Pigments used to color molded thermoplastics

Over the past two months, we have been discussing key factors to consider when choosing color for your plastic molded parts. Our final discussion on color will revolve around the use of pigments and dyes to give color to molded parts. Because there are many different pigments that will give color, the selection of the proper pigment is typically left to the colorant manufacturer. The following information about pigments and their properties can prepare you with background information to use when discussing an application with a colorant supplier.

Pigments and Dyes

Colorants fall into two broad categories: pigments and dyes[1]. Pigments are colorants that do not dissolve into the plastic, whereas dyes are colorants that do go into solution. Pigments can be divided into inorganic and organic pigments. Inorganic pigments have superior heat resistance and weathering properties compared to both dyes and organic pigments. Yet, some inorganics are perceived as health hazards[2]. Thus, the industry trend is shifting from the use of inorganic pigments to organic pigments. A thorough discussion of organic pigments can be found here [[3]]. Dyes are used in applications where powerful tinting is needed. Dyes give brilliant color, yet tend not to hide (cover) surface imperfections as well as pigments. Also, dyes tend not to perform well in outdoor applications.

WHITE

White pigments are dominated by the use of titanium dioxide (TiO_2). It has excellent hiding power and ultraviolet (UV) resistance. Yet, TiO_2 can have a negative effect on glass filled resin systems: the hard TiO_2 particles tend to break down the glass as it is dispersed in the resin. This has a negative effect on the physical properties of the final molded product. When working with glass filled resins, barium sulfide (BaS) is a better choice to obtain the white color. BaS will not break down the glass. Yet, BaS's hiding power is much less than TiO_2 and must be used in higher concentration.

Another white pigment is zinc oxide (ZnO). ZnO is not commonly used to obtain a white color since it cannot compete with the hiding power of TiO_2. However, ZnO has a practical use as a fungicide additive in plastics. If the application requires a white pigment with anti-microbial properties, ZnO is a good choice.

Antimony trioxide (Sb_2O_3) is a white pigment, though cost is too high to be used solely for color. In combination with chlorinated or brominated polymers it is an effective fire retardant, yet its use has been reduced due to increased regulations from RoHS (Restriction of Hazardous Substances).

YELLOW

Common yellow and orange colors are made from iron oxide yellows, which are inorganic pigments. Iron oxide yellows give an opaque yellow color and are generally inexpensive. They are, however, sensitive to high heat (>150°C) and shift toward a red color when overheated[4]. Chrome yellow pigments give a bright yellow color, though their lead content limits their applicative use. Organic yellow pigments have greater transparency than inorganics, yet are susceptible to fading in outdoor applications.

RED

Red iron oxides, Fe_2O_3, are an inorganic red pigments that gives the familiar red barn color. Iron oxide reds are thermally stable and have relatively low cost. Their particle size can be optimized for hiding and transparency. Organic red pigments also give good color, though at a higher cost than red iron oxide.

BLUE and GREEN

Inorganic blue color is typically achieved with iron blue (ferric ammonium ferrocyanide), which is a reddish shade of blue with fairly good properties. Inorganic greens are made from various ratios of iron blue and chrome yellow. These inorganics are seeing reduced use due to their lead content. This, in turn, has increased the use of organic blues and greens; copper phthalocyanine (CPC) pigments. CPC pigments are commonly called phthalo blue and phthalo green. They have very good exterior durability, chemical resistivity and are heat stable. Though the cost per pound is fairly high, the cost per volume is moderate due to their excellent color strength.

BLACK

Almost all black pigments are carbon blacks. They absorb UV and are the most stable in exterior exposure. Carbon black pigments have a range of particle sizes. The particle size is what determines the degree of jetness (intensity of blackness). The highest degree of jetness comes from the smallest particle sizes, 5-15 nm. Various grades of carbon black are available in the 50-200 nm size. Larger particle sizes, around 0.5 μm, give a gray color. Due to the small particle size of carbon black, increasing the pigment loading will commonly give rise to higher viscosity. Increased dispersion of the small carbon black particles in the resin has been shown to give improved mechanical properties[5]. Other black pigments include acetylene black and iron oxide black. Acetylene black pigments increase electrical conductivity. When a lighter shade of black is required, iron oxide blacks are used.

METALLIC PIGMENTS

The most important metallic pigments are aluminum flake pigments. Particle size of the flakes greatly affects the appearance of the part. Smaller particle size offers excellent hiding, decreased brightness and a darker appearance. Larger particle sizes reflect more light and thus have a more metallic appearance. Additionally, larger particle sizes have less noticeable knit lines. The larger particle sizes are typically used around 10% concentrate loading with a negative effect of reduced physical properties. Fiber reinforced nylons, however, are not affected by such high aluminum pigment loadings[6].

INERT PIGMENTS

Inert pigments absorb very little, if any, light. They are commonly used as space fillers to reduce the cost of the molded part. Calcium carbonate ($CaCO_3$) is commonly used as a filler to reduce cost. Its whitening effects are very small. Clays can be added and have a benefit of reducing oxygen and water vapor permeability.

Hopefully this article gives some background and insight into colorants and their selection. Having the combined knowledge of how color is perceived, what can affect color matching and what colorants are used should give a strong foundation for understanding and achieving acceptable color in a molded plastic part.

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[1] Harris, Ronald M. Coloring Technology for Plastics. New York: Plastics Design Library, 1999.

[2] Kanu, Rex C., Thomas H. Spotts, Michael Chesebrough. "The Effects of Some Organic and Inorganic Pigments on the Tensile and Impact Properties of Injection-molded Polypropylene." International Journal of Modern Engineering Fall 2001.
<http://www.ijme.us/issues/fall2001/articles/polypropylene.htm>.

[3] Herbst, W., Klaus Hunger. Industrial Organic Pigmtents. Weinheim: VCH, 1997.

[4] Zeno W. Wicks, Jr., Frank N. Jones, S. Peter Pappas. Organic Coatings: Science and Technology. 2nd ed. New York: Wiley, 1999.

[5] Kim, Dae-Jin, Kwan-Ho Seo, Ki-Heon Hong, Sang-Youl Kim. “Effects of dispersing agents on dispersity and mechanical properties of carbon black/PET.” Polymer Engineering and Science 39.3 (1999): 1548-2634.
[6] Bung, Hans-Henning. “Metallic Looking Plastics with New Silver and Colored Aluminum Pigments.” ANTEC 1998.