THETA

Performance Coatings : Active Surface Nano-Technology

# Superior Anti-bacterial Performance of TiOSOL: Hybrid Dual Action films

A major concern in healthcare (e.g. hospitals, residential care units) and community (e.g. schools, swimming pools) environments is the transmission of infection where contamination readily occurs through infected individuals. Surfaces can act as reservoirs for microbes in these locations where infectious agents such as *Methicillin resistant staphylococcus aureus* (MRSA) can survive up to 9 weeks. Those affected face increased mortality and morbidity risks and as well as raising resource costs through cleaning and sanitization. Increased resistance exhibited by bacteria to conventional antibiotics make these outbreaks a greater concern. Further unease exists with excessive use of disinfectants, particularly chlorine or peroxide containing chemicals where concerns about toxicity and mutagenesis exist. Therefore, the alternative of self-sterilising surfaces shows huge potential to reduce the microbial density of an environment and lowering transmission.

The antimicrobial activity of photocatalytic titanium dioxide ($TiO_2$) has been well reported. As a light activated material, photons of light generate electron-hole pairs that migrate to the surface of the $TiO_2$ particle. There they react with surface water to produce a number of reactive oxygen species (ROSs) *via* a series of oxidation and reduction reactions. The principle reactive species responsible for the anti-microbial action is the hydroxyl radical which attacks organic material in a highly oxidative, nonspecific fashion. The hydroxyl radical causes the breakdown of the cell wall and cytoplasmic membrane where leakage of cytoplasm, including critical ions such as $K^+$, results in cell death. However, due the requirement of light for activation in dark or dimly lit areas the anti-microbial efficiency can be reduced or halted completely.

There are many antimicrobial agents using various mechanisms of action, organic (Triclosan, polycations), inorganic (copper), biological (bacteriophages) and surface treatments (plasma). A common problem encountered with many anti-microbial coatings and agents is the formation of biofilms. Biofilms increase the ability of microbes to adhere to a surface but also negate any anti-microbial effect as the biofilm acts as barrier between the surface and the microbes. TiOSOL™ was developed in tackle these shortcomings by taking a multi-faceted approach by ensuring a continuous anti-microbial action under any conditions. The composite film produces a hybrid dual action coating, see Figure 1. In areas not illuminated consistently different modes of

anti-microbial activity are utilised to boost the efficiency of $TiO_2$ while the breakdown of organic matter by $TiO_2$ eradicates the issue of biofilms.

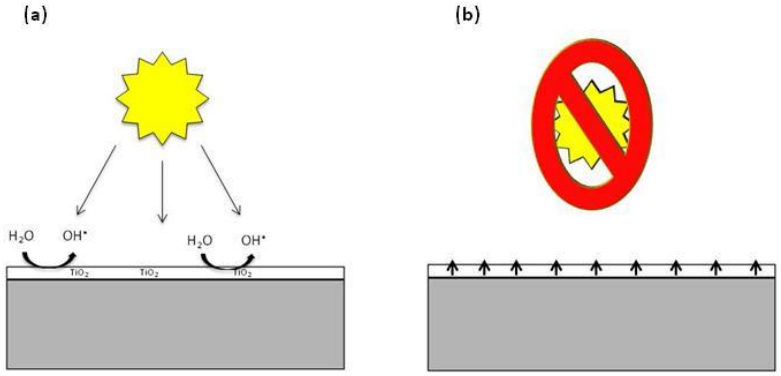


**Figure 1**. Dual action mechanism of TiOSOL™ film

Biological survival studies were carried out to explore the anti-microbial efficiency of TiOSOL™ films demonstrate their exceptionally potency at killing both gram negative *Escherichia coli* ATCC 25922 and gram positive *Staphylococcus aureus* ATCC 25923 under fluorescent illumination and in dark conditions. Test conditions and procedure were executed using aseptic techniques and all testing was carried out in triplicate. To ensure accuracy two parallel serial dilutions and inoculated Petri dishes were carried out where an average was taken. Samples were divided into a number of control and test categories as set out in Figure 2. Both coated and uncoated aseptic samples were spiked with a bacterial load, incubated for 15 hours at 30-35°C under fluorescent light irradiation as well as in the dark. 'Pre-activated' samples were irradiated with fluorescent lighting prior to testing.

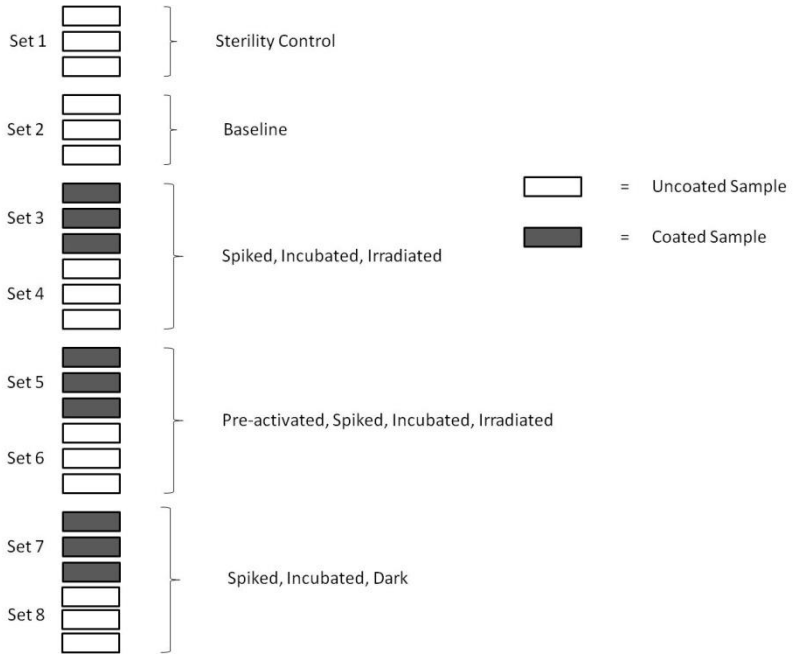


**Figure 2**.Microbiological survival test sample regime

The microbiological results were successful in displaying the anti-bacterial properties of TiOSOL™, see Table 1. Results reveal that environmental stresses or lack of resources cannot be attributed to the testing conditions as no significant losses (<log 1) were encountered for any of the controls.The hybrid films produce a bio-cidal surface that totally reduces microbial density, not a single colony forming unit was present for the coated samples for both gram negative and gram positive test regimes.

| **Conditions** | ***Escherichia coli* ATCC 25922** | ***Staphylococcus aureus* ATCC 25923** |
|---|---|---|
| Baseline | $2.8x10^7$ | $2.77x10^8$ |
| Control 1 (uncoated) | $2.0\ x10^7$ | $1.36\ x10^8$ |
| Control 2 (uncoated) | $1.8\ x10^7$ | $1.54\ x10^8$ |
| Control 3 (uncoated) | $2.3\ x10^7$ | $1.64\ x10^8$ |
| Coated with Light | <100 (below detectable levels) | <100 (below detectable levels) |
| Coated with Pre-light activation | <100 (below detectable levels) | <100 (below detectable levels) |
| **Coated in Dark** | <100 (below detectable levels) | <100 (below detectable levels) |

**Table1**. Microbiological survival test results of dual action hybrid films

All coated samples (**including samples left in the dark**) recorded a total loss of bacteria density below detectable levels. TiOSOL™ films produced using THETA patented solubility technology are durable, functional coats formed by conventional coat/anneal methods and can be easily applied to common surfaces underlying their commercial use. The dual action films exhibit excellent physical properties, in areas such as transparency, adhesion, abrasion and porosity. Functional testing demonstrates the films to have superior antimicrobial activity under both light and dark conditions illustrating their scope in reducing infection transmission on surfaces of internal environments.