Formulation of low carbon footprint opacifying agents

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Decorative paints utilise rutile titanium dioxide (TiO_2) as a white pigment to give paints opacity due to its high refractive index (≈ 2.7). The extraction, refinement and processing of TiO_2 however, uses a huge amount of energy and has a high carbon footprint of around 5.2 tCO_{2e} $tTiO_2^{-1}$ (greenhouse gas emissions only) [1]. The price of TiO_2 is also rising as resources dwindle and demand grows.

Because of the high carbon footprint that is associated with TiO_2 and the huge quantities of paint produced, if it could be replace, even partially, by something with a lower carbon footprint, it would have a profound effect on the overall carbon footprint and economics for the paint manufacturer. Subsequently, the aim of this research is to formulate a low carbon footprint opacifying agent which can be used to substitute (fully or partially) TiO_2 whilst maintaining high opacity and white pigmentation.

One way of doing this is to incorporate air voids into the paint formulation as voids of the correct size and shape can efficiently scatter light. They can do this in three ways [2]:

1. Voids that scatter light
2. Small voids which reduce the refractive index of the binder/air mixture
3. Foams which scatter light at the air-polymer interface

The production of air void containing particles can be accomplished via two routes:

1. Top-down methods
2. Bottom-up methods

Top-down methods involve modifying an existing particle so that it contains air voids, whilst bottom-up methods involve developing a particle from raw materials that contains air voids. Some potential approaches are outlined in Table 1.

Table 1 – table outlining potential strategies for top-down and bottom-up methods

Top-down methods	Bottom-up methods
• Ground minerals (e.g. $CaCO_3$) • Clay minerals (e.g. kaolin) • (Flash) calcined clays • Cenospheres (e.g. from fly ash)	• Biomimicry (copying structures from nature) • Biotemplating (using bacteria as a template to create structures) • Hollow particles (e.g. latex spheres) • Flat air molecules • Multi-shelled hollow spheres • Coated pigment particles • Precipitation (e.g. $CaCO_3$)

Flat air particles are particles that contain planar air voids, which, if parallel to the substrate will theoretically have a higher opacity than TiO_2 [3] (see figure 1).

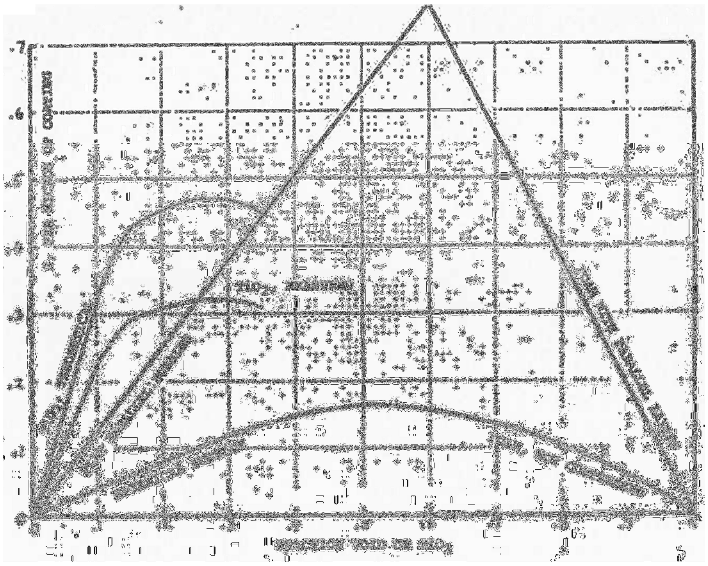

Figure 1 – theoretical maximum light scattering coefficient (S) per thickness of coating (μm) against fraction of voids, for TiO_2 and various types of air voids in resin [3]

According to the literature, this has not been done before, so it is unknown whether the theory is correct. If it is, and said particles are produced, it could have a profound effect on the paint industry.

Fly ash cenospheres are hollow spheres that occur as by-products of energy production and are as such a waste product. Generally their size is too large to be used as opacifying agents, but if there is a fraction of smaller cenospheres which could be exploitable as an opacifying agent and these could be obtained in sufficient quantities, then this waste product could be used to increase the sustainability and lower the carbon footprint of paint formulations.

By undertaking experiments into the top-down and bottom-up approaches, the theoretical principals will be proven or dismissed, and once a theory has been proved on one or more of the aforementioned methods, further experimental work will be undertaken to optimise the process. Ultimately, the final product will need to be optimised to work within a full paint formulation to give high opacity and white pigmentation.

1. TDMA, *Titanium Dioxide Industry Average Carbon Footprint*. http://www.tdma.info/index.php?id=25 (accessed 9th January 2013)
2. Braun, J.H. (1997). Titanium Dioxide – A Review. *Journal of Coatings Technology* **69**(868): 59-72
3. Ross, W.D., *Theoretical Computation of Light Scattering Power: Comparison between TiO2 and Air Bubbles*. Journal of Paint Technology, 1971. **43**(568): p. 49-66