Performance Coatings : Active Surface Nano-Technology

Self-cleaning by light induced superhydrophilicity with THETA thin film titanium dioxide

Maintenance of the exterior of buildings raises a number of issues with its high cost, particularly with tall buildings or hard to reach areas, see Figure 1, that necessitate scaffolds, cradles and even abseiling. Safety requirements can be extensive and window cleaning is considered the most dangerous job in the UK with several deaths each year. The environmentally unfriendly use of detergents and water wastage lends it to be a resource heavy activity. Self-cleaning glass and facades can hold the key to alleviate these problems with thin film titanium dioxide (TiO_2) providing the greatest results.

Figure 1. Environments with high potential for self-cleaning surfaces

TiO_2 is a semiconductor material with photocatalytic properties. One of these photocatalytic properties include light induced superhydrophilicity which can be activated by sunlight. Activated **THETA** TiO_2 films attract water resulting in it lying flat on the surface creating a water sheeting effect instead of forming droplets, see Figure 2. This produces a self-cleaning effect as oil/dirt can be easily rinsed away. The film reduces the cost of maintenance due to the film remaining cleaner for longer as well as easier to clean by inhibiting the ability of dirt to adhere to the surface. Self-cleaning surfaces are particularly applicable in difficult to reach areas, reduce the use of detergents and water and the sheeting effect accelerates drying minimising unsightly streaking and spots.

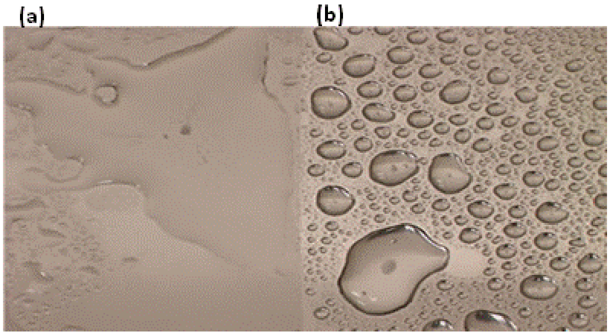

Figure 2.(a) Coated surface with sheeting of water and (b) uncoated surface with beading of water

The film is permanent lasting the lifetime of the underlying substrate (e.g. glass, ceramic etc.) exhibiting excellent physical properties, including durability, transparency, through **THETA's** patented solubility technology. Ultraviolet light from sunlight is sufficient to maintain the superhydrophilic surface where substrates coated with TiO_2 films show substantially clearer surfaces than those without.

Determination of the effect is carried out using a goniometer measuring the contact angle. The contact angle is the angle at which a liquid meets a solid surface, see Figure 2. If a liquid is attracted to the surface the droplet will spread out on the surface producing a small contact angle. If water has a small contact angle with a surface, the surface is said to be hydrophilic. If water has a large contact angle, the surface is said to be hydrophobic. On hydrophilic surfaces, water droplets will exhibit contact angles of ca. 20°. If the solid surface is superhydrophilic contact angles close to 0° are achieved.

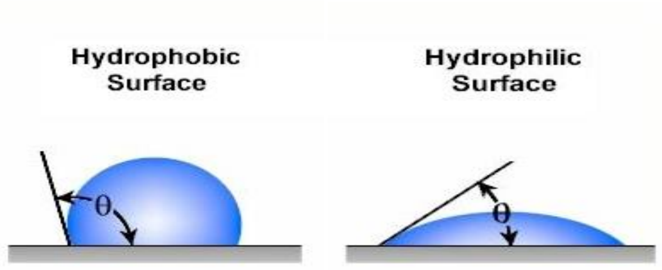

Figure 2. Contact angles of droplets on hydrophobic and hydrophilic surfaces

The irradiation of the film creates a surface that is highly hydrophilic or superhydrophilic with a low contact angle of 0°±1° by changing the nature of the surface and increasing its wettability. TiO_2 is activated when a photon of UV light generate electron-hole pairs. The photogenerated holes migrate to the surface and weaken the bond between the titanium and oxygen atoms. These oxygen atoms are liberated to created oxygen vacancies with the conversion of Ti^{4+} to Ti^{3+}. Water molecules are chemisorbed at these sites creating a more hydroxylated surface increasing the surfaces ability to hydrogen bond with water it comes into contact with. Even with storage in the dark for a few days the hydrophilic surface is maintained however long storage leads to a gradual increase of water contact angle due to relaxation of the surface from replacement of hydroxyl groups with oxygen from the air.

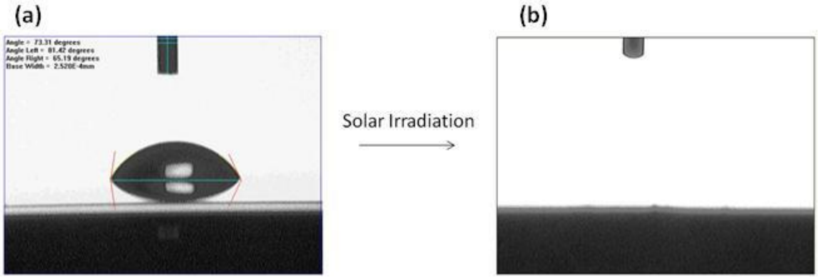

Figure 4. Reactivation of TiO_2 film with solar irradiation from (a) hydrophobic 73° to (b) hydrophilic 0°±1°

Deactivation of the superhydrophilic property may occur outdoors through contamination of the surface by organics, e.g. dirt and oil, on the film. The increased activity of **THETA's** films speed up the breakdown of these contaminants while increased solar absorption efficiency lead to a faster regeneration of super-hydrophilicity, see Figure 4, in comparison to commercial alternatives. The increase in regeneration is due to careful manipulation of the TiO_2 structure through 'doping' of elements in the crystal as well as introduction of surface bound species. The flexibility of **THETA's** solubility technology allows the introduction of a wide variety of 'dopants' elements including metals and non-metals, cat-ions and anions. These increase the quantum efficiency of the TiO_2 particles by reducing electron-hole recombination while increasing solar absorption and accelerating the formation of reactive oxygen species (ROS).