Titanium dioxide (TiO₂) is a key element for creating whiteness and opacity in paints and coatings. Since 2008, TiO₂ 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 TiO₂ consumption. This is particularly true in the architectural coatings segment where TiO₂ 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 TiO₂ works.

**BASICS OF OPACITY**

Opacity, or hiding power, is the ability of a paint film to hide a substrate. 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. 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. 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 TiO₂ loading. Initially, increasing the amount of TiO₂ in a paint formu-
Optimizing TiO₂

So how can paint manufacturers reduce their dependence on TiO₂—and thus the cost of opacity and whiteness? Let us consider the benefits of each of the technologies previously mentioned.

Dispersants/Surfactants: TiO₂ 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 TiO₂ particles.

Clay Minerals: Clay extender pigments can reduce TiO₂ levels by providing optimal particle spacing, increasing dry hiding and tint strength, and brightness.

Polymer Emulsions: Specially engineered polymer emulsions can dramatically improve TiO₂ efficiency by interacting with the TiO₂ and thereby preventing pigment flocculation. The technology incorporates special functional monomers in the polymer chains. The functional groups associate with the TiO₂ particles and essentially the latex particles act as dispersants for the TiO₂. This approach offers additional advantages: the interaction of the polymers with the TiO₂ yields improved film properties such as scrub resistance.

These proven technologies are helping manufacturers to reduce TiO₂ levels by as much as 20%, and—as a result—contribute towards significantly improved profitability. With TiO₂ 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


5. BASF markets clay extenders under the brand names Satintone®, Ultrex®, Mattex®, and ASP. ASP grades are well known TiO₂ 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.


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