

INTRODUCTION

The provision of biocidal films for different substrates such as ceramic, glass and stainless steel surfaces is an area of significant interest, particularly in places of high microbial density such as hospitals, public bathrooms, commercial kitchens etc.[1] This research reports on the development of visible light activated photocatalytic titania films producing surfaces with continuous high microbial performance with excellent physical properties.

Titanium Dioxide: Photocatalysis

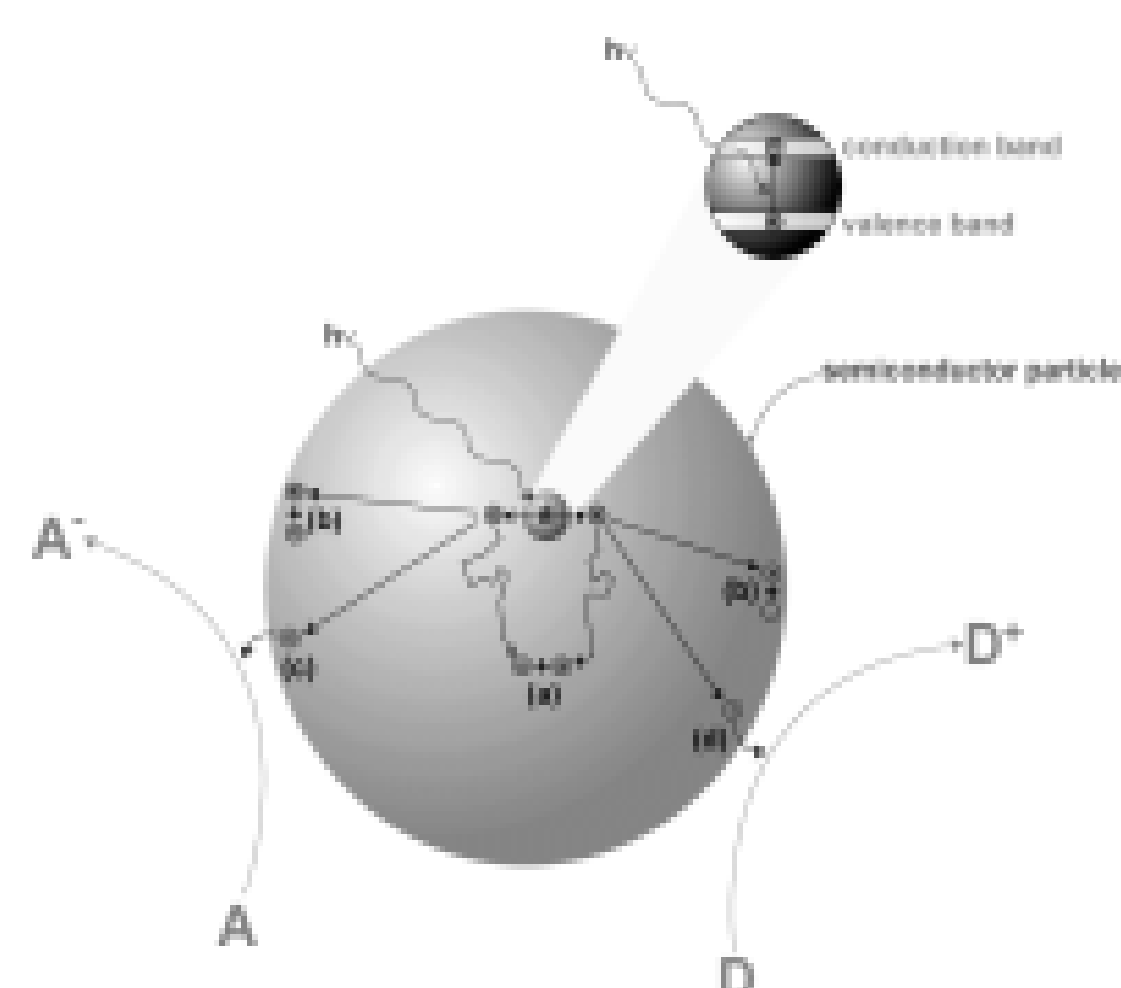


Figure 1: Mechanism of Action

The antimicrobial activity can be enhanced by exploiting visible light rather than UV like traditional Titania products [3]. This can be achieved by the introduction of a selected impurity or 'dopant'.

Photocatalytic titania has the ability to convert electromagnetic energy to chemical energy and generate activated species which can be utilised to attack the cell wall of microbes leading to lysis and death [2].

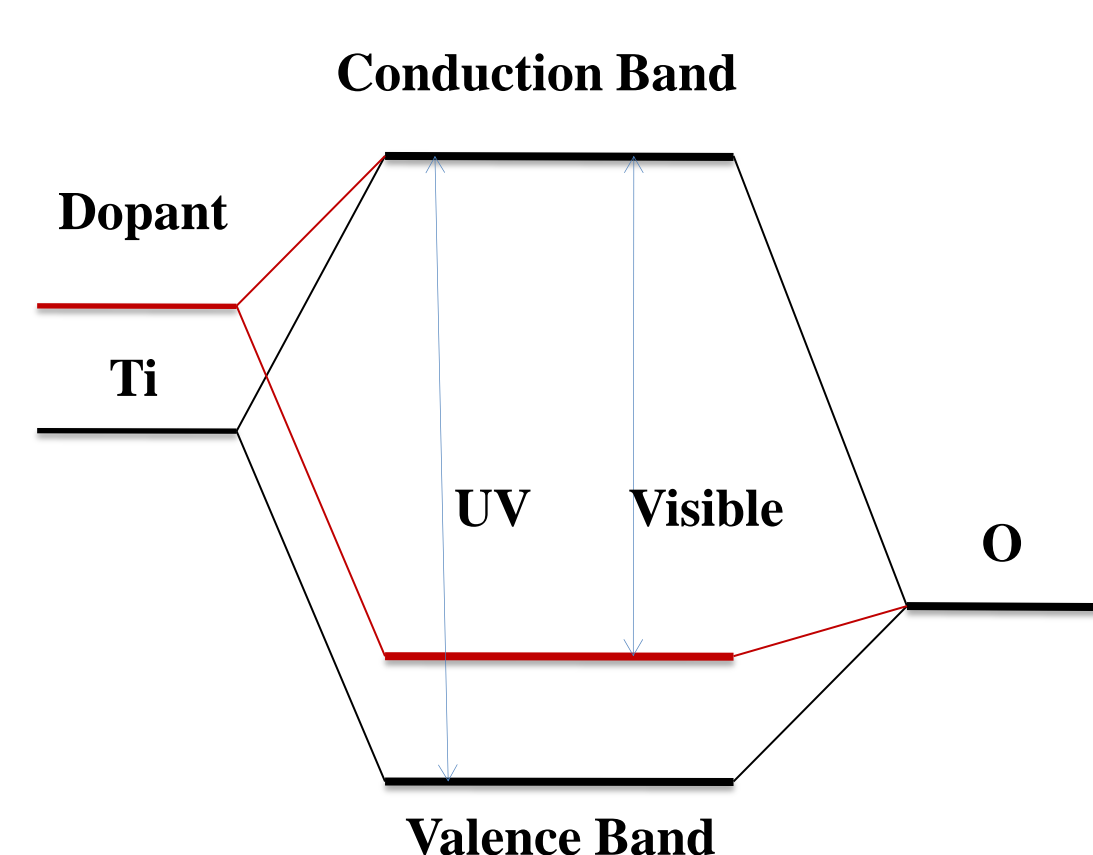


Figure 2: Visible Light Activation

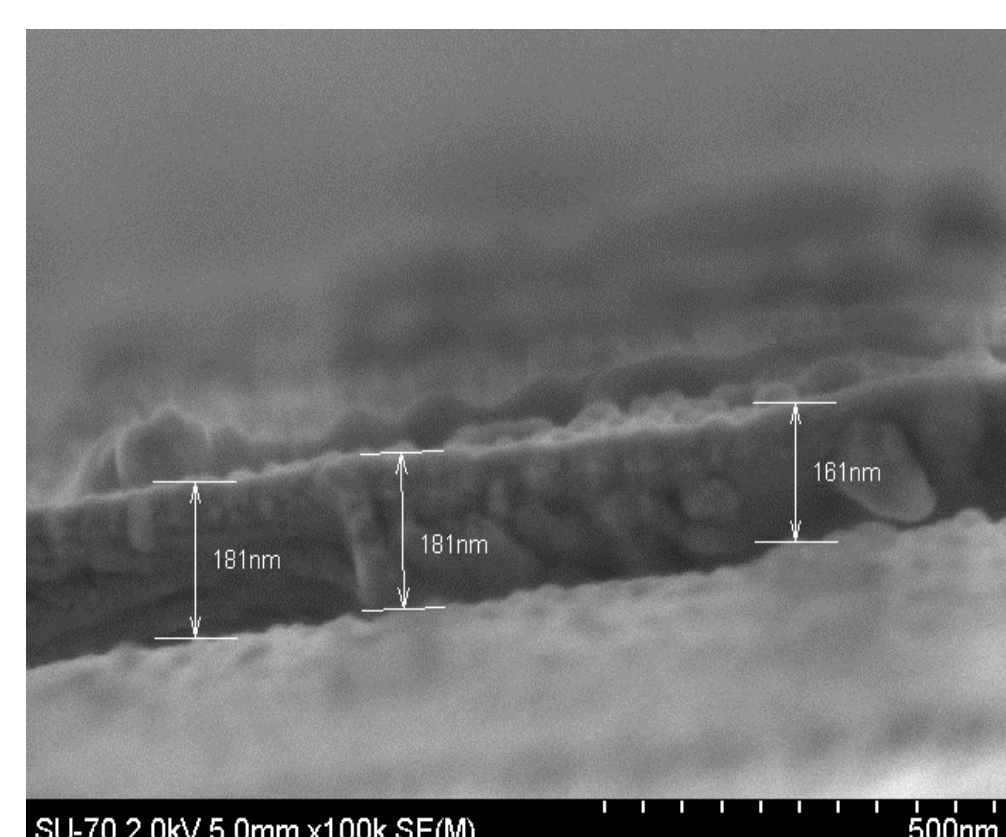


Figure 3: Film Thickness

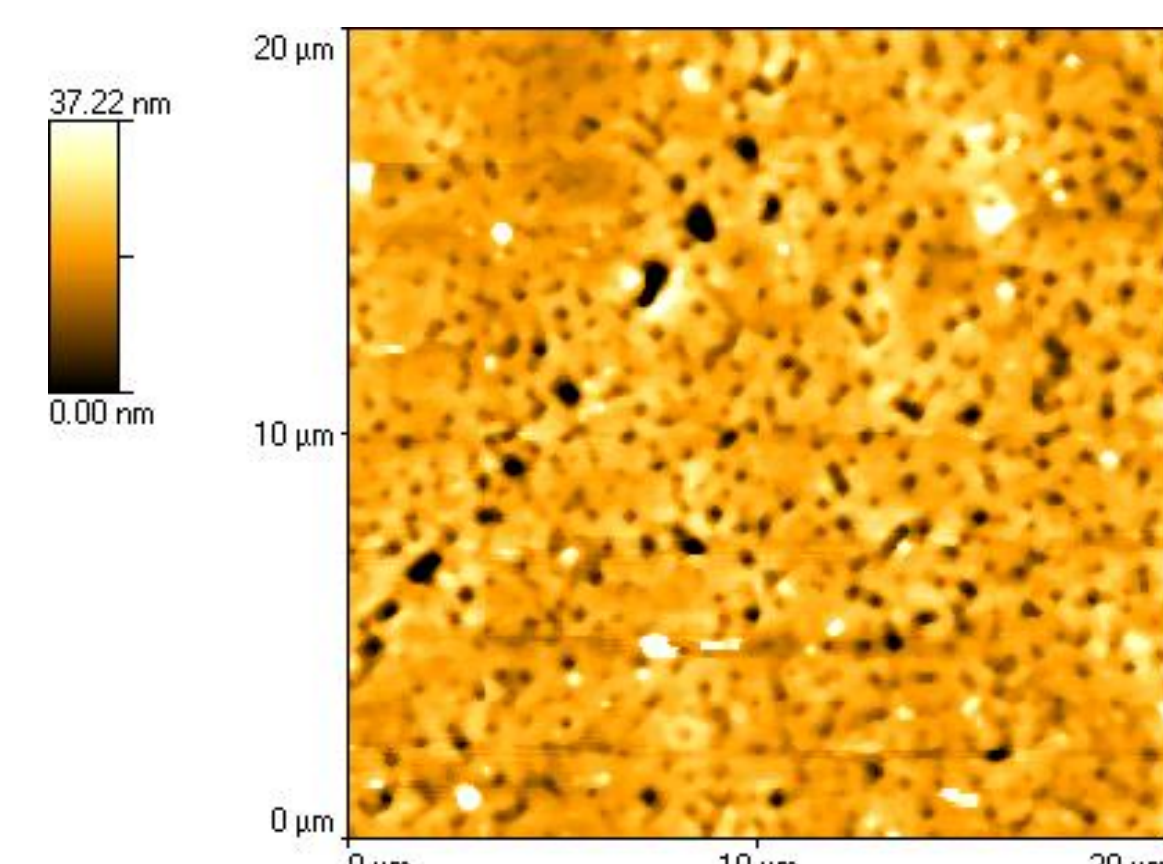


Figure 4: Film Porosity

Ceramic tile substrates were coated to a film thickness of approximately 200 nanometres. The films were porous in nature increasing the surface area and efficiency of the antimicrobial action.

EXPERIMENTAL METHODS

Microbiological survival testing was performed with Isotron Ireland Ltd. (ISO 17025 certified facility). Test conditions were representative of conditions found in typical internal settings. Gram negative *Escherichia coli* NCTC 12923 was selected and sustained with a Trypticase soy broth (TSB).

Results were recorded in triplicate and incubated samples were maintained at 30-35°C for 15 hours. A number of controls were employed. Samples listed as "Pre-activated" were illuminated for 24 hours before spiking with a bacterial load. Upon completion all test cultures were extracted, diluted, plated on sterile solid TSA plates and counted.

REFERENCES

- [1] Page *et al.*, *J. Mater. Chem.*, 2009, 19, 3819-3831
- [2] Maness *et al.*, *App and Env. Micro.*, 1999, 65, 4094-4098
- [3] Hashimoto *et al.*, *Jap. J. App. Phys.*, 2005, 44, 8269-8285

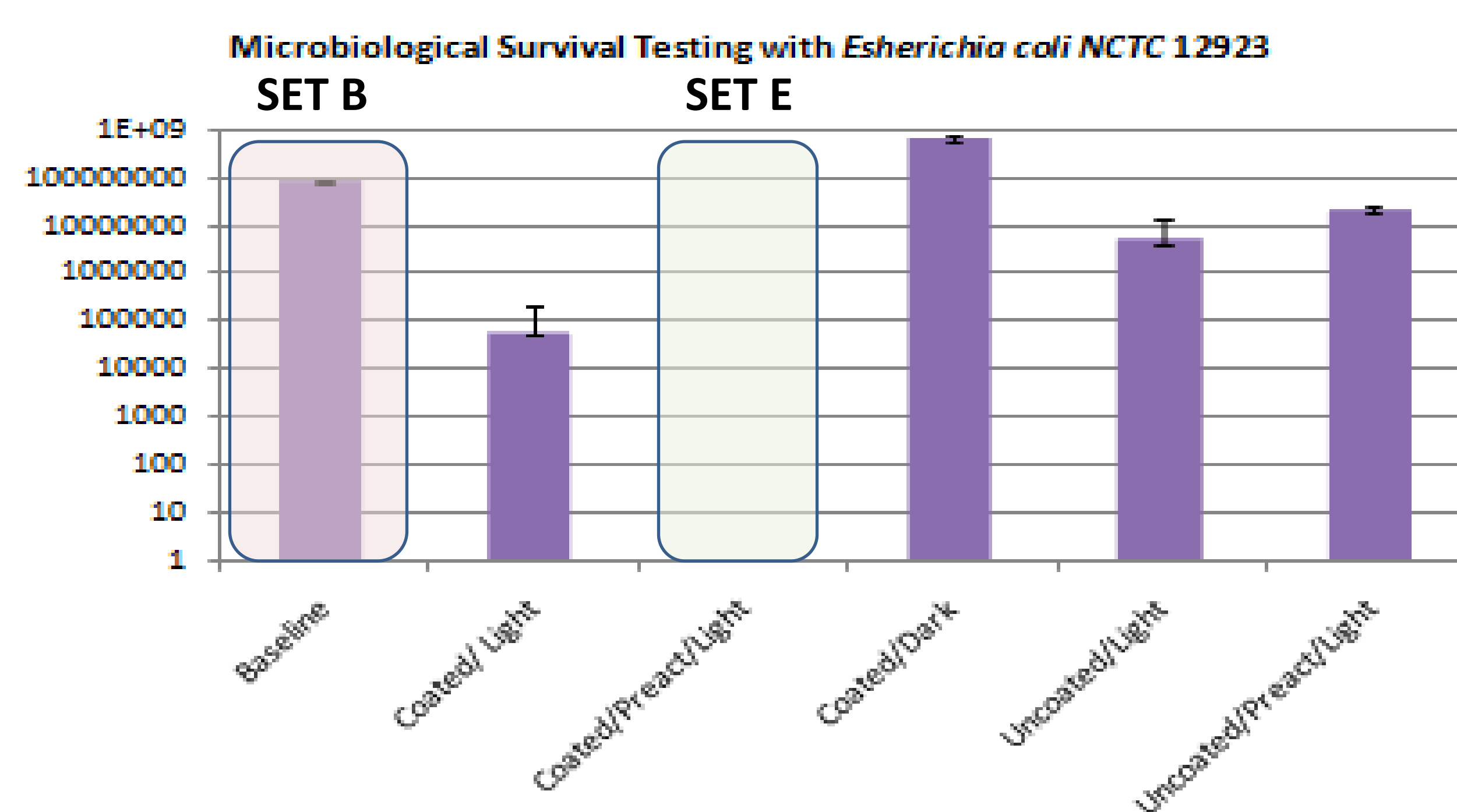
RESULTS

The antimicrobial effect of the photocatalytic titania films is confirmed with a **5.85 log** reduction (>99.999%) and a **3.1 log** reduction (>99.9%) on the incubated coated samples illuminated by fluorescent lighting. In fact on the pre-activated samples not a single cfu was counted.

| | SET A | | | SET B | | | SET C | | | SET D | | | SET E | | | SET F | | | SET G | | |
|--------------------|---------|---------|---------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|---------|---------|---------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| | Plate 1 | Plate 2 | Average | Plate 1 | Plate 2 | Average | Plate 1 | Plate 2 | Average | Plate 1 | Plate 2 | Average | Plate 1 | Plate 2 | Average | Plate 1 | Plate 2 | Average | Plate 1 | Plate 2 | Average |
| Tile 1 | 0 | 0 | 0 | 80 | 84 | 82 | 83 | 89 | 86 | 35 | 30 | 32.5 | 0 | 0 | 0 | 204 | 215 | 209.5 | 70 | 85 | 77.5 |
| Tile 2 | 0 | 0 | 0 | 73 | 74 | 73.5 | 40 | 50 | 45 | 37 | 49 | 43 | 0 | 0 | 0 | 168 | 182 | 175 | 53 | 47 | 50 |
| Tile 3 | 0 | 0 | 0 | 61 | 51 | 56 | 22 | 30 | 26 | 46 | 55 | 50.5 | 0 | 0 | 0 | 170 | 155 | 162.5 | 40 | 32 | 36 |
| Average cfu / tile | 0 | 0 | 0 | 70.5 | 70.5 | 70.5 | 52.3 | 52.3 | 52.3 | 42 | 42 | 42 | 0 | 0 | 0 | 182.3 | 182.3 | 182.3 | 54.5 | 54.5 | 54.5 |
| Average Count | 0 | 0 | 0 | 7.1 x 10 ⁷ | 7.1 x 10 ⁷ | 7.1 x 10 ⁷ | 5.2 x 10 ⁴ | 5.2 x 10 ⁴ | 5.2 x 10 ⁴ | 4.2 x 10 ⁶ | 4.2 x 10 ⁶ | 4.2 x 10 ⁶ | <100 | <100 | <100 | 1.8 x 10 ⁷ | 1.8 x 10 ⁷ | 1.8 x 10 ⁷ | 5.5 x 10 ³ | 5.5 x 10 ³ | 5.5 x 10 ³ |

Table 1: Results of Microbiological Survival Tests

| | |
|--------|--|
| SET A: | Sterility Control |
| SET B: | Baseline |
| SET C: | Coated/Incubated with Light |
| SET D: | Uncoated/Incubated with Light |
| SET E: | Coated/Incubated with Light, Pre-activated |
| SET F: | Uncoated/Incubated with Light, Pre-activated |
| SET G: | Coated/Incubated in Dark |



Graph 1: Microbiological Survival Results

DISCUSSION

The titania films produce a biocidal surface that significantly (or totally) reduces microbial density. The microbiological results also reveal through the use of controls that environmental stresses or lack of resources cannot be attributed to the testing conditions.



Added to the successful results from gram positive *Staphylococcus aureus* ATCC 6571 and physical and chemical resistance analysis the films provide a higher performing option to current alternatives available.

ACKNOWLEDGEMENTS

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