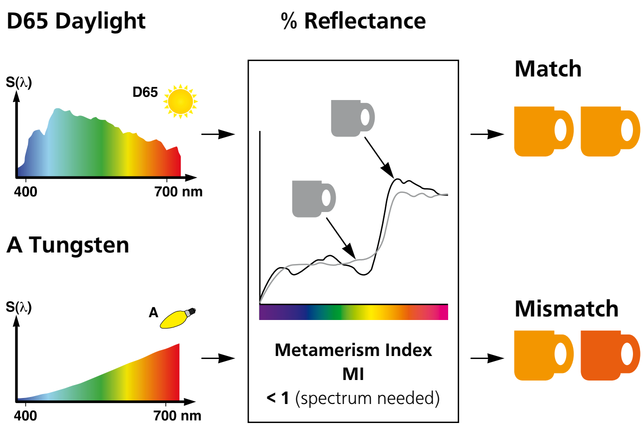
<u>Visual test of metamerism</u>

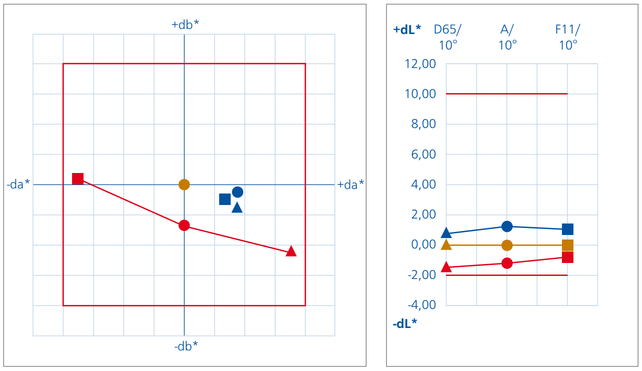
In a light booth standard and sample are viewed at the reference light source - most of the time D65. Then the light source is changed to at least one test light source which is significantly different from the reference light source. A common practice is to visually evaluate the sample pair under illuminant A and a fluorescent light source representing TL84 or CWF. This can be easily done using the byko-spectra lighting cabinet. The light booth supports commonly defined standard illuminants and an automatic sequencing of different light sources for standard testing procedures can be programmed.

<u>Instrumental test of metamerism</u>

The reason for metameric plastic pellet batches is that the pigments or colorants used in the formulation are different. This can occur when e.g. raw materials are no longer available because of environmental issues or more cost efficient solutions require raw material changes. In any case, the spectral curves of the metameric pair are different. Typically, the curves cross each other at least three times.

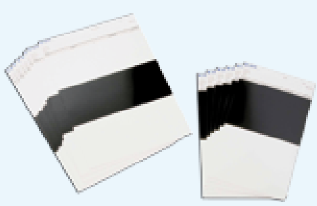
However L*a*b* values calculated for one illuminant are the same for both specimen, but are different for a second and third illuminant.The graph below shows measurements taken with the spectro-guide. The red line represents a metameric sample: the Da* and Db* values are significantly different for illuminant D65, A and F11 (TL84). In comparison the sample charted in blue has values that are very similar for all three illuminants. Therefore it is not metameric.





Color differences are charted for three illuminants
D65/10°▲ A/10°● F11/10°■

Objective Visual Evaluation
byko-spectra



Test Chart
byko-charts

Harmonization of Automotive Interior Parts

How many hours do you spend in your car? Most likely you will say "many". Therefore, the interior design needs to reflect a comfortable ambience. Color and grain of the different components need to be harmonized. At the same time, low gloss is required to avoid any reflections in the windshield disturbing the driver. In order to achieve these goals, the variety of materials is the big challenge for every car manufacturer.

Color harmony

The design group specifies color, gloss and grain. Once a new color or material or process is approved, a new "style" is born – ready for implementation. At this point, the supplier quality group takes ownership and starts working with various part suppliers. Master standard plaques are developed with usually a flat and several grained areas. These are sent to the suppliers as their targets. The majority of interior colors are achromatic where our eyes notice even smallest differences. Therefore, the tolerances need to be very tight to guarantee a uniform look.

Typical color tolerances
Color: ΔL^*, Δa^*, Δb^* = +/- 0.5

Innovative technologies are needed to guarantee objective and reliable measurement data within these tight tolerances. Only testing instruments with excellent precision will be able to guarantee consistent color.

The spectro-guide S guarantees superior accuracy and excellent inter-instrument agreement due to innovative LED technology. It is unique as it measures both, color and gloss by the push of a button. Moreover, the spectro-guide S offers improved technical performance for 60° gloss in the low gloss range 0 - 10 GU.

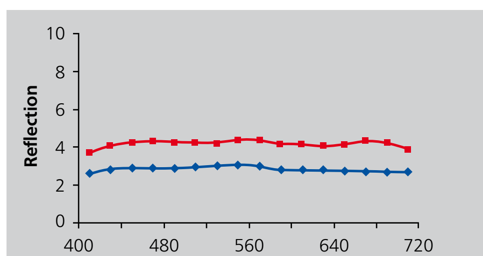
Instrument Geometry

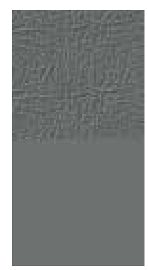
The automotive maker needs to define the measurement geometry to be used. There are two types of instruments: 45/0 and sphere geometry

45/0 – Control Color as you see it

The 45/0 geometry uses 45° circumferential illumination and 0° viewing perpendicular to the sample plane. A high gloss sample with the same pigmentation is visually judged darker by the eye when compared to a matte or structured sample. This is exactly what a 45/0 instrument measures:

Differences in gloss/texture → Color differences





Example: automotive interior plaque
Difference between two grains: ΔE^* = 3

BYK-Gardner Solution

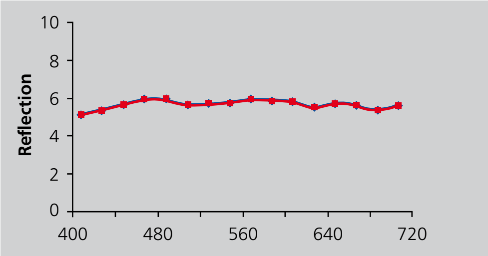
Solid Color & Gloss
spectro-guide S

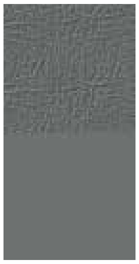
Sample Holder
Small Parts 11 mm

d/8 – Control the hue of Color

A sphere geometry illuminates the sample diffusely by means of a white coated integrating sphere. Color is measured independent of the sample's gloss or surface texture.

Differences in gloss/texture ↛ Color differences





Example: automotive interior plaque
Difference between two grains: ΔE* = 0

Solid Color & Gloss
spectro-guide

Objective Visual Evaluation
byko-spectra

In order to control gloss within very tight tolerances excellent technical performance is needed. The micro-gloss S was especially designed for matte finishes with small tolerances: The technical performance for 60° gloss in the low gloss range (0-10 GU) was improved to guarantee a repeatability of +/- 0.1 and inter-instrument agreement of +/- 0.2.

International standards provide different angles of incident for gloss measurement, namely 20°, 60°, and 85°. The choice of geometry depends on whether one is making a general evaluation of gloss, comparing high gloss finishes or evaluating low gloss specimens for sheen. The 60° geometry is used for comparing most specimens and for determining when the 20° or 85° geometry may be more applicable. The 85° geometry is used for comparing specimens for sheen or near grazing shininess. International standards recommend to use the 85° geometry for specimens with a 60° gloss value lower than 10.

Gloss Control

In order to avoid any disturbing reflection in the windshield a matte surface finish is essential. Additionally, a matt surface implies a more luxurious feeling. The challenge is to achieve low gloss appearances using different materials with different grains. The smallest gloss variations of a matte surface will be immediately recognized. Thus, very tight tolerances for gloss are needed.

Typical gloss tolerances
60° Gloss: < 5 GU +/- 0.3 to 0.5

Instead of working with absolute gloss numbers the supplier production QC needs to be based on the signed-off part and only the differences should be checked. This procedure eliminates the reproducibility error – the gloss is measured relatively on the same type of material and same surface. Therefore, a difference of 0.3 gloss units from part to part can be considered as a significant difference.

Gloss level	60° value	Recommended geometry
Semi gloss	10 to 70 units	60° geometry
High gloss	> 70 units	20° geometry
Low gloss	< 10 units	85° geometry

With this explanation in view, one might wonder: Why is the 60° geometry still specified by car manufacturer to evaluate gloss of matte surfaces? There are two main reasons. First of all the 85° measurement area (5 x 38 mm/0.2 x 1.5 in) is often too large for evaluating small and curved parts. Secondly, there are many grains with deep and large valleys which at a certain depth would trap light illuminated at a low gloss angle.

BYK-Gardner Solution

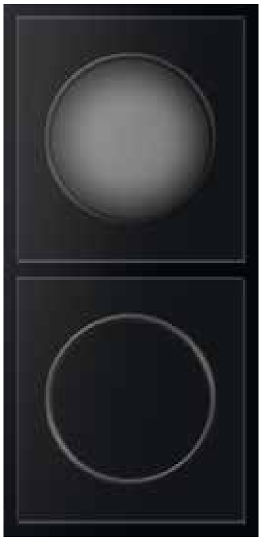
Solid Color & Gloss
spectro-guide S

Sample Holder
Small Parts 11 mm

Gloss
micro-gloss S

Fogging Test

High temperatures can cause polymers, textiles and natural materials used in automotive interior to outgas volatile and semi-volatile organic compounds (VOC and SVOC). The term "Fogging" refers to the film that collects on the inside of vehicle window glass. Of particular interest is the windshield, as fogging is potentially creating a visibility and safety problem for the driver. Therefore, the fogging test has become an important means for automotive manufacturers as well as their part suppliers to control product quality.



International standards outline three methods for determining the fogging characteristics of interior materials: the reflectometric method, the gravimetric method and the haze method.

Fogging Behavior DIN 75201 – Reflectometric method

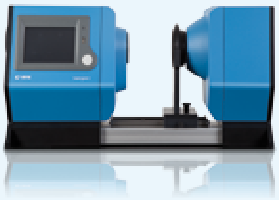
According to the reflectometric method, a prepared sample is placed in a beaker that is then covered with a glass plate. The plate's specular reflectance is measured and recorded using a 60° gloss meter.

For a period the sample is heated, while the glass plate is cooled. The heat causes the sample to release gasses that condense on the cooled glass plate creating a "Fog". The 60° specular gloss of the fogged glass is measured.

Fogging Behavior – Haze method

The haze method uses the same process as the reflectometric method, but instead of gloss, the transmission haze is measured. The haze-gard i measures the light transmission through the glass plate both before and after the fogging process.

Standard	Title
DIN 75201	"Determination of the windscreen fogging characteristics of trim materials in motor vehicles"
ISO 17071 DIN EN 14288	"Leather – physical and mechanical tests – determination of fogging characteristics"
ISO 6542	"Rubber- or plastic coated fabrics – determination of fogging characteristics of trim materials in the interior of automobiles"
SAE J1756	"Determination of the fogging characteristics and interior automotive materials"



Transparency
haze-gard i, horizontal

Transparency
haze-gard i, vertical

Overall Harmony of Consumer Electronics

Design knows no limits. This is also reflected in the world of consumer electronics such as notebooks, printers, mp3-players, phones, cameras or home appliances in general. For example, as smartphones have become our permanent companions their look including design and color is most important and follows current fashion trends! Depending on the preferences of a specific target group manufacturers offer a variety of colors with glossy or matte surface finishes which need to be controlled.

What most consumer electronics have in common is that they are so called multi-component products. Uniform color and gloss of all parts will create a valuable look and is perceived as a high-quality product. In order to guarantee consistent quality a routine QC management system needs to be established among the complete supply chain.

Color and gloss instruments with excellent precision for toughest QC requirements

A variety of materials, from plastic to metal to screen printed glass, are used for consumer electronics and need to be harmonized. Therefore, color and appearance has to be controlled in the daily production process according to

”customer relevant” tolerances. Neutral colors only tolerate very small color deviations and require very tight tolerances. High chromatic colors will accept larger tolerances, but are dependent on its hue. Only testing instruments with excellent precision like the spectro-guide or BYK-mac i will be able to objectively control any color.

Color measurement of solid colors

As an example, the majority of vacuum cleaners are produced in high chromatic solid colors. The overall appearance is influenced by color and gloss. In order to ensure uniform quality, both attributes need to be controlled. The spectro-guide spectrophotometer is the ideal solution for this task, as it measures color and gloss simultaneously. Thus, the cause of a mismatch can be clearly identified.

Small parts like keyboards buttons or smartphone switches require a color instrument with a very small aperture and a repeatable sample placement. The color-guide with a 4 mm aperture together with the optional sample holder guarantees repeatable results and a convenient sample placement.

BYK-Gardner Solution

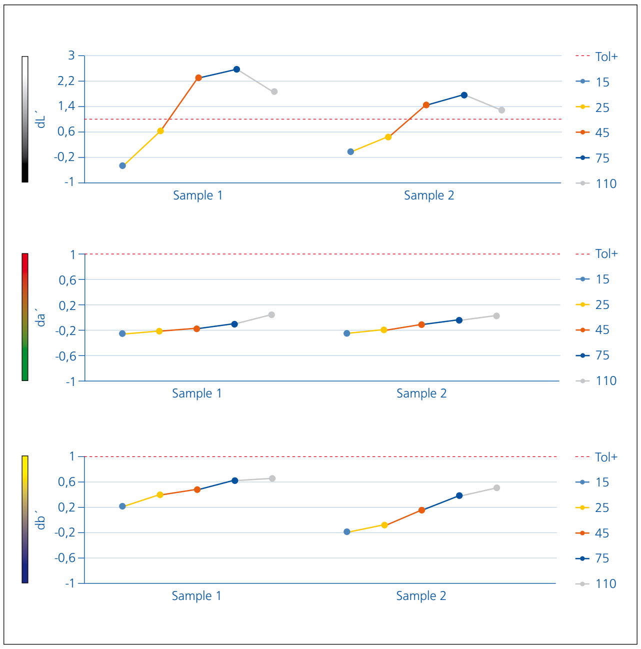
Solid Color & Gloss
spectro-guide, 11 mm

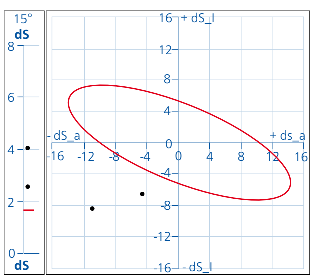
Solid Color
color-guide, 4 mm

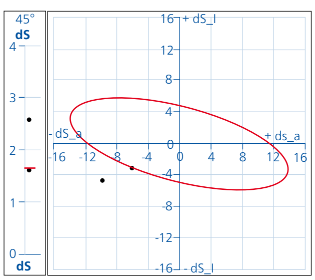
Sample Holder
Small Parts 4 mm

Color measurement of effect colors

In contrast to solid colors, products with effect finishes change their appearance with viewing angle and lighting conditions. This is a special challenge on parts with very tight fits. For example on notebooks, the track pad and the surrounding housing should have the same color and appearance even though both parts are made of completely different materials. In the following graph color and effect data (sparkle and graininess) obtained from BYK-mac i help to analyze a potential cause of a total color mismatch. Lightness as well as sparkle considerably vary between the reference and the two samples. For small parts the BYK-mac i with a 12 mm aperture can be used together with a specially designed sample holder.

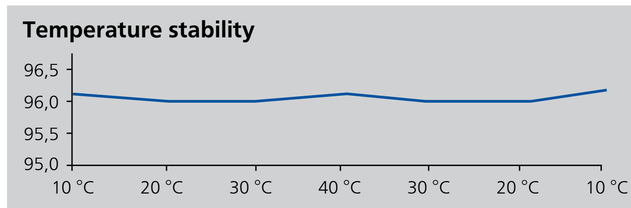






Measurement of gloss

The control of gloss on all parts of consumer electronics is as important as the color matching. If one component has a different gloss level than the rest, the consumer will immediately recognize it as different and associate it with "inferior quality". Gloss is highly dependent of the mold condition and variation of process parameters such as mold temperature, injection rate or material variations. Therefore, especially high volume products require routine gloss check. Depending on the product specifications the accepted gloss variations can be as small as +/- 0.5 gloss units. Objective measurement results that are repeatable and temperature independent are most important in harsh mass production processes. The micro-gloss has been the unsurpassed industry standard guaranteeing accurate and reliable readings under any circumstances.



Lightfastness and UV stability tests

Consumer electronic products are exposed to varying lighting conditions every day. To ensure aesthetic endurance, it is of high importance that the materials are lightfast. Hence, accelerated weathering tests are performed, which simulate the effects produced by exposure to daylight filtered through window glass. Specimens are exposed to a xenon-arc light source for a defined number of hours and specified conditions. The extend of degradation varies depending upon the properties of the raw materials. The spectro-guide spectrophotometer is the ideal solution to quantitatively measure color fastness using ΔL*, Δa*, Δb* for achromatic colors or using ΔL*, ΔC*, ΔH* for chromatic colors.

Multi-Angle Color & Effect
BYK-mac i 12 mm

Sample Holder
BYK-mac i 12 mm

Gloss
micro-gloss

Quality Control for Injection Molding

In plastics processing injection molding is the most common method of part manufacturing. The variety of molded parts produced by injection molding extends from smallest components like cell phone buttons up to entire body panels of cars. Plastic moldings are manufactured in production batches of up to several million. In addition to dimensional stability, color and gloss are the decisive quality criteria.

In principle injection molding consists of high pressure injection of the raw material into a mold which shapes the polymer into the desired shape. Initially, plastic material, usually supplied in granular or powder form by the raw material manufacturer, is fed by gravity from a hopper into a heated barrel with a reciprocating screw. As the raw material is moved forward in the heated barrel by the screw, the granules get mixed, homogenize and melt. Following the plasticizing process, the hot molten plastic material is injected through the axial feed of the screw under high pressure into the mold. For thermoplastic materials, the melt needs to be cooled in the mold to ensure the necessary dimensional stability. Once the part is sufficiently cool, the mold opens and the part is ejected.

Influence of plasticizing

Melt temperature

High influence on color & gloss:
- Higher temperature → darker, lower saturation

Dwell time

Medium influence on color & gloss:
- Longer dwell time → darker, lower saturation

Screw speed

Low influence on color & gloss:
- Parts tend to be brighter

Influence of molding parameters

Mold temperature

High influence on gloss:
- Polished mold: Higher temperature → gloss ↑
- Eroded mold: Higher temperature → gloss ↓

Injection rate

Medium influence on color:
- Higher rate → amorphous thermoplastics tend to be brighter
- Higher rate → Depending on material slightly different impact on color change

High influence on gloss:
- Polished mold: Higher rate → gloss ↑
- Eroded mold: Higher rate → gloss ↓

Influence of flow distance
- Amorphous thermoplastics → tend to be darker, brighter
- Semicrystalline thermoplastics → tend to be brighter

Influence of material:

PP/PMMA

Very color stable

Polyamide/ABS

Sensitive to color change (especially in b-value)
- Higher melt temperature → darker
- Higher melt temperature → increased yellowness

BYK-Gardner Solution

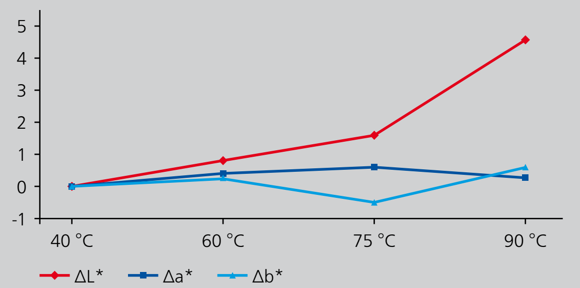
Solid Color & Gloss
spectro-guide

Sample Holder
Small Parts 11 mm

Production Process Control

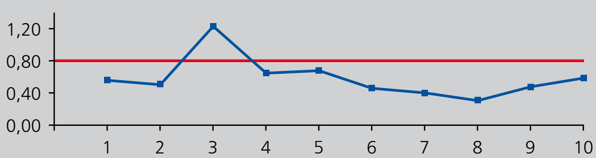
The challenge of an economical production is the reduction of cycle time to achieve a higher output. Reduced cycle times can only be achieved by increased production speed, coupled with increased temperature or pressure. Changes to these process parameters, will have a direct impact on color as well as on gloss. Due to the complexity of the production process an objective QC system is needed to guarantee a high quality product at the end.

ABS plaques produced at varying mold temperature



In order to guarantee consistent color and gloss a frequent sampling rate is needed depending on total production rate.

Tolerance ΔE*



As some colors might change depending on temperature (= thermochromism) the measurement should always be performed at temperature of the final product to achieve comparable results.

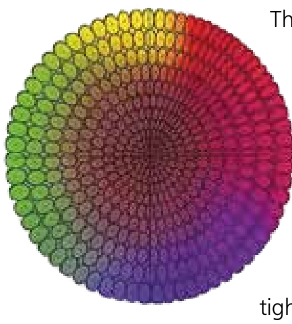
Thermochromism:

A temperature-induced and completely reversible change of the absorption behavior of a material in the visible range.

Overall Harmony

Uniformity and consistency of color is percieved as high quality. Many finished products consist of multiple components. Most of the time, the components are manufactured by different suppliers and at different locations. But in the end the assembled product should be uniform in color. Thus, not only the production process needs to be controlled, but also the overall harmony of the finished product. Color tolerances are dependent on the application and the hue.

Studies have shown that CIE Lab color space is not uniform.



The above diagram shows the CIELab color space divided into an infinite number of ellipsoidal micro-spaces. All colors within one ellipse are perceived as the same color. Reason being, a difference in hue is more obvious than a difference in chroma. Tolerances for hue must be tighter. Chromatic colors have larger ellipses than achromatic colors. Therefore, larger tolerances can be used. The size and shape of the ellipses are different dependent on the hue. Thus, tolerances need to be defined by color families. Over the years new color systems and equations (ΔECMC – ΔE94 – ΔE99 – ΔE2000) were developed based on visual comparison studies for solid colors to improve the visual correlation.

Gloss
micro-gloss

Objective Visual Evaluation
byko-spectra

Consistent Quality for Profile and Pipe Extrusion

You are looking out of your window directly onto your beautiful terrace. Both, window profiles as well as decking material, have been selected from most modern materials and with great attention to the detail. Now, what does this have to do with color & appearance control? A whole lot!

Plastic is the most versatile and important material in today's world. In the past plastic products were often considered as cheap and having inferior quality. This image has completely changed over the years and depending on the application it might be preferable compared to a natural product. For example more than 50 % of all installed windows worldwide are made of plastic – a trend consistently growing. Development of new, innovative plastic materials is especially demanded for outdoor applications. Thermoplastic WPC (wood-plastic composites) products have only been in existence for a few years and are gaining rapidly market share. Manufacturers use the feature "consistent color and gloss over 10/15/20 years" as an essential quality criteria to differentiate themselves from competition. Thus, weathering resistance needs to be carefully and objectively tested.

Weathering Ageing Test

Weathering is a routine performance test to determine durability of plastics under extreme weather conditions. The most popular areas for weathering studies are located in Arizona and South Florida. Samples can also be placed into weathering chambers performing accelerated tests to simulate changes in temperature, humidity and UV levels.

Weathering:
A photochemical process in which a combination of water, time, temperature variations and UV radiation can alter material properties.

When plastics are used outdoors, weathering can damage general polymer properties. Most of the damage in plastics results from UV radiation. The extend of degradation varies depending upon the resin system, additives, colorants, stabilizers and processing conditions.

Typical effects may include:
- Surface Chalking
- Color & Gloss changes
- Embrittlement

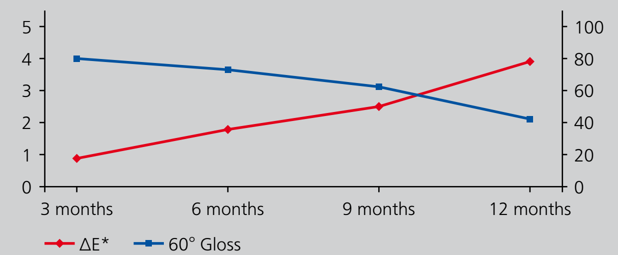
Some colorants such as Carbon Black are UV absorbers which act as UV stabilizers. Other colorants which are not UV stable will undergo degradation and pigments and dyes will change color. Inorganic pigments tend to turn dark and dull, while organic pigments and dyes tend to fade in color. Thermoplastic and thermoset resins degrade and typically yellow upon exposure. The color would usually appear lighter in the L* value and yellower in the b* value.

BYK-Gardner Solution

Solid Color & Gloss
spectro-guide

Gloss
micro-gloss

Objective Visual Evaluation
byko-spectra



Weathering of PP decorative trim

Yellowness Index

For near-white or near-colorless products – like window profiles – an one-dimensional number is calculated from the spectral data, the so called Yellowness Index. This index quantifies the degree to which a sample's color shifts away from an ideal white. The larger the value, the more yellowish the sample appears.

$$YI = 100 \times \left[1 - \frac{0.847Z}{Y}\right]$$

Typically the Yellowness Index of the reference is measured, which represents the ideal white. Samples (or changes) are compared to the reference and differences are calculated. Positive values will indicate that the sample is more yellow. Negative values will indicate that the sample is more blueish.

Very often such samples do not strictly appear just yellow, but show a significant difference in hue and lightness. Therefore, a three dimensional description of color using ΔL*, Δa*, Δb* differences is getting more and more popular.

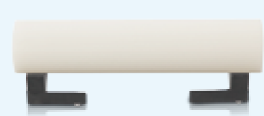
Measurement of Curved Parts

Curved plastic samples like pipes reflect color differently than flat samples. As light is projected onto the surface of a curved sample, the curvature changes the direction of the specularly reflected light. To accurately access the color of the curved sample, the total reflected light must be measured.

In order to achieve good measurement results, the curvature radius of the sample to be measured shall surpass ten times the diameter of the measurement aperture. If this ratio can not be maintained, it is recommanded to use a fixture which allows your sample to sit flat against the aperture of the instrument. Additionally, the fixture should serve as a baffle to block out excess light.

Averaging the measurement from several different areas will give good overall representation of the surface characteristics.

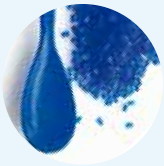
Sample Holder
Curved Parts



Curved Parts Accessory
Cylinder Kit

BYK-Gardner Solution for Plastic Parts

Raw Materials



Molded chips

Accessory
- byko-charts

Pellets

- Glass Sample Cup
- Wet Drawdown Template – C

Autmotive Interior

small – large parts
flat – curved parts

Accessory
- Sample Holder “Small Parts 11mm” for spectro-guide

Injection Molding

small – large parts
flat – curved parts

Accessory
- Sample Holder “Small Parts 11mm” for spectro-guide

Profile/Pipe Extrusion

flat – cylindrical parts

Accessory
- Sample Holder “Curved Parts”
- Curved Parts Accessory - Cylinder Kit

Consumer Electronics

small – large parts
flat – curved parts

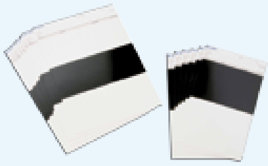
Accessory
- Sample Holder “Small Parts 4mm” for color-guide
- Sample Holder “BYK-mac 12 mm”

Plastic Accessories

Glass Sample Cup
Cat. No. 6136

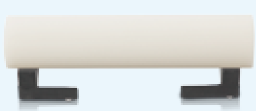
Template – C
Cat. No. 6445

Sample Holder
Small Parts 11 mm
Cat. No. 6845

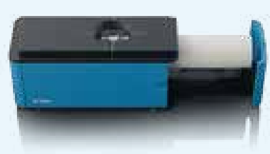


byko-charts
Cat. No. 2812

Sample Holder
Curved Parts
Cat. No. 6459



Curved Parts Accessory
Cylinder Kit
Cat. No. 6464



Sample Holder
Small Parts 4 mm
Cat. No. 6825

Sample Holder
BYK-mac i 12 mm
Cat. No. 6408

BYK-Gardner Solution for Plastic Parts

BYK-Gardner Objective Eyes

BYK-mac i

Multi-Angle Color and Effect Control.

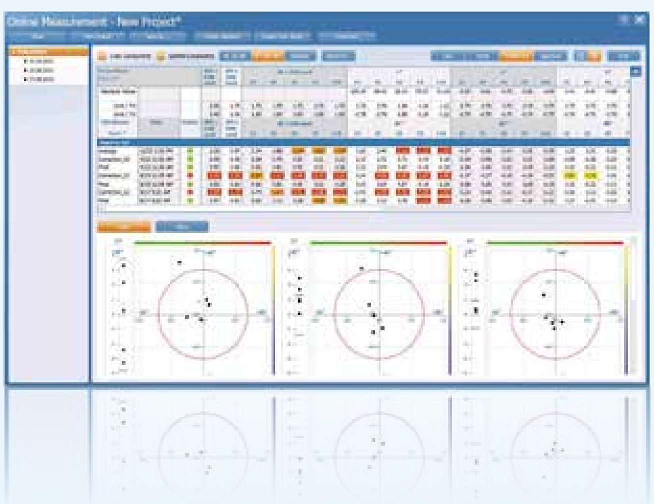
Cat. No. 7034 - 12 mm I Cat. No. 7030 - 23 mm

spectro-guide

Total Appearance Control. Color and Gloss in One Unit.

Cat. No. 6834 - sphere I Cat. No. 6801 - 45/0
Cat. No. 6836 - sphere S I Cat. No. 6802 - 45/0 S

BYK-Gardner Software



smart-lab

Online Measurement. Instant Data Analysis.

Cat. No. 4862

haze-gard i

The Objective Standard for a Clear View.

Cat. No. 4775

micro-gloss

The New Intelligence in Gloss Measurement.

Cat. No. 4446 - micro-TRI-gloss I Cat. No. 4452 - micro-TRI-gloss S

BYK-Gardner Light Booth

byko-spectra *effect*

Visual Evaluation of Effect Finishes.

Cat. No. 6027

byko-spectra

Simulation of Different Lighting Conditions for Visual Color Evaluation.

Cat. No. 6047

For a live demo please view our videos on **www.byk.com**

BYK-Gardner GmbH
Lausitzer Straße 8
82538 Geretsried
Germany
Tel. 0-800-gardner
(0-800-4273637)
+49-8171-3493-0
Fax +49-8171-3493-140

BYK-Gardner USA
9104 Guilford Road
Columbia, MD 21046
USA
Phone 800-343-7721
301-483-6500
Fax 800-394-8215
301-483-6555

BYK-Gardner Shanghai Office
6A, Building A
Yuehong Plaza
No. 88 Hongcao Road
Xuhui District
Shanghai 200233
P.R. China
Phone +86-21-3367-6331
Fax +86-21-3367-6332

225 023606