REDUCING THE COST OF WHITE OPACITY

Optimized Use

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Titanium dioxide (TiO_2) is a key element for creating whiteness and opacity in paints and coatings. Since 2008, TiO_2 costs have risen more than 70%, and current prices now exceed $1.70 per pound. As a result, paint manufacturers are reviewing their technology options to identify opportunities to reduce TiO_2 consumption. This is particularly true in the architectural coatings segment where TiO_2 is the largest component of raw materials costs.

How can paint manufacturers leverage this broad technology base to help them reduce the cost of whiteness and opacity? Before we can answer this, it is important to first understand how TiO_2 works.

BASICS OF OPACITY

Opacity, or hiding power, is the ability of a paint film to hide a substrate.[1] At complete opacity, the reflected light will not recognize the substrate underneath the paint film. Dark colored paints achieve opacity by light absorption of colored or black pigments. The principal factor that determines the opacity of a white paint film is light scattering efficiency. Scattering is a measure of light interaction with the pigment particles suspended in a polymer matrix. The magnitude of the interaction of the light with the suspended particles determines the hiding power of the paint film. The scattering efficiency is determined by two factors: refraction and diffraction of light.

Refraction of Light

Refraction, or bending of light, occurs when light passes through the interface between the resin medium into the pigment particle. The magnitude of light bending by refraction is approximately proportional to the square of the difference in refractive indices of the polymer matrix (RI=1.48) and the pigment particles.[2] Rutile titanium dioxide (RI=2.76) has the highest refractive index of all white pigments, hence its high performance as a white opacifier.

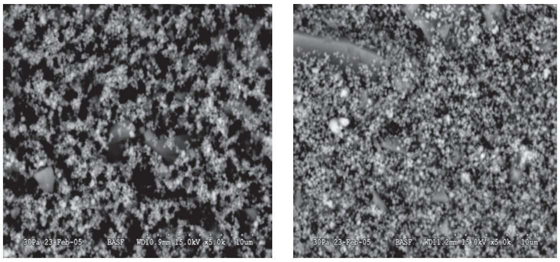
Light can also be refracted at an interface between air (RI=1.0) and polymer (RI=1.48). An analogous phenomenon between water and air can be observed every time you pour a beer; brown beer has a white frothy head due to light refraction in the foam. Similarly, incorporation of air in a paint film will produce opacity and whiteness.

Diffraction of Light

Light diffraction is a phenomenon of light bending around suspended particles. The Mie Theory predicts that maximum diffraction occurs when the size of the particles is approximately half the wavelength of the light source.[3] Since the visible light has an approximate wavelength of 500 nm, the pigment particles should be around 250 nm for maximum diffraction.

Diffraction efficiency is also dependent on the TiO_2 loading. Initially, increasing the amount of TiO_2 in a paint formu-

# of Titanium Dioxide



Titanium dioxide particles are agglomerated | Titanium dioxide particles are optimally spaced

Figure 1—Correlation between hiding power and dispersion state of titanium dioxide particles: scanning electron microscope (SEM).

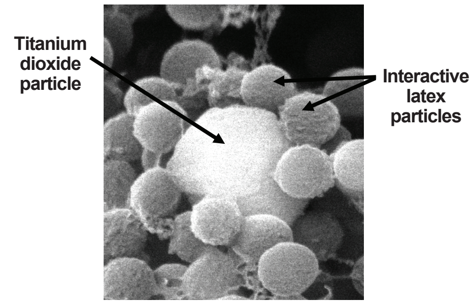


Figure 2—Using polymer emulsions to achieve TiO_2 efficiency**.**

lation improves opacity by increasing the light scattering power of the coating. Since the relationship between TiO_2 loading and light scattering power is not linear[2] (Kubelka-Munk equation), once maximum opacity is reached, further increases in the amount of TiO_2 do not improve the coating opacity. Also hiding power is lost because of the "crowding effect,"[2] which describes the loss of scattering efficiency of each individual TiO_2 particle due to reduction in spacing between the TiO_2 particles at higher loadings. Fine size extenders can be used as spacing particles to avoid this crowding effect.

Another factor to consider for maximizing opacity is optimum dispersion of the pigment particles in the paint. If the TiO_2 particles are poorly dispersed, light scattering efficiency is reduced due to localized crowding in the pigment agglomerates.

OPTIMIZING TIO_2

So how can paint manufacturers reduce their dependence on TiO_2—and thus the cost of opacity and whiteness? Let us consider the benefits of each of the technologies previously mentioned.

Dispersants/Surfactants: TiO_2 efficiency is strongly influenced by the type and amount of dispersant. Studies have shown that optimum color strength, gloss, and hiding power result from the correct match of dispersant and pigment. Dispersants work by enhancing pigment wetting and stabilization during the grind stage. Enhanced pigment wetting speeds the breakdown of pigment agglomerates and increases the number of primary pigment particles. The chemistry, molecular weight, and ionic character of the dispersant help it adsorb onto the surface of these primary particles. This adsorption neutralizes the attractive forces between them and allows the dispersant to provide both steric and electrostatic stabilization to the TiO_2 particles.[4]

Clay Minerals: Clay extender pigments can reduce TiO_2 levels by providing optimal particle spacing, increasing dry hiding and tint strength, and brightness.[5]

Polymer Emulsions: Specially engineered polymer emulsions[2,6] can dramatically improve TiO_2 efficiency by interacting with the TiO_2 and thereby preventing pigment flocculation. The technology incorporates special functional monomers in the polymer chains. The functional groups associate with the TiO_2 particles and essentially the latex particles act as dispersants for the TiO_2. This approach offers additional advantages: the interaction of the polymers with the TiO_2 yields improved film properties such as scrub resistance.

These proven technologies are helping manufacturers to reduce TiO_2 levels by as much as 20%,[7] and—as a result—contribute towards significantly improved profitability. With TiO_2 prices expected to continue to rise, advancing these technologies further and finding new solutions for reducing the cost of white opacity will benefit the coatings industry.

References

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2. Natesan et al., "Engineered Low-VOC Acrylic Polymer Emulsions: A Novel Tool to Improve Titanium Dioxide Efficiency," Proc. Annual Meeting of Federation of Societies for Coatings Technology, Nov. 2, 2006.
3. Kowka, R.A., Technical Report, DuPont Titanium Technologies.
4. See product information on Dispex®, Efka®, and Hydropalat® dispersions, www.basf.com.
5. BASF markets clay extenders under the brand names Satintone®, Ultrex®, Mattex®, and ASP. ASP grades are well known TiO_2 extenders designed to work in low PVC semi-gloss and gloss paints. Ultrex is one of the highest brightness structured calcined kaolin and is intended for paints requiring high hiding, high whiteness, and clean colors.
6. Wildeson, J., Smith, A., Gong, X., Davis, H.T., and Scriven, L.E., "Understanding and Improvement of TiO_2 Efficiency in Waterborne Paints through Latex Design," *JCT CoatingsTech,* 5, No. 7, p. 32-39 (July 2008).
7. See product information on Acronal Optive® polymers, www.basf.com.

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