Introduction to Coloring Plastics for Special Decorative Effects

COLORING BASICS

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This is the first of a 4-part series on the decorating of plastics. We usually associate "decoration" with secondary processes such as painting or affixing a decal or label. But the underlying color is important for several reasons. First, it is an integral part of the design and can greatly affect the final appearance. Also, special effect colorants, dealt with in Part 2, are decorative in their own right. Sometimes they eliminate the need for secondary processes to yield an eye-catching product. More often, they are used in combination with secondary decoration processes to produce unique visual effects. The remaining articles will cover secondary processes, with an entire article devoted to laser marking.

Perceived value determines what the customer is willing to pay for our products

The primary considerations are as follows: 1) Basic Functionality - Does it do what it's supposed to? 2) Quality and Reliability - Will it keep doing it as long as the customer needs it to? 3) Convenience Features - Is it easier to use than other products with the same functionality and reliability? and 4) Aesthetics - Does it address the customers' emotional needs?

Where does plastic decoration fit in? Plastic decoration deals directly with aesthetics. It increases the perceived value by satisfying the customers' specific emotional needs, and by removing emotional barriers, generates sales.

Color adds value

To gain a better appreciation for the role of color in plastic, we spoke to Ron Harris, Chief Technology Officer for Ferro's Color and Glass business unit. According to Dr. Harris, color adds value in several ways. "On the one hand, color is sometimes used to convey aspects of the company's brand. 'Coke Red' and 'Pepsi Blue' are examples. In the case of many consumer products, color is used to attract the eye and differentiate the product from those of the competition. One recent example that stands out is the Power Mac desktop computer, which is offered in 6 bright colors. Color can also be used to address functional aspects of the product design. For example, the distinctive yellow color now appearing in some plastic milk containers not only attracts you to the product but also helps the milk retain its flavor longer by screening out harmful light rays that can break down the Vitamin D. Similarly, the white and colored pigments used in rigid PVC home siding help protect the polymer by absorbing the sun's UV rays."

Harris adds, "Most people in our field understand that color arises from the interaction of visible light with the object being observed – a matter of absorption and reflection. If all wavelengths are reflected, we observe 'white'. If an object absorbs the blue end of the visible light spectrum, we observe yellow, as seen in the lenses of popular 'blue-blocker' sunglasses. Most are also familiar with the use of color to screen out UV radiation. Only recently are we learning how to use color to exploit the infrared (IR) region." These are the sun's heat rays. Several companies now are offering lines of IR reflecting pigments. Vinyl siding colored with such pigments stays relatively cool and resists warping and buckling.

On a final note, Harris commented, "Many designers fail to recognize that color becomes an integral part of the plastic material and should not be an afterthought. It has to be dealt with using a total systems approach. Yes, the color can enhance the part's functionality, but there's the

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potential for the color to degrade certain material properties, such as impact strength, if not done right." In dealing with clients for the past decade, the Sabreen Group has learned, for example, that some grades of titanium dioxide white pigment promote chain scission in polycarbonate, destroying its vaunted impact strength. Other properties that can be adversely affected by colorants are dimensional stability and gloss. Blow molders sometimes observe warping problems in the threaded necks of bottles due to pigments such as phthalocyanine blue and green. The resulting necks are out of round and do not mate properly with their injection molded caps. Also, if not dispersed properly, pigment particles at the surface of a colored part can scatter light diffusely and reduce gloss.

Color terminology

Given that color becomes an integral part of the material system, we now take a closer look at how we describe color, how we color plastic, and how the color can affect secondary decorating processes. Color formulators generally speak of color in terms of three attributes: Hue, Chroma, and Value. Hue describes the color in relation to Red, Orange, Yellow, Green, Blue, Indigo and Violet (ROYGBIV). Chroma relates to the purity and intensity of color. You reduce the chroma by adding white or black to the color formulation. Value refers to lightness/darkness. On a scale of 0 to 100, bright whites approach 100, and jet blacks approach 0. The desired color is achieved by mixing different pigments and dyes to match the Hue, Chroma, and Value of the target. Another important term is "metamerism." If two colors appear to match when viewed under one lighting condition (e.g., fluorescent light) but not others (daylight, incandescent), they are said to be metameric. Metamerism typically arises when two "matching" colors are formulated with different combinations of pigments and dyes.

Colorants are classified as pigments and dyes. They exhibit color through the combined effects of visible light absorption and scattering, and the color we observe is determined by the wavelengths of visible light that are reflected back to us. Typical color formulations contain four colorants. White and black are used primarily to control the Value and Chroma, and two colored pigments or dyes are used to establish the Hue. The resulting color is governed by the laws of Subtractive Mixing - the same laws governing color achieved through printing and painting. Your desktop digital ink-jet printer, for example, makes use of Yellow, Cyan, and Magenta colored inks.

Coloring plastics and its effect on secondary processes

Coloring plastic starts with colorant selection. Most colorants can be used only in a limited selection of polymers. Dyes, for example, have low solubility in polyethylene (PE) and polypropylene (PP) and migrate out. Polyamides (nylon, e.g.) react with most organic pigments, and many pigments and dyes have insufficient heat stability to withstand the high processing temperature of polycarbonate. How does this affect secondary processing? Consider a tool housing molded in nylon and then decorated by pad printing. The colorants typically used in pad printing are organic pigments, whereas nylon colors are usually formulated with inorganic pigments and dyes. If parts of the decoration are intended to match the nylon's base color, you may run into metamerism. For example, the colors will appear to match under the store's fluorescent lighting but not when viewed at home under an incandescent bulb.

Pigments and dyes are just part of the total color formulation. Almost without exception, color formulations will include processing additives to aid pigment dispersion. The most cost effective dispersion aids are metal soaps, such as zinc and calcium stearate. Ethylene bis-stearamide (EBS) wax is also commonly used. Such additives can cause adhesion problems with secondary processing. We find this problem more likely to occur with PE and PP. These are very non-polar plastics, and during melt processing (e.g., injection molding) the more polar dispersion aids tend to migrate to the surface. When this happens, even pretreatments such as corona discharge fail to assure good adhesion of paint and printing. Fortunately, the color formulator has a large arsenal of dispersion aids and can switch to a less polar, higher molecular weight dispersant if he or she is informed the part will be post decorated. Oxidized PE wax is an example of a higher molecular weight dispersant that can be used in a wide range of polymers. On a more positive note, we rarely have such problems with styrenic plastics such as general purpose polystyrene (PS), high impact PS, or ABS. The more popular dispersion aids are much more soluble in these resins and have little tendency to migrate out.

Several difficulties may arise if the application requires extended exposure to light or weather. Many inexpensive pigments and dyes degrade under these conditions and are not recommended. The coloring cost often goes up considerably. In addition, the color formulator will often include stabilizers to protect the plastic from the damaging effects of light (visible and ultra-violet). These additives may present problems to the decorator if they migrate to the surface. Again, communication is part of the solution. The color formulator may be able to avoid problems with secondary processes such as printing by selecting additives with higher molecular weight and correspondingly lower tendency to migrate. For example, there are now a number of oligomeric and polymeric light stabilizers available that are so resistant to migration they can be used in thin film applications.

Similar problems can occur when dyes are used in the color formulation. We have seen cases where decorated plastic toiletry items became discolored because a dye migrated out of the plastic under the influence of bath oils. The formulator solved the problem by replacing the dye with one that was much less soluble in most solvents likely to be found around the house. There was a slight increase in cost, but field complaints were totally eliminated. We may see more problems of this kind due to recent concerns regarding heavy metal pigments. In the past, cadmium pigments were the colorants of choice for nylon and polycarbonate parts intended for general industrial use. They offered the most cost effective means of producing a bright red, orange, or yellow. Traditionally, “Fire Engine Red”, “School Bus Yellow”, and “Safety Orange” were formulated with cadmium-based pigments. Today, these colors are being formulated with combinations of dyes and metal oxide pigments such as chrome or nickel titanate.

Other additive packages that can lead to migration and cause problems with secondary processing are plasticizers, flame retardants, internal mold release agents, and slip agents. The latter are often included in bottle closures to reduce friction between the cap and the bottle. We cited the problems with plasticizers in a previous article [1].

In summary, if we do not view color as part of the total material system, we risk problems at the secondary processing stage or, worse yet, in the field. We end our discussion with a list of basic questions to be answered when starting a plastics coloring project. By taking the time to get the answers we go a long way to designing a robust product.

1. What is the specific application (general purpose, food contact item, toy, package subject to CONEG regulation, etc.)?
2. Which polymer(s) is being used?
3. How are the polymers being processed? (Note: injection molding subjects the polymers to much higher shear rates than extrusion processing and requires more heat stable colorants.)
4. At what temperature is the plastic being processed and what is the residence time at this temperature?
5. What are the light stability and weather exposure requirements?
6. What functional additives are required (stabilizers, plasticizers, flame retardants, slip agents, etc.)?
7. What chemicals or solvents will the part encounter in its use, and what are the chemical/solvent resistance requirements?

Additional reading

This article provides but a brief introduction to an enormous field of study. There is a collection of articles that have been presented at the Society of Plastics Engineers Color and Appearance Division RETEC and ANTEC technical conferences between 1995 and 1998 that contain a number of articles of interest to those involved with plastics decorating, each of which goes into far more detail than we have space for here. If you wish to learn more about pigments and dyes and how they are compounded into plastic, Charvat’s recently published Coloring of Plastics – Fundamentals referenced below is excellent reading. ■

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