Ti-Pure™
Titanium Dioxide

The Advantage for Plastic Films

Especially Suited for White Films

Chemours™

Contents

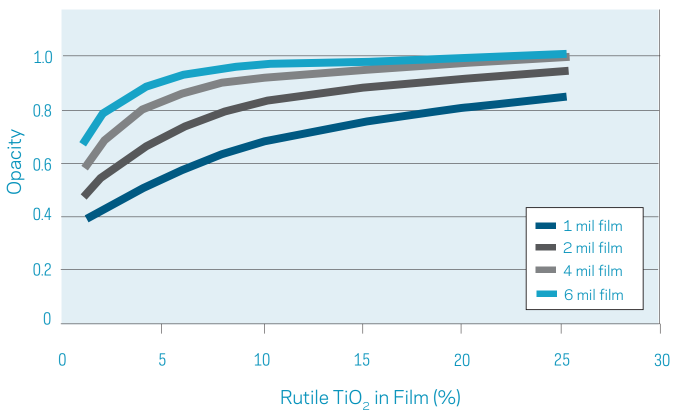
Plastic films can be bent, molded, printed on and twisted into different shapes and designs that are not easily achievable with other materials. Its versatility is only limited by the imagination of the artist shaping and designing the film. Much like an artist, plastic film fabricators require a canvas to paint their picture. The most common and effective canvas is a white film, one that does not allow light to shine through, i.e., high opacity. There are several options to create the white plastic film. One technique is to add a material in the film construction that can alter or attenuate the light so that the light is scattered. Film producers most commonly use rutile TiO_2 to make a clear plastic film opaque

(see Appendix 1 for more details).

High Opacity with TiO_2

Many film producers balance film thickness, TiO_2 content, and cost to find the most effective solution for film opacity. Therefore, a model that calculates the optimal TiO_2 content for a chosen film thickness and target opacity is highly valuable. Such a model would highlight the effectiveness of TiO_2 in producing a more opaque backdrop versus increasing film thickness. The output of a model which demonstrates the relationship between TiO_2 concentration, film thickness and opacity is shown in Figure 1. A more detailed version of the model is available from your masterbatch supplier.

Figure 1: Relationship Between TiO_2 Content, Film Thickness and Opacity



Note: Opacity = Reflectance0 / Reflectance∞

Table 1: Pressure Development for Various Titanium Dioxide Products for Film Applications

Grade	bars/kg TiO_2 per hr for 70% TiO_2
Benchmark TiO_2 for film	0.93
Typical TiO_2 for film	2.89
Premium TiO_2 for film	0.45

Data are calibrated for direct comparison—200 mesh screen used for filtration

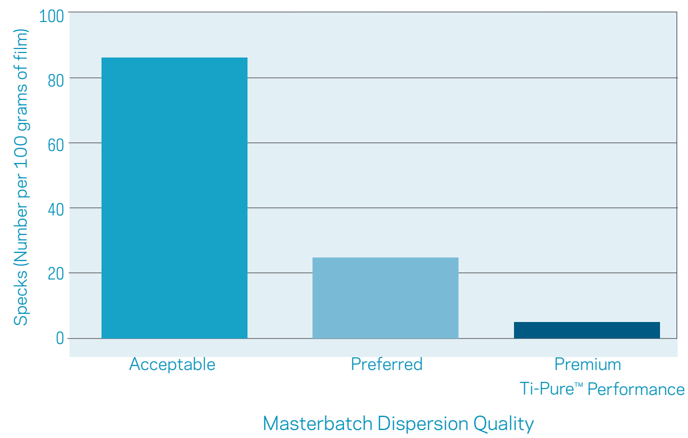
Ease of Production and High Quality with TiO_2 Masterbatch

Film fabricators are not only looking to produce a high quality white film but also seek ease of production. Hence, it is extremely important to be aware of processing differences between TiO_2 masterbatches. For example, one of the main variables in producing a white film is the rate at which the polymer melt exits the film die for a given film thickness. This rate is determined by the equipment design, melt pressure and polymer viscosity as well as the TiO_2 masterbatch (see Appendix 2 for details).

When specifying a grade of TiO_2 for the masterbatch, TiO_2 dispersibility is key to achieving ideal film processing. The maximum throughput of the film is related to the extruder's backpressure and its rate of increase. Evaluations of various grades of TiO_2 have demonstrated that some grades can cause a more rapid pressure increase (as measured by bars per hour) than others. The pressure increase of various types of TiO_2 based on the amount of pigment used is shown in Table 1.

Highly dispersible TiO_2 in the masterbatch is another important factor in producing a good quality plastic film as well as ease of production. Numerous sources of defects, such as polymer gels, TiO_2 dispersion in the masterbatch, and contamination impact the film quality. A common quality evaluation for film is a visual check to note the amount of defects within the film. These defects are referred to as "specks" and can be visually counted per weight of film. Figure 2 shows the relationship between TiO_2 dispersion in the masterbatch and film defects (number of specks).

Figure 2: Relationship Between TiO_2 Dispersion in Masterbatch and Film Defects



Cost Effective Solution with TiO_2 Masterbatch

It is no surprise that a cost-conscious film producer would like to make thinner opaque films, or more film area with the same weight of resin. For example, this can be achieved by increasing the take-off speed which produces a thinner film using the same weight of resin; therefore, more film surface is produced. To achieve this goal, the producer must optimize process variables such as take-off speed, temperature and extruder RPM. But in order to keep the integrity and the quality of the film intact, there can be limitations to these process parameters. Some TiO_2 grades are designed to minimize these limitations, dependent upon surface chemistry, and give the film producers much more flexibility to achieve a more cost effective solution without sacrificing quality (see Appendix 3 for details on how TiO_2 choice impacts film production). In other words, selecting the right TiO_2 masterbatch not only reduces pressure buildup, improves quality and opacity performance, but also provides greater flexibility in film processing which can reduce cost.

Appendix One: Refractive Index

There are many different materials that can be added to a polymer to attenuate visible light. Inorganic solids such as titanium dioxide, lithopone blends, zinc oxide, zinc sulfide and others have been used in plastic films to achieve opacity. Opacity is achieved by scattering visible light due to the difference in refractive indices between the added solids and polymer matrix. Of course, the larger the refractive index difference, the greater the scattering of visible light and the more opaque the plastic film will appear. Therefore, the goal is to maximize the refractive index difference between the polymer matrix and the solid. It is clear that by using rutile TiO_2, which has the highest refractive index of commercially available white pigments, one can achieve this goal.

The refractive index values listed in Table 2 highlight that solids such as, calcium carbonate and lithopone, dispersed in polyethylene offer a weak opacity option. This is because the refractive index difference between the polymer matrix and the dispersed solid is low. The same result is observed in other polymer systems such as polyvinyl chloride (PVC). The refractive index difference for PVC and lithopone is approximately 0.16. The refractive index difference for rutile TiO_2 and PVC is 1.25. Therefore, any substitution of TiO_2 with lithopone will decrease the refractive index difference and reduce opacity, as measured by tinting strength (shown in Figure 3).

Figure 3: Tinting Strength in Plasticized PVC

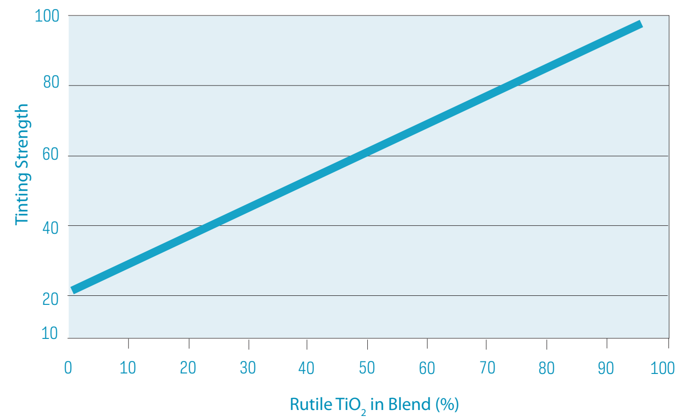


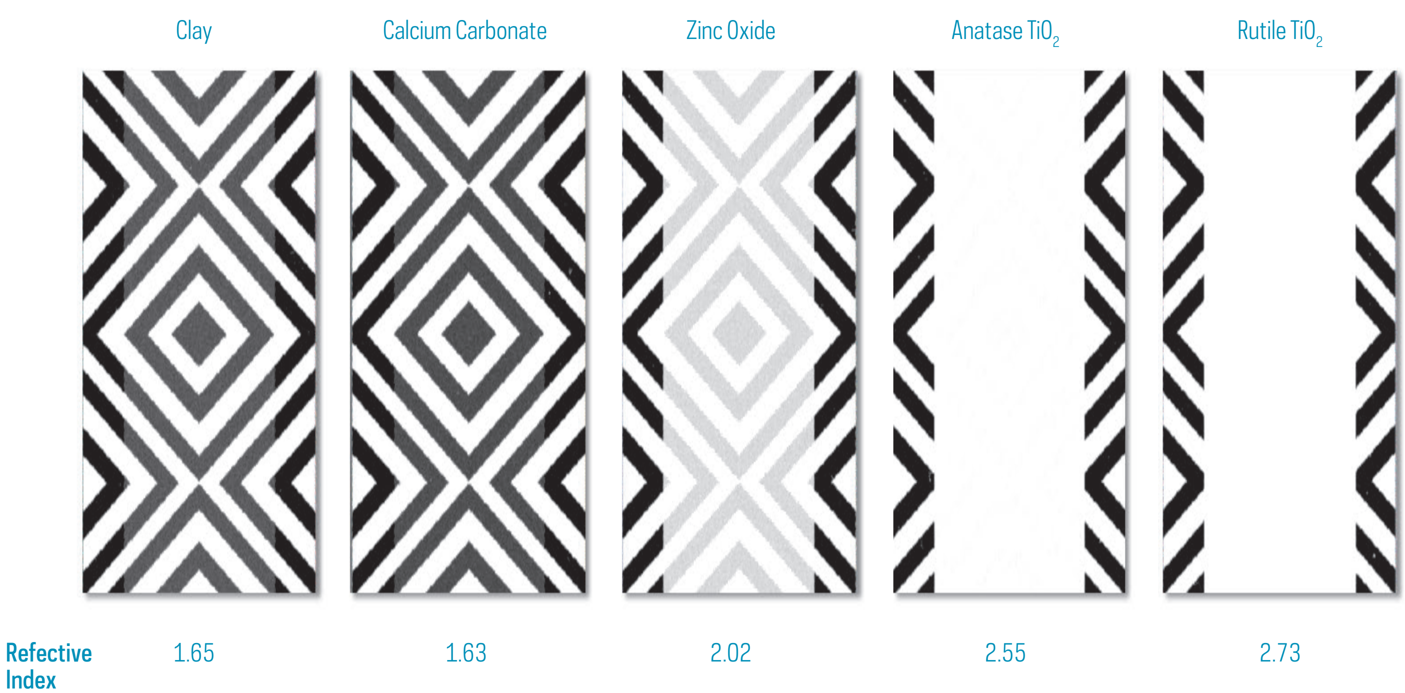
Table 2: Indices of Refraction for Some White Pigments and Common Polymers

White Pigment	Reflective Index	Plastic	Reflective Index
Rutile TiO_2	2.73	Polystyrene	1.60
Anatase TiO_2	2.55	Polycarbonate	1.59
Antimony Oxide	2.09–2.29	SAN	1.56
Zinc Oxide	2.02	Polyethylene	1.50–1.54
Basic Carbonate, White Lead	1.94–2.09	Acrylic	1.49
Lithopone	1.64	Polyvinyl Chloride	1.48
Clay	1.65		
Magnesium Silicate	1.65		
Barytes ($BaSO_4$)	1.64		
Calcium Carbonate ($CaCO_3$)	1.63		

The unmatched power of titanium dioxide as an opacifying agent when several inorganic solids are mixed into a polymeric system can be seen in Figure 4. This visual representation demonstrates the theory of how the difference in refractive index is crucial to obtaining opacity in films.

Titanium dioxide provides opacity by restricting the amount of light passing through a film by either reflecting or scattering visible light. There are two crystalline forms of TiO_2 that are used in plastic film applications, rutile and anatase. Rutile TiO_2 has a higher refractive index due to a more dense crystalline form versus anatase, therefore it provides a higher level of scattering. The difference in the scattering performance of the two crystalline structures becomes more evident as the TiO_2 content in the film is increased. The advantage of rutile over anatase at a constant film thickness and equal concentrations of TiO_2 is shown in Figure 5.

Figure 4: Effect of Refractive Index on Opacity



Another method of demonstrating the superior efficiency of rutile TiO_2 to scatter visible light is to measure contrast ratio of pigmented films. By placing the films over black and white backgrounds, the ratio of scattered visible light intensity is recorded. This is the result of the scattering from the TiO_2 in the film and the background. The background scattering occurs due to the air between the film and background surface. As shown in Figure 6, rutile has a higher contrast ratio in films containing the same concentration of TiO_2 and film gauge. This advantage is even more apparent when the film background is removed.

Figure 5: Rutile TiO_2 Provides More Scattering of Light

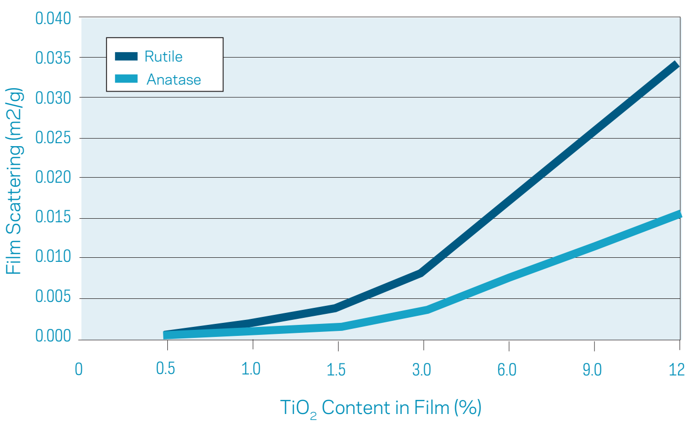
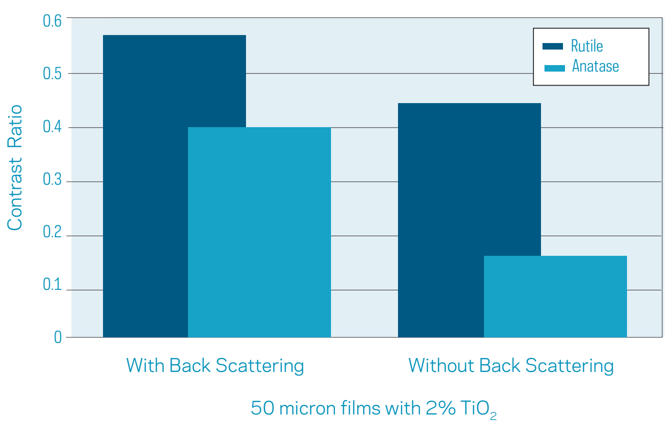


Figure 6: Contrast Ratio Measurements for Films Containing Anatase and Rutile



The evaluation is based on comparing films extruded at high temperature (above 280 °C) and increasing the take-off speed to demonstrate the widening of operational parameters for cost savings.

Appendix Two: Pressure Buildup and Impact on Rate

The throughput of an extruder is defined by the mechanical specifications such as the screw design and the dimensions. The addition of TiO_2 masterbatch into the polymer melt for film production detracts from the maximum throughput by either affecting the viscosity profile of the melt and/or by creating pressure within the processing equipment. During the production of a white film, pressure develops as the agglomerates of undispersed TiO_2 masterbatch are trapped. As the pressure increases, the RPM of the extruder must be lowered to maintain good quality, therefore restricting output and film yield.

The output of the metering section of a single screw extruder is given by the following formula:

Output = 0.5pWHS—pWH3G/12μ

Where p = number of parallel flights

W = width of extruder screw channel

H = height of extruder screw channel

S = screw speed (rpm)

G = pressure drop

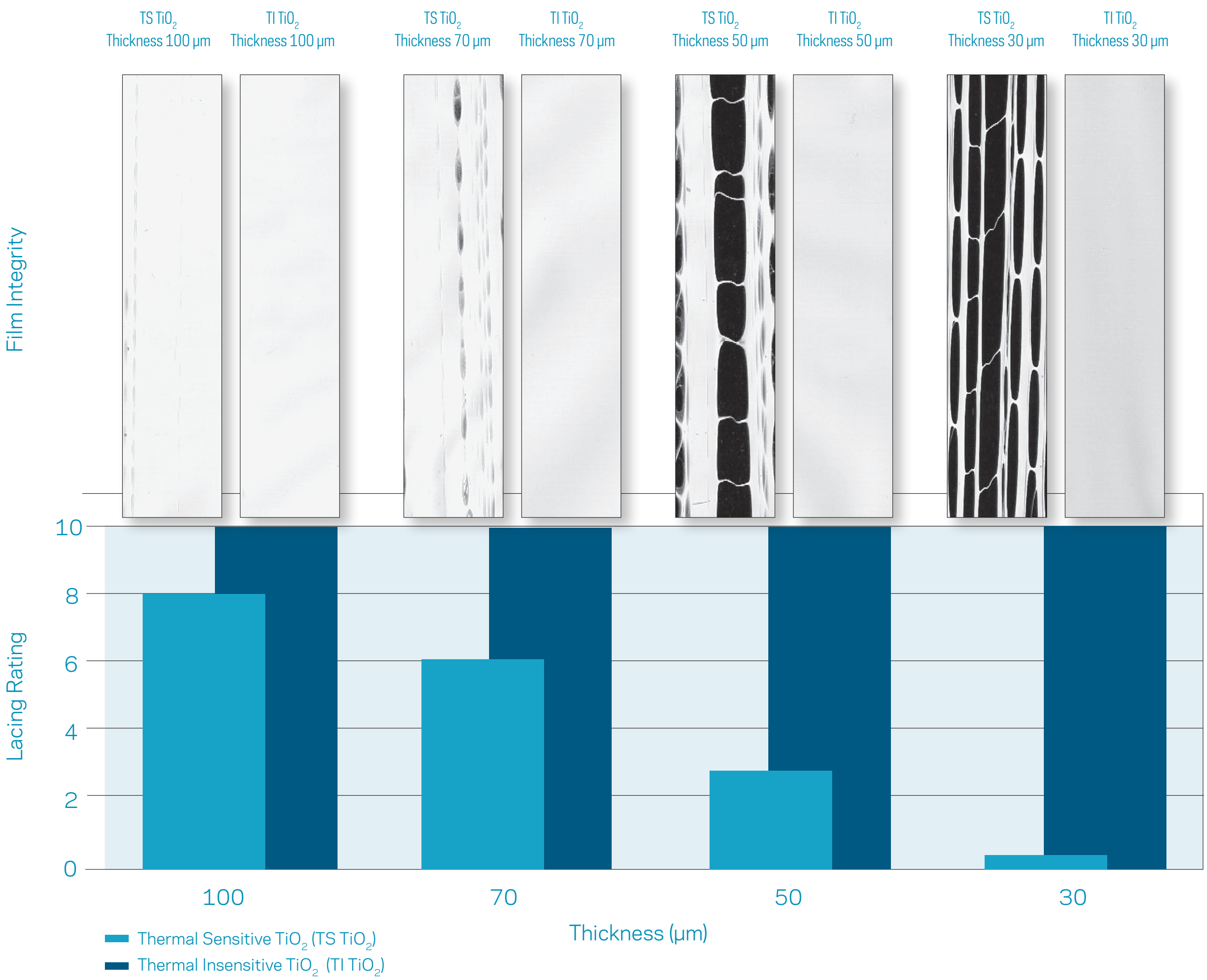
μ = viscosity of polymer

The first term represents the drag flow—the flow due to the rotation of the screw. The second term is the pressure driven flow. In a well designed screw, achievement of maximum rate is limited by those items which effect viscosity, μ, and pressure, G.

Appendix Three: TiO_2 Surface Chemistry Impact on Film Processing

The TiO_2 surface chemistry can influence processing of a polymer melt. The design of the surface chemistry can provide positive attributes for a film application. The surface treatment of a TiO_2 particle can cause defects in a film when formulation and process parameters are not adequately adjusted, especially at fast processing speed or high temperature. Titanium Dioxide is classified as either thermally sensitive or insensitive based on the surface treatment. A thermally sensitive TiO_2 causes the polymer matrix integrity to degrade which will generate a weak spot in a film structure that can be aggravated during strenuous film processing. This degradation can be subjectively quantified using a rating termed as "lacing". Films that are thermally robust are classified as a ten in the lacing scale (see Figure 7). Keep in mind that as undesirable degradation of the polymer increases, the lacing rating decreases.

Figure 7: Film Integrity and Lacing Rating Between Thermally Sensitive and Insensitive TiO_2



The information set forth herein is furnished free of charge and based on technical data that Chemours believes to be reliable. It is intended for use by persons having technical skill, at their own risk. Because conditions of use are outside our control, we make no warranties, express or implied, and assume no liability in connection with any use of this information. Nothing herein is to be taken as license to operate under or a recommendation to infringe any patents.

For more information, visit www.titanium.chemours.com

Replaces: K-15753-1
C-10461-1 (1/18)