Ti-Pure™

Influence of Paint Quality on the Environmental Footprint of Architectural Paints

Chemours™

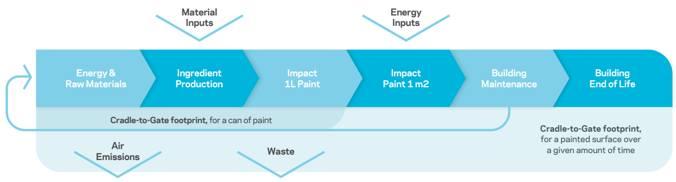
Coatings provide both protection and aesthetic appeal. Just a thin layer of paint can extend the useful life of everyday objects and thus avoid the environmental burden that would come with an early replacement.

Consequently, the sustainability of coatings should be assessed over the entire product life cycle to adequately capture the impact of coatings performance in a given application.

Coatings are formulated products, i.e. they are made from a blend of ingredients such as resins, pigments, fillers and additives. Choosing the right ingredients are essential to achieving the desired product specifications in commonly used performance metrics such as opacity, hiding power, washability, scrub resistance, and others. With their embedded environmental footprint, ingredients also influence the environmental impact profile of coatings. Life Cycle Assessment (LCA) forms a solid basis for holistic formulation choices, where ingredients are not judged in isolation, but in consideration of their impact on the on the performance throughout the life cycle of the ultimate article [1].

This means that in order to assess the environmental impact of an architectural wall coating one needs to assess not only the environmental impact of the raw materials needed to make the paint, but also how much paint is required to cover the wall and how long it will take before the owner will decide to repaint the wall as this will imply a new production of paint and use of raw materials. Being the white pigment of choice, TiO_2 plays a crucial role in the properties of architectural coatings, hence the ecological footprint. In this paper we are comparing the use of a commonly used 'universal' grade, like the Ti-PureTM R-902+ pigment to the performance of the Ti-PureTM TS6300 pigment (a so called highly treated grade).

Figure 1: LCA cycle for a typical architectural paint



We will further describe the working mechanism of this highly treated grade and the typical usages. We will compare the technical performance of 3 paints made with both grades and discuss the environmental impact of these paints, where we use the carbon footprint as an indicator.

Working Mechanism of highly treated TiO_2

Figure 3 shows that as the distance between two TiO_2 particles decreases, the scattering efficiency of these particles is reduced significantly.

This phenomenon is well understood and often referred to as the "crowding" effect. This explains the lower TiO_2 efficiency at high TiO_2 concentrations.

Alternatively, spacing the TiO_2 under these conditions will result in an increase in TiO_2 efficiency and consequently increase hiding power. One way to create this spacing is encapsulating the TiO_2 particles in a thick layer, providing the necessary steric hindrance. In practice this can be realized by depositing special forms of silica and alumina on the pigment surfaces to envelop them with a porous, voluminous coating. These thick, porous coatings function as spacers to keep the TiO_2 particles separated from one another, minimizing the overlap of TiO_2 scattering volumes and vastly improving the TiO_2 scattering strength.

Highly treated TiO_2 grades are most effective in flat coatings formulated near or above Critical PVC (CPVC) and are therefore sometimes referred to as "flat" grades. This is in contrast to more conventionally treated TiO_2 grades that can be used in many different coatings applications, which are referred to as "universal" grades.

The oxides deposited on the surface of the highly treated TiO_2 grades must be porous to minimize the dilution of the TiO_2 in the pigment (a non-porous coating of similar thickness would result in a pigment with over 80% oxide coating and less than 20% TiO_2 by weight). Because this oxide layer is so porous, these pigments have higher oil absorption than universal grade TiO_2 pigments, which decreases the CPVC significantly. This effect on CPVC is shown in Figure 4, where the hiding power (spread rate) versus TiO_2 volume concentration curve for a series of paints (TiO_2 and resin only) made with a universal TiO_2 grade is compared to that of a series of paints made with a highly treated flat TiO_2 grade. The CPVC value decreases from 41.5 for the universal TiO_2 to 32.3 for the highly treated TiO_2.

Figure 2: Microscopic pictures of highly treated TiO_2 (Ti-PureTM TS 6300, left), and a universal type (Ti-PureTM R902+, right)

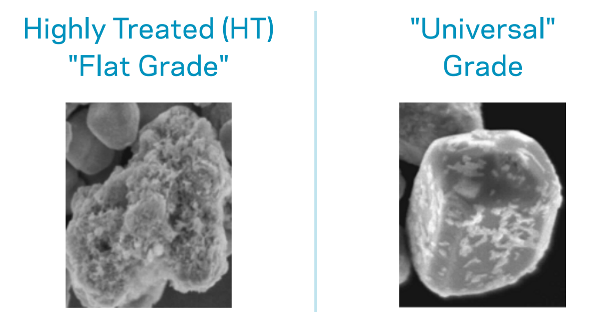
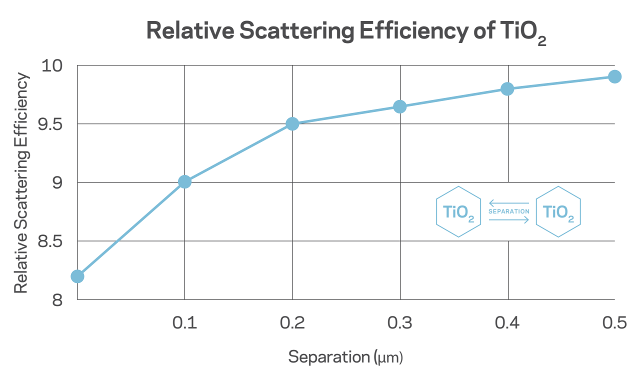


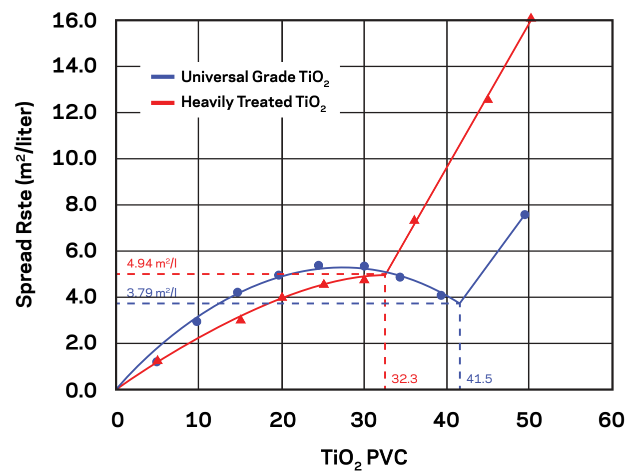
Figure 3: Relative scattering power as a function of TiO_2 particle separation



Using simple geometry, we calculate that, if the particles are packed perfectly, the surface to surface distances at their CPVC values are 0.053 and 0.079 microns for the universal and highly treated grades, respectively. Based on this difference in particle spacing, we would expect the two types of particles to have different scattering strengths at their CPVC value. Indeed, in Figure 3 we see that the effect of surface-to-surface distance is strongest when the particle separations are small, as is the case here.

The difference in CPVC values for the two types of pigments has important consequences for the opacity of paints formulated above the CPVC. In Figure 4 we see paints that are brought to PVC values above the CPVC by increasing their TiO_2 content. In contrast, commercial paints are brought to PVC values above their CPVC using extenders, since extender particles are significantly less expensive than TiO_2. The replacement of resin by extender is, in fact, one aspect of the cost savings advantage of formulating above the CPVC (the other being the formation of light scattering air voids). To maximize the amount of resin that can be replaced by extender before reaching the CPVC point, formulators typically use two types of extender with different particle sizes – a fine extender and a coarse extender. At the CPVC, the larger extenders are packed as tightly as possible, with the interstices between the particles being packed as tightly as possible by the small extender particles and the TiO_2 particles. That is, the small extender and TiO_2 particles are packed locally at their CPVC value. Increasing the PVC above the CPVC requires resin to be removed from the film and replaced by air – we can no longer increase the volume concentration of the particles because they are already packed as tightly as possible.

Figure 4: Impact of concentration on hiding power of universal and highly treated TiO_2 grades



As stated, when using a combination of large and small particles, the small particles, including the TiO_2 particles, are packed at their CPVC value. The light scattering strength of the TiO_2 particles is, therefore, the scattering strength at the CPVC value for that particular pigment grade. From Figure 4 we see that the highly treated grade of TiO_2, at its CPVC value (32.3) scatters light roughly 30% more strongly than the universal grade does at its CPVC (41.5). One benefit of using a highly treated TiO_2 grade above the CPVC is, therefore, that under such crowded conditions, the highly treated TiO_2 particles remain further apart than do the universal particles, and therefore scatter light more efficiently. This benefit overcomes the fact that the highly treated grade has a lower TiO_2 content – and therefore fewer scattering centers per kilogram – than the universal grade.

The second advantage of highly treated TiO_2 grades in paints formulated above their CPVC is related to the contribution to opacity from air void scattering. As air has a low refractive index, the average refractive index of the coating decreases as air is added, thereby increasing the efficiency of the TiO_2.

Additionally, these air pores scatter light themselves and so contribute to the total dry hiding power by scattering of light.

The total scattering strengths of those paints shown in Figure 4 that are above the CPVC are shown as a function of porosity index in Figure 5. As can be seen, the combination of greater TiO_2 light scattering strength and greater air void scattering strength for the highly treated pigment grade results in a significant opacity improvement, at the same porosity index, over the universal pigment grade.

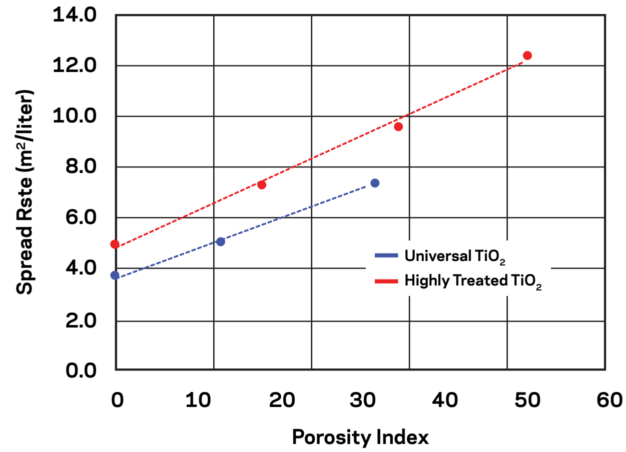
Figures 4 and 5 clearly show that, in the part of the formulation space above the CPVC, the highly treated grades outperform the universal grades, despite its lower TiO_2 content. As a consequence, the hiding power of paints formulated with the highly treated grade will be higher.

For these reasons, increasing the air void content of a paint film will always increase its opacity. Note, however, that rate at which the air void content increases opacity is not the same for the two different grades of TiO_2 considered here.

This rate is reflected in the slopes of the lines in Figure 5. In this figure we see that the slope of the line for the highly treated pigment is somewhat greater than that of the universal grades. Although the difference does not look large by eye, the slope of the highly treated line is 26% greater than the slope of the universal line, meaning that, at equal air content, the air voids for the highly treated grade scatter light 26% more strongly than those of the universal grade. We will discuss this further in the next section.

Although air voids are beneficial to opacity, the integrity of a paint, in particular its strength against scrubbing, decreases as the air void volume increases, and the optimal volume of air in these paints is a compromise between these two important properties. We can imagine the combination of air and resin to be a foam, and the strength of this foam will be a function of the amount of air in it. This quantity is referred to as the porosity index of the film, and paints with equal porosity index and the same resin typically have similar strengths.

Figure 5. Spread rate as a function of air content in paints formulated above the CPVC.



Use of highly treated TiO_2 in paint systems

Because of the practical limitation of the amount of air that can be incorporated into a paint film, it is important that this air scatter light as efficiently as possible. As is the case for any scattering center, the efficiency with which air voids scatter light is determined by their size. This size is determined, in part, by the type of TiO_2 used in the paint. This is illustrated in the following experiment where three paints with different extender packages (A pure clays, B fine $CaCO_3$, C medium sized $CaCO_3$) are made up once with 24 weight % of universal pigment and once with the same weight % of the highly treated grade. The figure below summarizes some basic properties of these paints. The arrow indicates the trend of the considered quality. The graph in the upper left corner shows the cradle to gate carbon footprint of these 6 paints (that is taking only the footprint into account of the raw materials to make the paints). The paints containing the clays (A) have a slightly higher carbon footprint compared to the paints containing only $CaCO_3$ as an extender, as can be expected due to higher carbon footprint of the clays compared to of the higher carbon footprint of $CaCO_3$.

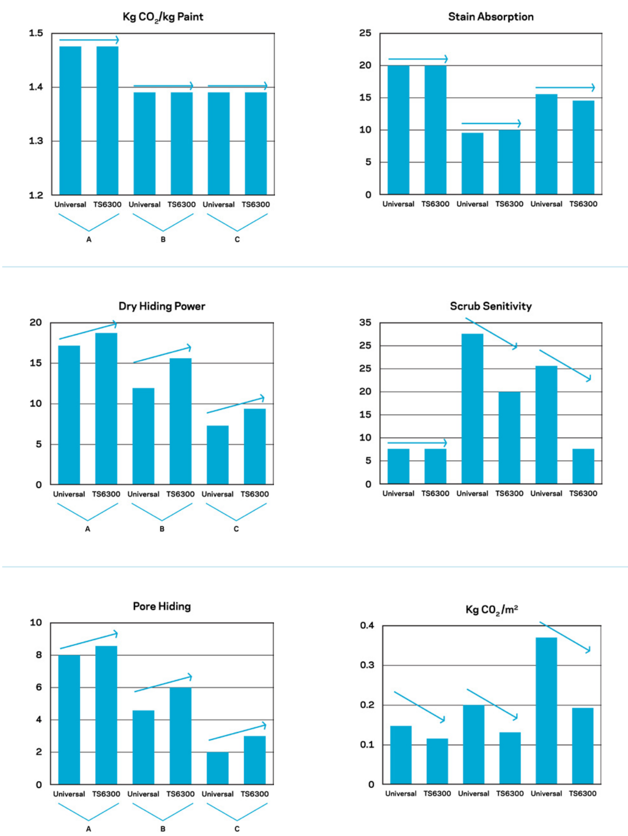
However, if one wants to get an idea on the cradle to grave carbon footprint one needs to take into account how much paint is required to cover a wall and how often one needs to repaint the wall during the lifetime of that wall.

The dry hiding power of a paint is a good estimate of how much paint is required to cover the wall. Figure 6 indicates that for each of the extender packages the dry hiding power increases when switching from a universal pigment to a highly treated pigment. As explained above, this is due to an increase of pore hiding and to a better spacing of the TiO_2 particles (results not shown).

Consequently one will need less paint based on a highly treated TiO_2 type to cover 1 m2 of the wall.

Despite the larger contribution of pores to the hiding power, the sensitivity of the pores for stains does not increase (lower left graph) when switching from a universal pigment to the highly treated one in the three paints. Also the scrub sensitivity of the paints made with the highly treated grades, expressed as the number of microns that are removed after 200 wash cycles (ISO 11998) remains constant or even decreases.

Figure 6: Overview of basic paint properties of 3 paints with Clays (A), fine $CaCO_3$ (B) and medium sized $CaCO_3$ as extender, formulated with a universal with a universal TiO_2 grade and a highly treated TiO_2-grade (TS 6300)



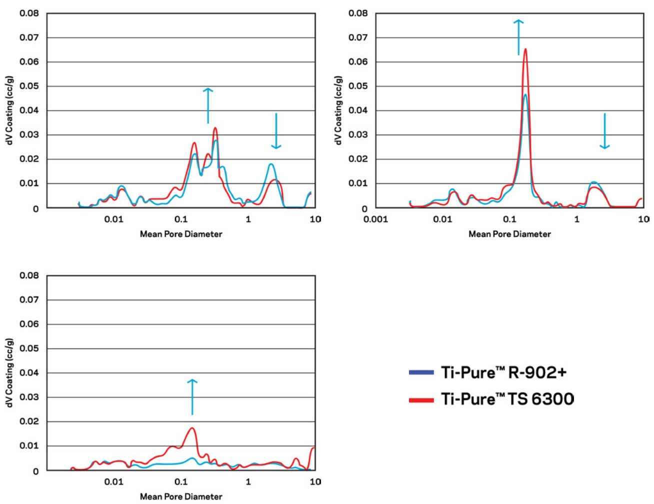
This implies that not only the amount of air present affects film strength, but also the size of the air voids. As was the case with opacity (discussed in the previous section), the air voids for the highly treated grade are more beneficial to the paint than those from the universal grade.

As the stain absorption is not affected significantly by the conversion from the universal to the highly treated grade, and the scrub sensitivity for the highly treated grade is as good as, if not better than, that of the universal grade, it is safe to say that the lifetime of the paint based on a universal pigment and on highly treated pigment will be very comparable, hence the number of repaints will be comparable as well. This allows us to say that the cradle to grave carbon footprint of a paint formulated with a highly treated grade will be lower compared to the cradle to grave carbon footprint of a paint formulated with a universal type of TiO_2.

To understand better the contribution of the pores to hiding power these 6 paints were studied by Hg-porosimetry. This technique allows us to measure the total volume of pores of a defined size. The results are shown in the graphs below, where the volume of the pores is plotted as a function of the pore size for these paints.

Figure 7 shows that the volume of the pores (or the number of pores) with a pore diameter of around 2-3 micron decreases when switching from a universal grade (blue curve) to a highly treated TiO2 grade (red curve), while the volume of pores with a diameter of 0.2-0.3 micron increases. It can be calculated [4] that the optimal diameter of pores to scatter light is around this 0.2-0.3 micron, giving another argument for the observed increased pore hiding when using a highly treated grade.

Figure 7: Pore volume as a function of pore sizes for three paints differing in extender package containing a universal type of TiO_2 (Ti-pure^{tm} R902+) and a highly treated type (Ti-Pure^{tm} TS6300)



Conclusions

The scattering efficiency of TiO_2 is negatively impacted by crowding effects. This can be partially overcome in paints formulated above CPVC and containing more than 12% TiO_2, by switching to a highly treated grade, resulting in a better TiO_2 scattering efficiency and in an increase of the scattering coming from air pores. This translates in a lower amount of paint that is necessary to cover a wall. In addition, it is shown that these more efficient air pores do not have a negative impact on properties like scrub sensitivity and stain absorption. Therefore, it can be concluded that paints formulated with highly treated grades have lower cradle to grave carbon footprint compared to paints formulated with universal types of TiO_2.

About Ti-Pure™ Titanium Dioxide from Chemours

Ti-Pure™ titanium dioxide (TiO_2) from Chemours strives to make the world brighter, more durable, and efficient by tackling some of society's greatest challenges through TiO_2 innovation and reliability. For nearly a century, we have produced and delivered high-quality TiO_2 for customers around the globe in coatings, plastics, and laminates applications. Guided by industry-leading innovation, technical expertise, and continued collaboration, we're committed to moving our customers and our planet forward.

Watch a short video to learn more.

Paints that contain Ti-Pure™ offer:

- **Better Processability**: High-quality Ti-Pure™ TiO_2 pigments ensure consistency from batch to batch.
- **Superior Hiding Power:** Creating brighter brights and whiter whites, Ti-Pure™ increases hiding power for uniform, one-coat coverage without needing to prime.
- **Ease of Application:** With fewer drips, smoother brush strokes, and faster drying times, Ti-Pure™ pigments boost paints' productivity.
- **Uncompromising Endurance:** The UV protection afforded by Ti-Pure™ leaves a durable, washable surface that resists fading, cracking, and discoloration over time.

For more information, visit **tipure.com** or contact us at **tipure.com/en/contact-us.**

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