Color Measurement. The exhibit presented largely color measurement solutions for automatic control of typical materials such as plastic pellets, masterbatches or semi-finished goods, exemplifying the trend toward fully automatic control of color.

Color under Control

Before plastic products are ultimately produced by means of extrusion or injection molding, an objective color check is absolutely necessary today. Only products whose appearance and color match can be sold at the agreed-upon price. However, a truly objective color evaluation in the course of the overall production sequence always consists of a visual check and an objective check by means of color measuring instruments.

Fig. 1. Calibrated LED lighting technology for use in standard light booths (photo: Schröder)

Visual Color Check with the Aid of LED Lighting

Accurate reproduction of color on the basis of a color standard is an essential prerequisite when it comes to meeting the ever more demanding requirements for quality assurance and the pressures to reduce costs. In addition to quality control on the basis of measurements, a visual assessment of the color matching attainable most important prerequisite. Illumination has the greatest influence when evaluating samples visually. Improper lighting can lead to incorrect evaluations and unavoidably to complaints as well as increased production costs.

Metamerism to DIN 6172

Colors, pigment and dyes can appear to give the same visual impression of color even though they differ in terms of chemical or spectral composition. It is often required that different materials have identical colors, for instance, the fabric used in a car's interior and the plastic instrument panel. If such materials are judged under different lighting conditions, they may seem to be identical when viewed under one defined standard light source, but appear completely different under another light source.

The color matching systems that are employed today and which are based on the use of fluorescent lamps satisfy current standards for color matching. The fluorescent tube is a practical light source for a color matching box, but the spectral distribution of these tubes exhibits several peaks that result from the different gas discharge processes taking place within the fluorescent lamp and which can have an effect on the color rendering properties of the lighting. Aging of the fluorescent lamp poses another problem. The color of the light generated by the types of phosphors used in fluorescent lamps changes with age. This color shift is perceived quite readily by the human eye. While alternative light sources such as filtered halogen light or xenon are good simulators of different daylight spectra, they are very expensive and short lived.

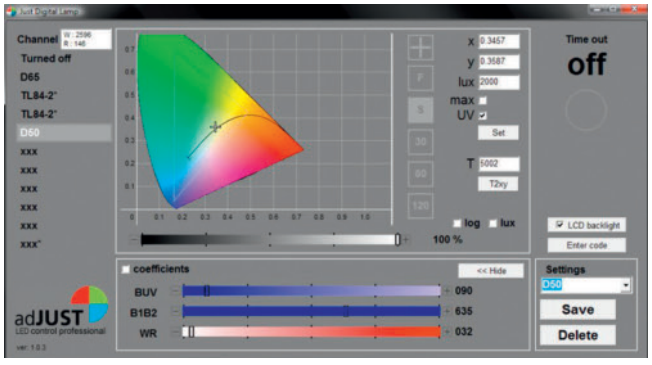

Fig. 2. Software for the new light booth (photo: Just Normlicht)

Just Normlicht GmbH, Weilheim, Germany, has succeeded for the first time in developing a multi-spectrum LED light source with which any light spectrum can be created at a high quality level. Using this multi-spectrum LED light source, it is possible to simulate not only the D65 types of daylight, but also other types of light such as A, C, D50, D55, D75 and any type of artificial light at an exceptionally high quality level. To prevent metamerism caused by optical brighteners, UV components are also incorporated.

The LED Color Viewing Light **(Fig. 1)** is the first standard light source in the world that utilizes LED technology in a multi-stage, controlled calibration procedure and against which each individual multi-spectrum LED light source can be calibrated continuously during operation.

By using this modern lighting technology, it is now also possible to simulate a huge color space with extremely high quality with the aid of special software **(Fig. 2)** and in this way incorporate all possible appli-

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Fig. 3.
The Gonio Vision Box (photo: Cramer, Münster)

cations in a single device. An additional major benefit is the tenfold longer service life of LED light sources compared to conventional fluorescent tubes and an almost 100-fold longer service life compared to halogen lamps with a filter.

Visual Evaluation of Special-effect Surfaces in Accordance with ASTM E 2539-2008

Conventional standard light booths are not adequate for visual evaluation of special-effect surfaces. In the new Standard ASTM E 2539-08 – Standard Practice for Multiangle Color Measurement of Interference Pigments – two illumination directions are recommended:

- 45° illumination in conjunction with measurement and evaluation at six angles: -15°, 15°, 25°, 45° , 75° and 110° of gloss.
- 15° illumination in conjunction with measurement and evaluation at two angles: -15° and 15° of gloss.

According to the standardization organization ASTM International, West Conshohocken, Pennsylvania, USA, this arrangement is necessary to optimally describe differences in the case of interference pigments. This measuring setup is also found in the latest multiangle color measuring instruments such as the BYK-mac (**BYK-Gardner GmbH**, Wesel, Germany) and the X-Rite MA98 (**X-Rite Europa GmbH**, Regensdorf, Switzerland, or **X-Rite Inc.**, Grand Rapids, MI, USA).

It is precisely the new color effects on painted plastic parts from suppliers in the automotive industry that these different illumination directions and observation angles are required.

The Gonio Vision Box developed by **Merck KGaA**, Darmstadt, Germany, satisfies all of these conditions. This tool is constructed in a way that permits simulation of all color measuring systems currently on the market. As a result, the user is able to visually reproduce the color differences measured by a multiangle measuring instrument **(Figs. 3 and 4)**.

Objective Color Measurement Starts with the Raw Materials

Color measurement is a method that has been used for years to check color quality. This test is generally performed on the finished product using samples that have been selected from production manually or by means of automated measurement methods.

The following three approaches can be distinguished:

- Offline: The measurement results become available after several hours, making it virtually unsuitable for intervention in the process. Offline measurements are performed in laboratories for the most part.
- Online: The measurement result (based on samples from the finished product) becomes available in seconds, but quite a bit later in the course of the process, making it only conditionally suitable for possible intervention in the process in time. This method is employed with either the finished product or semi-finished product for the most part.
- Inline: The measurement result becomes available in seconds, directly in the melt at the extruder outlet, making it highly suitable for immediate intervention in the process.

Inline Color Measurement Directly in the Plastics Melt

ColVisTec AG, Berlin, Germany, presented an inline color measurement technique that for the first time permits use of spectral color measurement directly in the plastics melt. Continuous color measurement directly in the plastics melt in the extruder means uninterrupted documentation of changes in the process and permits immediate intervention when tolerances are exceeded. Full information about the homogeneity of the plastics melt and possible drifts are caused by process parameters such as temperature, pressure and extrusion rate fluctuations or selection of the wrong screw components →

Fig. 4. Special-effect paints require special light booths (photo: Cramer, Münster)

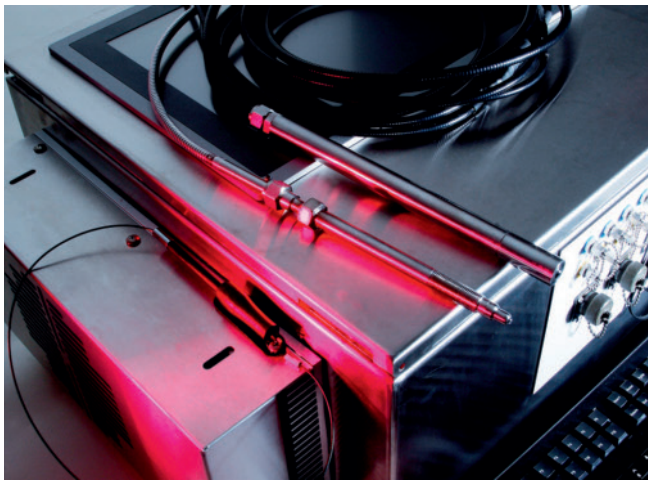

Fig. 5. RPMP measuring probe for installation in an extruder (photo: ColVisTec, Berlin)

and variations in the metering and quality of the raw materials used. Individually or in combination, these always lead to color changes and thus quality problems. Using inline technology, these are detected immediately and prevent production of a faulty batch or contaminated product.

The heart of inline color measurement is a spectrophotometer. This spectrophotometer, however, differs considerably from the spectrophotometers used to date in the offline approach. Based on a combination of glass fiber technology and special optical components, a very fine resolution with very stable results is achieved. Extensive software suitable for process control completes the system, which is easy to operate and can be readily incorporated into process management.

Fig. 7. Hunterlab SpectraTrend for use with plastic pellets (photo: Schröder)

The special RPMP probe (Reflection Polymer Melt Probe) was developed specifically for application in the plastics melt directly in an extruder.

The probe's tip, with a self-cleaning sapphire lens as the observation window, is equipped with the well-known 1/2″-20 UNF thread size (type: Dynisco) for installation in the extruder. It can be installed very easily in an existing threaded hole at the extruder outlet. The best-suited position is the chamber between the end of the screw and the die.

Fig. 6. Online color monitoring and control system (photo: X-rite Inc.)

This new, continuous monitoring based on inline color measurement is intended to minimize rejects and avoid the immense costs associated with work time, delivery delays, raw material usage and recipe optimization while providing uninterrupted verification of quality **(Fig. 5)**.

System for Controlling Color of Extruded Plastic Products

X-Rite Inc. and **Plastore Inc.**, Hudson, OH, USA, introduced an automatic control system for online monitoring of extruded products such as plastic window profiles **(Fig. 6)**.

The system employs colorimetric data from the VeriColor Spectro inline spectrophotometer from X-Rite for automatic control and adjustment of the material feed rate in order to maintain the preset color tolerances. At the same time, the system detects bulk density variations in the color concentrate and color changes that are caused by surface changes. Thanks to ACLCC (Automated Closed-Loop Color Control), the system achieves automatic control of color during ongoing production and, when necessary, automatic identification of non-conforming product, which can then be returned to the production process through use of additional gravimetric systems.

Hunterlab Inc., Reston, VI, USA, also presented a very versatile, cost-effective spectrophotometer in the form of the SpectraTrend HT for online process monitoring of products ranging from plastic pellets to extruded semi-finished goods. It operates extremely effectively when used for standard color deviations between the product and an ideal standard. The ColorTend HT features non-contact measurement, product monitoring and transmits the information about color and possibly height to the hand-held operating terminal, the utility software or the optional analog output. The sensor requires no direct contact with the product and is thus ideally suited for a variety of plastic products.

The system operates with a 0°/30° measurement geometry and uses the latest LED illumination technology, making it independent of ambient lighting conditions **(Figs. 7 and 8)**.

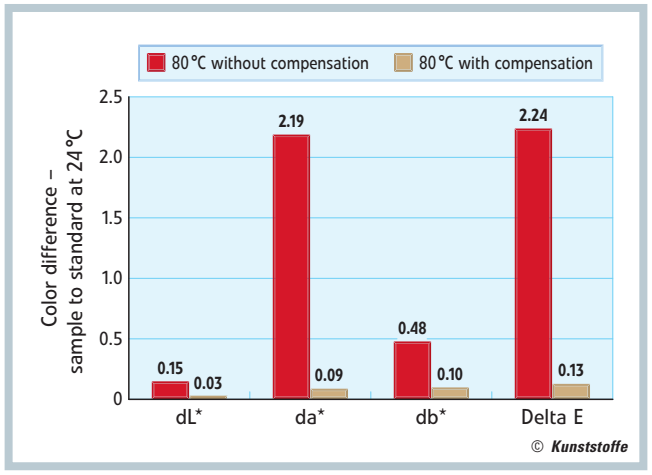

Fig. 9. The color of the end product can be established immediately through use of temperature compensation in an online process (photo: ColorLite GmbH)

Online Measurement Even on Hot Injection-Molded Parts

Fully automatic online color measurement that can be integrated directly into the production of injection molded parts represents one approach to time- and cost-saving production. A prerequisite is high reproducibility of the measurement results in spite of fluctuating temperatures. Until now, the problem was that the color was affected by the temperature. This meant that color measurement could be performed only after the parts had cooled, resulting in an additional time delay. Accordingly, the effect of temperature when measuring the color of the hot parts coming from the production system had to be taken into account.

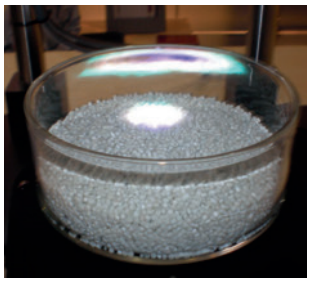

Fig. 8. Spectrophotometer with LED illumination independent of ambient conditions (photo: Schröder)

It was possible to develop a solution to this thermochromism problem in the course of a research project (funded by ZIM: Zentrales Innovationsprogramm Mittelstand) conducted jointly by **ColorLite GmbH**, Katlenburg-Lindau,

Germany, and the **Süddeutsches Kunststoffzentrum (SKZ) GmbH** (Southern German Plastics Center), Würzburg, Germany. It was observed that the temperature distribution within injection molded parts was very nonuniform. By simultaneously recording the temperature and spectral values at exactly the same position on the surface, compensation of the "thermochromism" takes place in real time, making it possible to adjust the color during the production process. The color is measured using a 45/0° geometry at a distance of 30 mm. Communication between the different evaluation and control systems presents no problems **(Figs. 9 and 10)**.

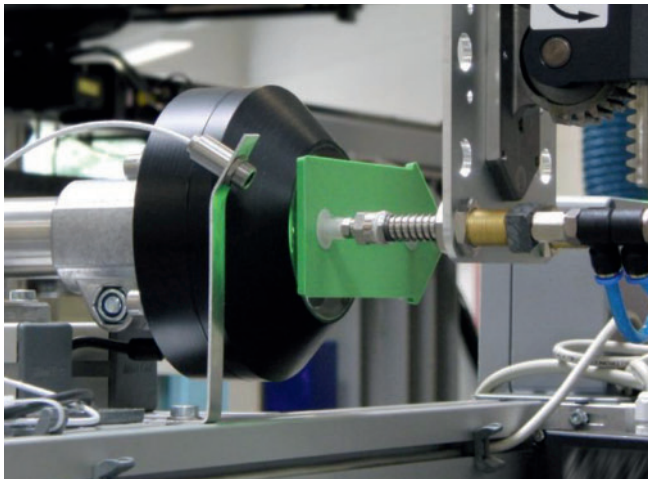

Fig. 10. Online color measurement at an injection molding machine with temperature compensation (photo: ColorLite)

Off-line Color Measurement on Various Plastic Products

Because of the wide variety of plastic products, the requirements for color measurement are extremely challenging. **Konica Minolta Sensing Europe B.V.**, Nieuwegein, Netherlands, introduced to the CM5, a universal color measuring instrument for almost all off-line laboratory measurements in the plastics sector.

The plastics sector encompasses materials ranging from raw materials such as pellets and color pastes, translucent and transparent semi-finished goods as well as finished products.

An instrument that can handle this wide range of products must be flexible not only in regard to measurement methods; it must also be easy to use. A basic requirement is minimal time for sample preparation, so that fast routine measurements in the laboratory as well as fast control of production are ensured **(Fig. 11)**.

The new CM-5 benchtop spectrophotometer from Konica Minolta offers exactly this combination of versatility and ease of use in order to meet all of the above requirements. The top port concept permits simple sample positioning and measurement of solid plastic samples and, through use of glass cuvettes, of samples in pellet or powder form as well. The instrument's cover can be slid to the side easily, giving access to the large transmission chamber for measuring transparent solids such as plastic film, preforms or other transparent plastic parts. Complete autonomy is assured by the extensive internal software in seven languages and a large color LCD display for numeric and graphical representation of measured data or simple pass/fail results. Additional functions such as automatic calibration, storage of individual user settings on a USB flash drive or the unique "user guidance" underscore the ease of use of the Konica Minolta CM-5.

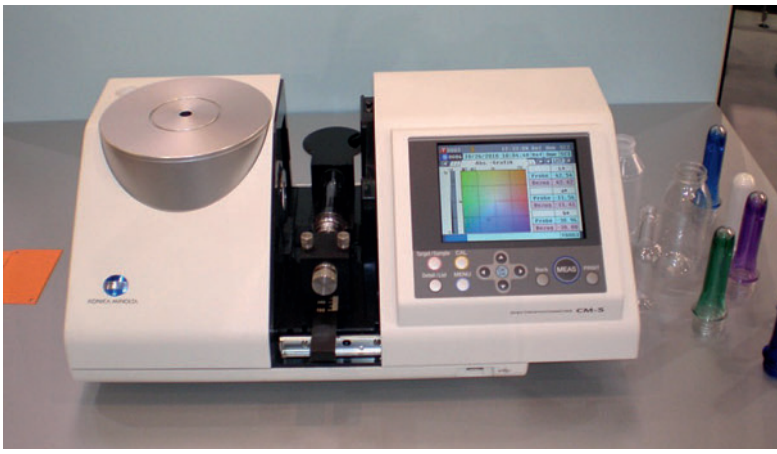

Fig. 11. CM 5 universal color measuring instrument being used to measure plastic preforms (photo: Schröder)

Conclusions

A variety of convincing systems for online and in-line measurement for color control was presented. Since the exhibits were largely the demonstration setups, it is still necessary to test these in actual practice. What is clear, however, is the trend to perform measurements as close as possible to the start of production. ■

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