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TiO_2: Uses of Titanium Dioxide

6: Uses of titanium dioxide

Titanium dioxide (TiO_2) is the most widely used white pigment, for example in paints. It has high brightness and a very high refractive index. The light passes through the crystal slowly and its path is substantially altered compared to air. If you have many small particles orientated in different directions, a high refractive index will lead to the scattering of light as not much light passes through. In lenses, high refractive index means high clarity and high polarising power.

Titanium dioxide has a higher refractive index than diamond and there are only a few other substances that have a higher refractive index. Cinnabar (mercury sulphide) is an example. Historically, cinnabar was used as a red pigment.

Uses for white pigment

Four million tons of pigmentary TiO_2 are consumed annually. Apart from producing a white colour in liquids, paste or as coating on solids, TiO_2 is also an effective opacifier, making substances more opaque. Here are some examples of the extensive range of applications:

- Paints
- Plastics
- Papers
- Inks
- Medicines
- Most toothpastes
- Skimmed milk; adding TiO_2 to skimmed milk makes it appear brighter, more opaque and more palatable.

TiO_2 in sunscreens

Almost every sunscreen contains titanium dioxide. It is a physical blocker for UVA (ultraviolet light with wavelength of 315–400 nm) and UVB (ultraviolet light with wavelength of 280–315 nm) radiation. It is chemically stable and will not become decolourised under UV light.

TiO_2 particles have to be coated with silica or alumina. This is because TiO_2 particles that come into contact with water produce hydroxyl radicals which are potentially carcinogenic. The silica or alumina coating prevents the titanium dioxide particles from coming into contact with the skin and with water making titanium dioxide very safe to use.

Addition to cement and tiles

Titanium dioxide can be added to the surface of cements, tiles and paints to give the material sterilising, deodorising and anti-fouling properties. This is because the photocatalytic properties of TiO_2 mean that, in the presence of water, hydroxyl free radicals are formed which can convert organic molecules to CO_2 and water and destroy microorganisms.

Self-cleaning glass

In 2001, the first self-cleaning glass was brought onto the market. This type of glass is coated in a thin layer of transparent anatase. To make the coating, anatase is first combined with an organic complexing agent consisting of organic molecules which can act as ligands and bind to the titanium ion with co-ordinate bonds. This process is necessary to convert the titanium dioxide powder into a more soluble form so that it can be spread over the glass surface evenly. Once the coating is applied, the glass is heated to burn off the organic complexing agent, leaving the anatase coating.

The cleaning process works in two phases:

- Photocatalytic breaking down of dirt.
- Washing off breakdown products when it rains.

Anatase absorbs UV light with wavelengths close to the visible spectrum. This activates the titanium dioxide by exciting electrons to higher energy levels. The activated titanium dioxide reacts with water to generate hydroxyl radicals which break down organic molecules. The hydroxyl free radicals on the surface of the titanium dioxide increase the hydrophilic ('water-loving') character of the glass. When it rains, the water runs off the glass in the form of a sheet and the dirt is washed off. The water sheet leaves almost no streaks and the glass looks clean.

Grätzel Cells

As concerns about the availability of finite resources like fossil fuels mount, there is an ever-growing need for ways of producing renewable energy. Silicon based solar panels are now widely used. They require two layers of specially constructed silicon crystals and are costly to produce.

The Grätzel cell diagram below (Figure 1) shows the cell is made up of layers. The top layer is made of glass coated with a conductive oxide like fluorine doped indium oxide. This is made by adding fluorine impurities to indium oxide (photo-anode). The next layer consists of nano-structured titanium dioxide. A photo-sensitive dye is adsorbed onto the TiO_2 layer and covered with an organic electrolyte solution containing I^-/I_3^-, a system which can easily gain or lose electrons and act as an electron carrier. The photo-cathode can be made by depositing a very thin layer of platinum on the bottom layer of glass or by having a very thin layer of graphite coating.

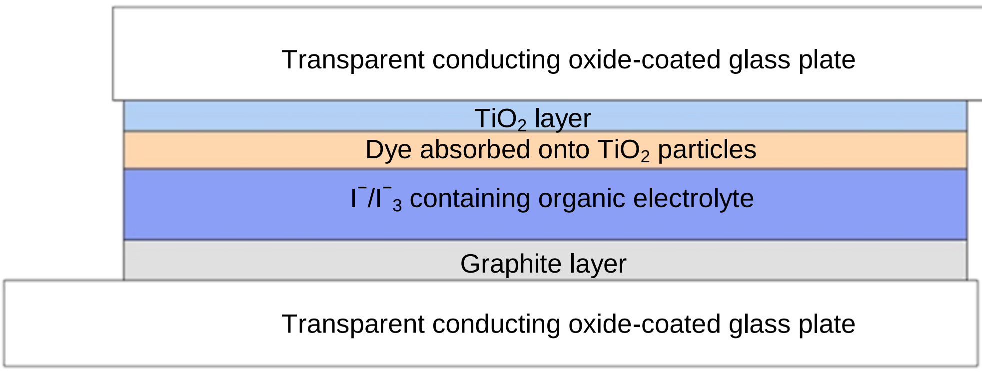

Figure 1: Grätzel solar cell structure.

How does the current flow?

1. Solar energy is absorbed by the dye-sensitiser (S), similar to chlorophyll in a leaf absorbing red light during photosynthesis (Figure 2).
2. An electron is raised to a higher energy level in the dye. The dye molecule becomes excited (S*).
3. The excited electron escapes from the dye molecule and the dye molecule is oxidised.

$$S^* \rightarrow S^+ + e^-$$

4. Electrons are passed to TiO_2 and accommodated in the conduction band. They flow through the TiO_2 conduction band and gather at the photo-anode.
5. The oxidised dye, S^+, gains an electron from the I^-/I_3^- system.

$$S^+ + e^- \rightarrow S$$

6. The I^-/I_3^- system then gains an electron from the photo-cathode.
7. Electrons flow through the wire and the load to replenish the used up electrons at the photo-cathode.

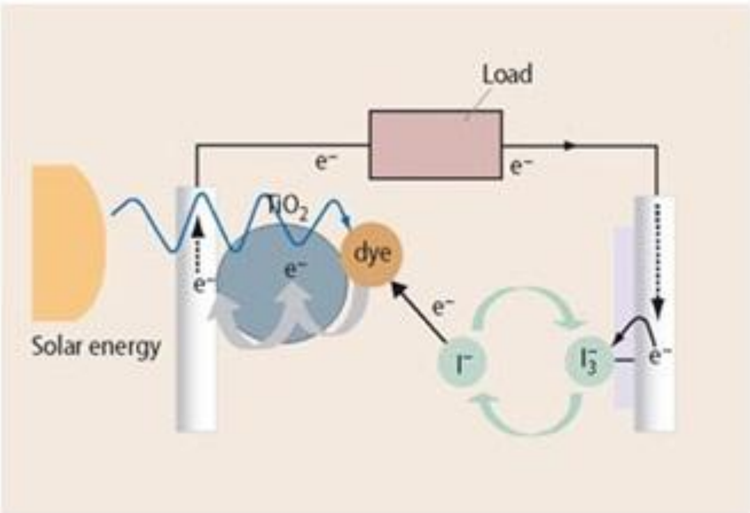

Figure 2 Grätzel cell process.[1]

Conventional solar panels consist of lots of solar cells and require flawless silicon crystals for each cell. The process of producing and growing flawless silicon crystals is complicated and slow, making the crystals expensive. The layers making up a Grätzel cell look complicated but are actually easier to produce than the perfect silicon crystals required for silicon based solar panels. This means Grätzel cells are potentially much cheaper to produce than silicon based solar panels.

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[1] *Chemistry in Education*, September 2007

A number of technical challenges have to be overcome before the cells can go into mass production. One is that the liquid electrolyte is affected by temperature changes therefore leading to freezing and expansion of the solvent or vaporisation and leakage.

As is always the case with inventions, funding needs to be found to scale up the process in order that this technological innovation can move from research lab into mass production. Grätzel cells are envisaged to make a contribution to renewable electricity production by 2020.