PREVENTION OF BIOFILM FORMATION BY GALVANIC MICROCELLS

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SUMMARY:

We found that electrochemical galvanic currents (GC) can generate anti-microbial activities, resulting in effective prevention of biofilm formation. Biofilms from bacteria and fungi are similarly affected. Various metal electrodes differ in their anti-microbial and biofilm preventing activities. We find that cells with Ti – TiO_2 electrodes are most highly effective in preventing microbial biofilm formation.
The galvanic biofilm-preventing activities are related to the distances between electrodes. The shorter these distances the larger the diameters of fungus-free zones that surround the electrodes. Utilization of galvanic cells has already proven to be useful in preventing fungal contaminations of paints. We now believe that galvanic cells may also effectively prevent biofilm formation on indwelling medical devices. We now aim to address this medical indication and develop the required technology to implement it.

INTRODUCTION:

Microbial biofilms affect medical, culinary and industrial products. Biofilms form on inert surfaces of a wide range of indwelling medical devices, primarily catheters (urinary, central vein, intratracheal etc.). Infections are resistant to antibiotics & antifungal agents, requiring removal of the inserted devices.
Industrial products such as foods and paints, water pipes and surfaces of water reservoirs are also substrates for bacterial or fungal biofilms.
Major efforts are thus directed towards developing effective means for preventing biofilm formation.
Our approach is to develop systems that prevent microbial biofilms by forming electrochemically generated, ionically conductive environments using galvanic microcells. We show here that we can prevent fungal biofilms with Cu – Zn electrodes in galvanic microcells and bacterial ones with Ti – TiO_2 electrodes for prolonged durations of more than 5 months.

Methods:

Galvanic currents were generated in microcells using Cu–Zn electrodes or Ti–TiO_2 electrodes. Fungal cultures of Trichoderma viride, Cladosporium cladosporioides and Aspergillus niger grown in modified Potato Dextrose Agar for 4 days with Cu-Zn electrodes immersed in the agar at distances of 2100-4500 υm. Bacterial cultures were of Enterococcus faecalis (ATCC).

RESULTS:

Usage of Galvanic Microcells Inhibits Microbial Cell Growth Galvanic currents (GC)s develop when ions from a metal electrode with a higher redox potential flow to an electrode with a lower potential [Fig. 1].

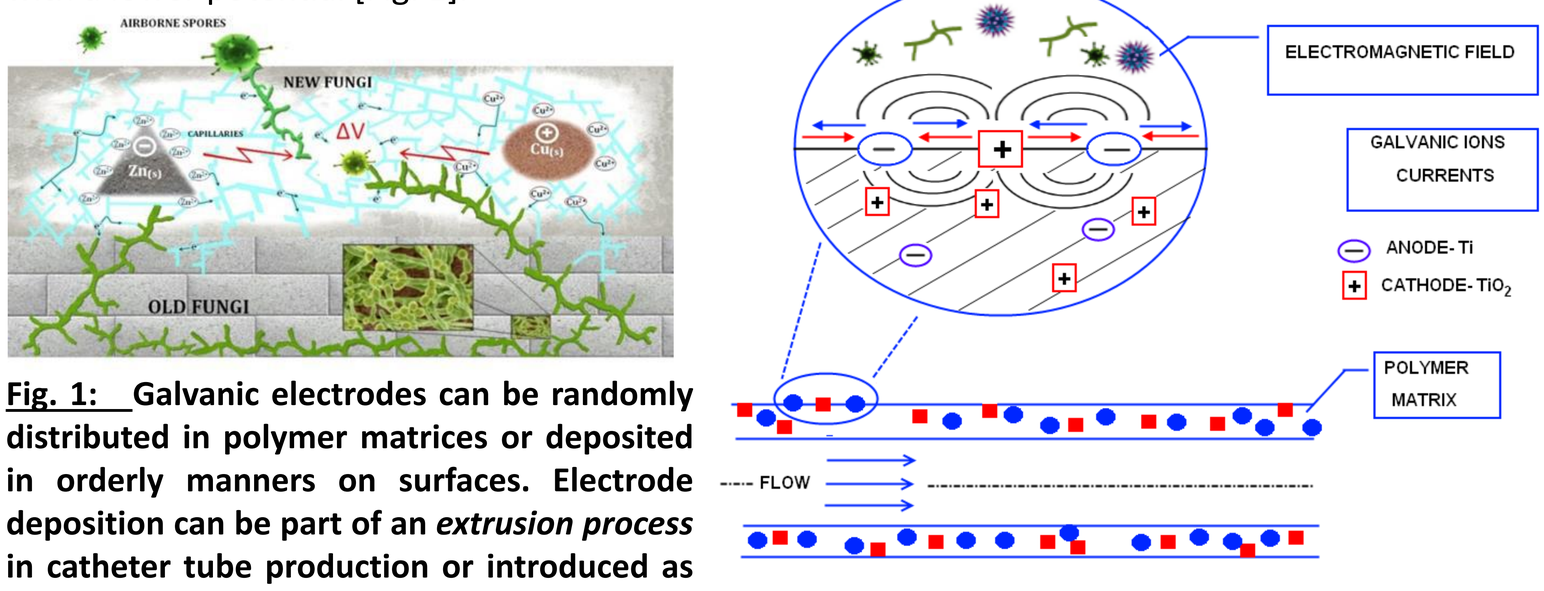


Fig. 1: Galvanic electrodes can be randomly distributed in polymer matrices or deposited in orderly manners on surfaces. Electrode deposition can be part of an *extrusion process* in catheter tube production or introduced as paint deposition.

We generated GC between Cu and Zn electrodes and evaluated their ability to inhibit fungal cell growth. The results are shown in Fig. 2.

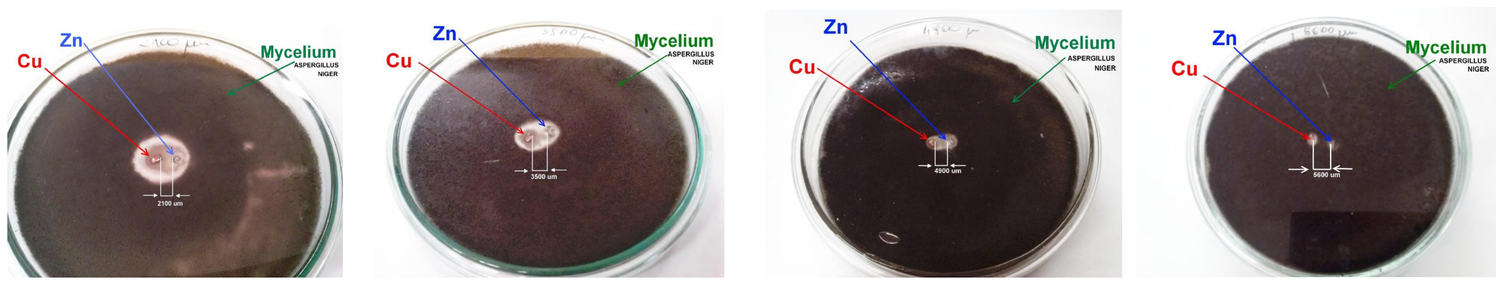
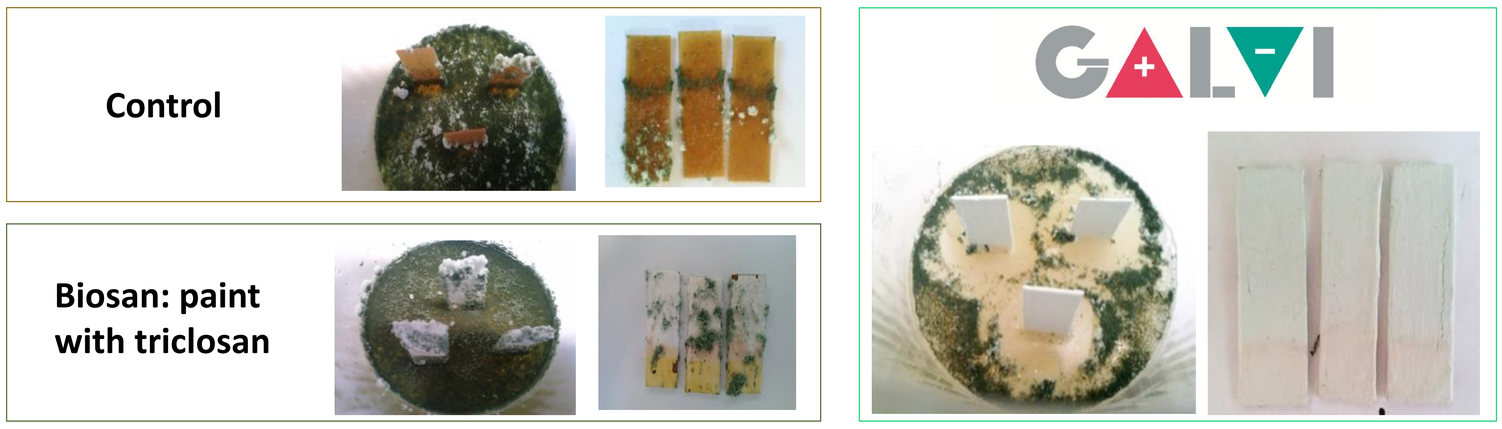


Fig. 2. Galvanic currents can be seen to inhibit fungal growth. As distances between electrodes vary, causing changes in the electric fields, the shape and size of the fungus-free halo changes as well. (Aspergillus niger). In paints, GC can inhibit fungal growth for more than 4 months.

Galvanic anti-fungal effects must be distinguished from well known anti-fungal toxicity of the metals that form the electrodes. This toxicity is noticeable primarily with the Zn electrode whereas galvanic antifungal effects affect both electrodes when the two are at close proximity and the antifungal effect diminishes as the distance between the electrodes increases



Galvanic Microcells Prevent Microbial Biofilm Formation

We further examined whether flow of galvanic ions can effectively inhibit microbial biofilm formation. The experiments were performed on bacterial Enterococcus faecalis (ATCC) cultures grown for 4 days in the presence of Ti – TiO_2 and Zn – Cu galvanic electrodes.. The results, Fig. 3 show that Ti - TiO_2 electrodes were most effective in inhibiting bacterial biofilm formation.

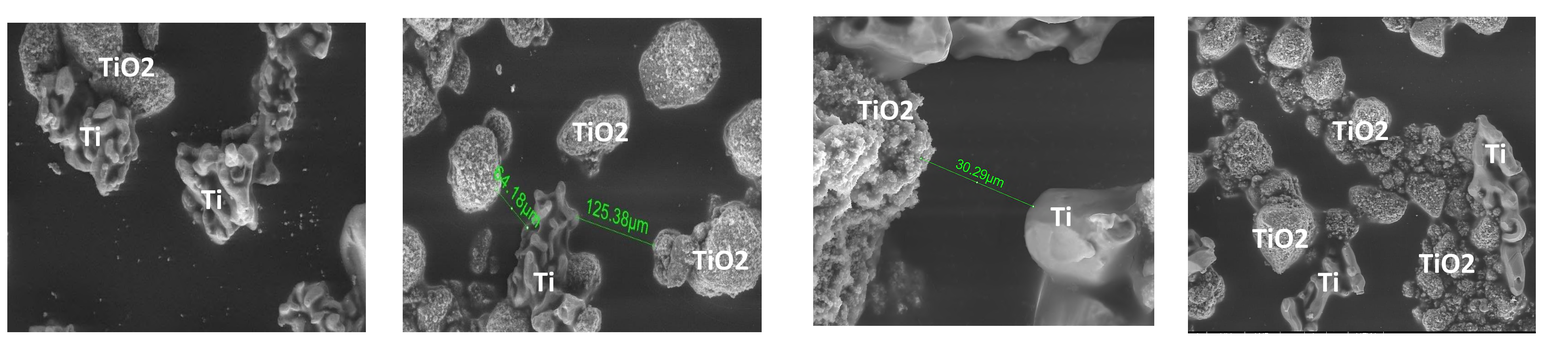


Fig. 3. Inhibition of bacterial biofilm formation by Ti – TiO_2 galvanic microcells