

Color Measurement for the Coatings Industry

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[Bibliography](#)10-2

Color is the most important appearance of coatings for their formulation, application, or inspection. Color is also the most subjective parameter to characterize visually, and characterization is often attempted under uncontrolled conditions that result in poor color judgement. Proper viewing conditions require controlled lighting in a viewing booth where the different types of light, such as simulated daylight, tungsten, and fluorescent light sources, can be used for evaluation. Visual evaluation always requires a physical standard for comparison because the “color memory” of the brain is quite poor without one, but very good when two samples are compared beside each other. Even when proper viewing conditions are used, it is often difficult to determine the direction and intensity of color difference between two samples. This process requires a trained colorist to make the evaluation.

A more accurate and consistent approach to evaluate color difference is the use of a color measurement instrument. The two types of instruments that can be used for this purpose are colorimeters and spectrophotometers. A colorimeter uses optical filters to simulate the color response of the eye, and a spectrophotometer breaks the visible spectrum into intervals that mathematically simulate the color response of the eye. The advantage of using spectrophotometers to determine color difference is in their accuracy, stability, and ability to simulate various light sources. Spectrophotometer cost and complexity of operation are greatly reduced on new versions of the instruments.

There are three different technologies that are used in modern industrial spectrophotometers: interference filters, gratings, and light-emitting diodes (LEDs). Interference filters require a filter for each wavelength measured and usually have 16 or 31 filters depending on the resolution required. Grating-based instruments have diode arrays of 20 to 256 elements to provide higher resolution for applications that require it. The advantage of interference filters is in their simplicity of operation and mechanical ruggedness. However, they are difficult to make consistent and deteriorate over time. High-performance instruments usually have gratings that give more resolution and better consistency, but they are usually more expensive and complex to build and calibrate. A new market entrant for spectrophotometers is based on LEDs of different illumination colors. Up to nine separate color LEDs are now available to cover most of the visible spectrum. The instruments operate by illuminating one LED at a time while measuring the reflected light. The advantage is that they can be made very small and cost less to manufacture. The disadvantages are reduced accuracy and stability, but the technology is improving with the advent of newer LEDs with better methods for compensation.

There are several different measurement geometries: sphere, 45/0, and multiangle. A sphere instrument illuminates a sample from all directions and views the sample at near normal or perpendicular. The 45/0 illuminates the sample at 45 degrees from all directions and views the sample normal. It is also possible to illuminate at 0 and view at 45. The multiangle approach illuminates at multiple angles and views at a fixed angle. It is also possible to illuminate at a fixed angle and view at multiple angles.

The use of proper geometry is important for color formulation or color inspection. Color formulation with sphere geometry eliminates the need to characterize the gloss and mathematically removes the gloss that is independent from the color formulation. Color inspection usually requires the instrument to have agreement with visual methods. A 45/0 instrument will give better correlation to visual assessment because it better approximates the conditions in a viewing booth. A sphere instrument with a specular exclusion port can eliminate sample high gloss to give good visual correlation but has difficulties with semigloss samples. The assessment can yield misleading information. This is very important when trying to match a coating to a plastic molded part.

Effect pigments such as metallic, pearlescent, and interference materials require multiple angles of illumination and viewing to characterize color at different angles. Multiangle instruments or goniospectrophotometers are available to measure three to five separate angles. A minimum of three angles are usually required to characterize effect pigments: (1) the near specular at 15 to 25 degrees from gloss, (2) 45/0, and (3) far from gloss of 75 to 110 degrees.

Consideration of the sample type to be measured should determine the variety of spectrophotometer to use. If samples are large and cannot be brought to the instrument, the instrument needs to be a portable. There are high-performance portable instruments for each geometry, but consideration should be given to the correlation to laboratory instruments because the communication of the measurements to a color lab is often required. If very small samples such as paint chips or small color bars are measured, the measurement aperture needs to be small. If the sample is nonuniform, the aperture should be as large as possible. Many instruments have changeable apertures that can be used for both samples. Fluorescent coatings require a spectrophotometer with a carefully controlled illumination source that is usually specified as daylight. Tungsten does not have the necessary ultraviolet and cannot be used as a good daylight simulator. However, pulsed xenon is a very good daylight simulator and can be adjusted in some instruments to match the spectrum of natural daylight exactly.

The required tolerances for color measurement are one of the most important considerations when selecting a color measurement instrument. If the comparison is always to a physical standard, and the formula is the same, a colorimeter can be sufficient. When high accuracy is needed for producing coatings in different locations throughout the world using numerical standards, only the very high-end instruments will be capable of results within acceptable visual agreement.

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