PREVENTION OF BIOFILM FORMATION BY GALVANIC MICROCELLS

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Microbial Biofilms Affect Medical, Culinary and Industrial products.

MEDICAL: Biofilms form on inert surfaces of indwelling medical devices, primarily catheters*. Infections are resistant to antibiotics & antifungal agents, requiring removal of the inserted devices.

(*urinary, intratracheal, central vein, peritoneal dialysis nephrostomes etc.)

INDUSTRIAL: Products such as foods and paints, water pipes and surfaces of water reservoirs are substrates for bacterial or fungal biofilms.

Major efforts are directed to preventing biofilm formation.

Strategies used to prevent biofilm formation included:

Chemical biocides: chlorohexidine, ion coatings with silver and to a lesser extent with zinc.

Interfere with attachment and expansion of immature biofilms. **EFFICACY LIMITED**

Antifungals: (1,3)-beta-D-glucan synthase inhibitors echinocandins- Caspofungin and micafungin, suggested to expand the effective range to fungal colonies.

Physico-mechanical strategies:

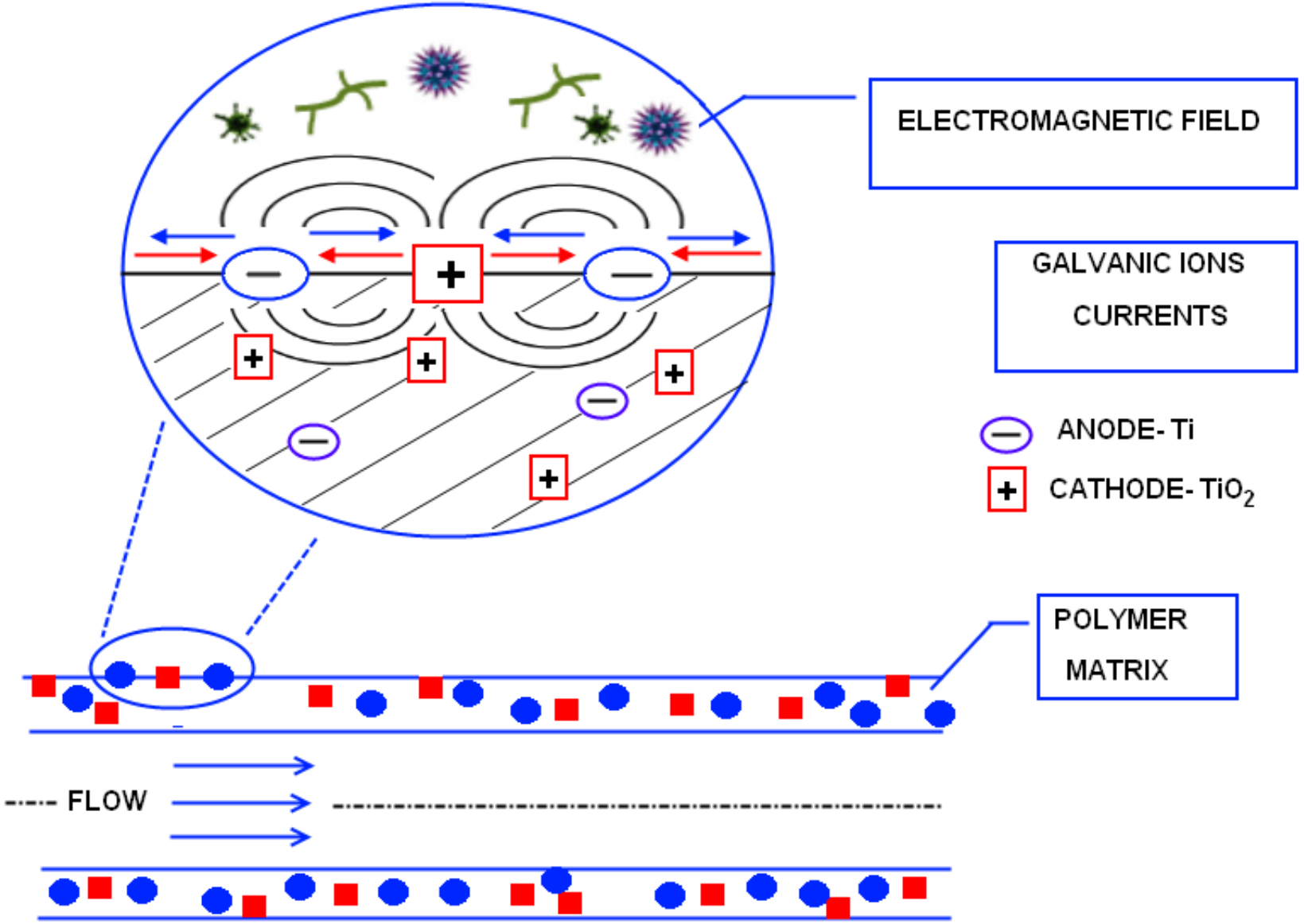
Surface-hydrophobicity, roughness.

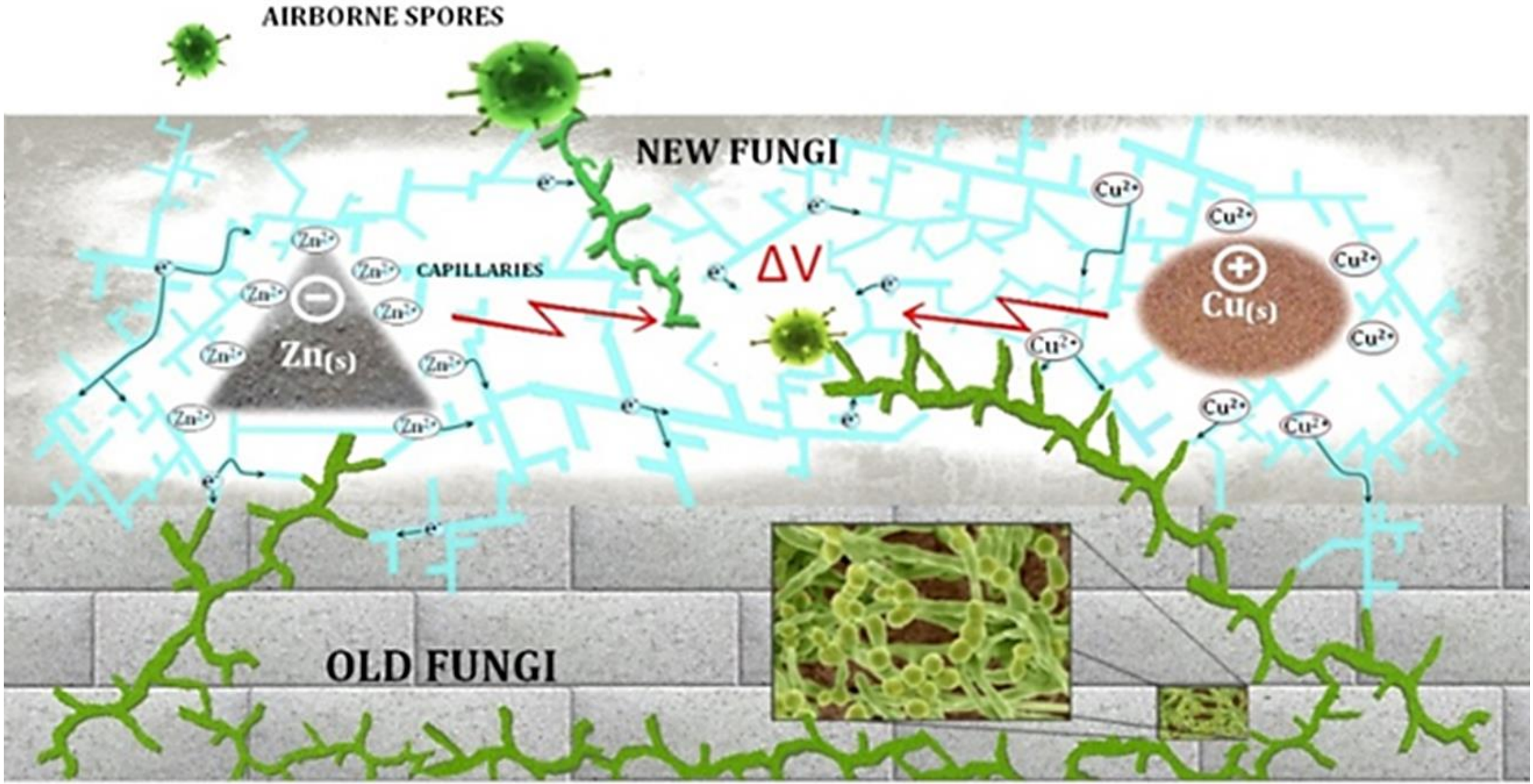
Usage of acoustic energy: efficacy hampered by strict requirements for specific wave amplitudes and frequencies, which are hard to achieve with piezo-electric elements.

We are contemplating usage of galvanic microcells for preventing biofilm formation.

Galvanic currents develop when ions from a metal electrode with a higher redox potential flow to an electrode with a lower potential.

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.

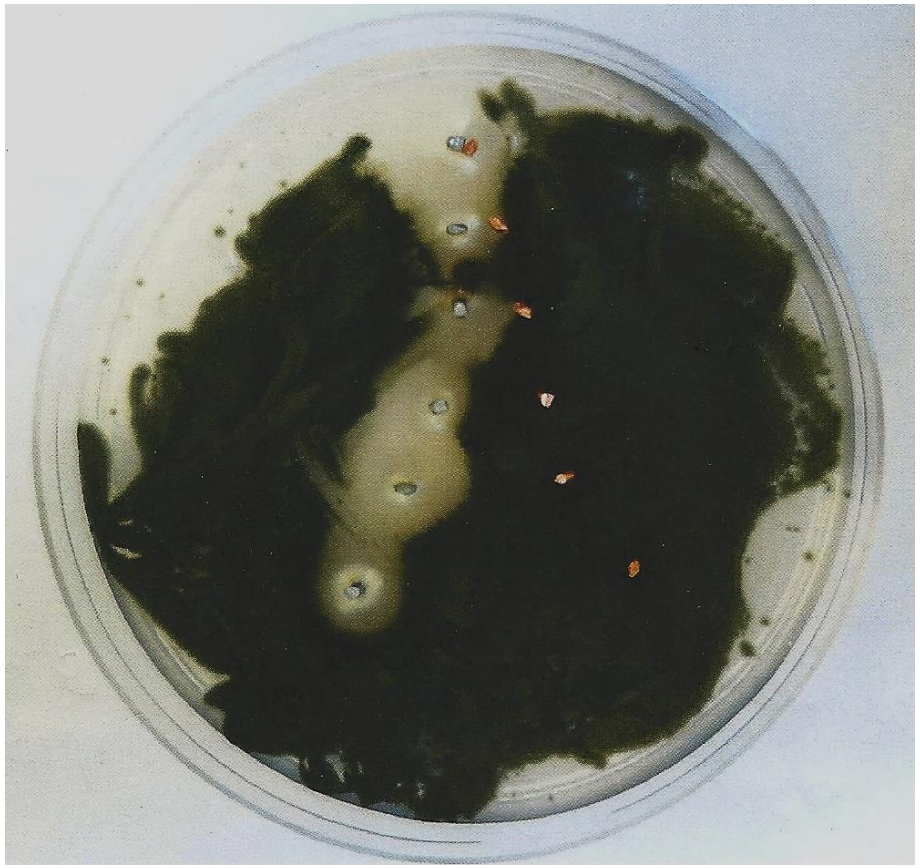



AIRBORNE SPORES
NEW FUNGI
CAPILLARIES
ΔV
Zn(s)
Cu(s)
OLD FUNGI

We show here that flow of galvanic ions can effectively inhibit Biofilm formation.

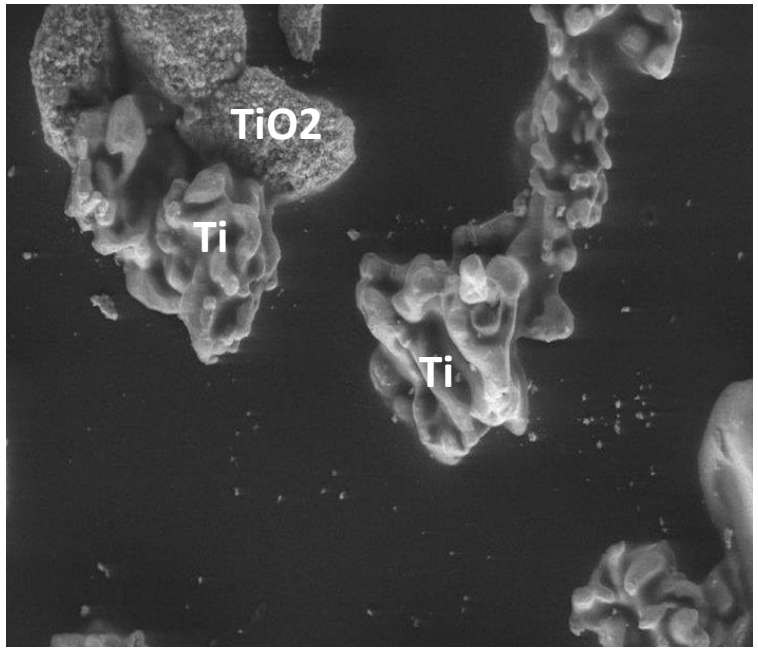
Two types of fungi are shown to be affected:

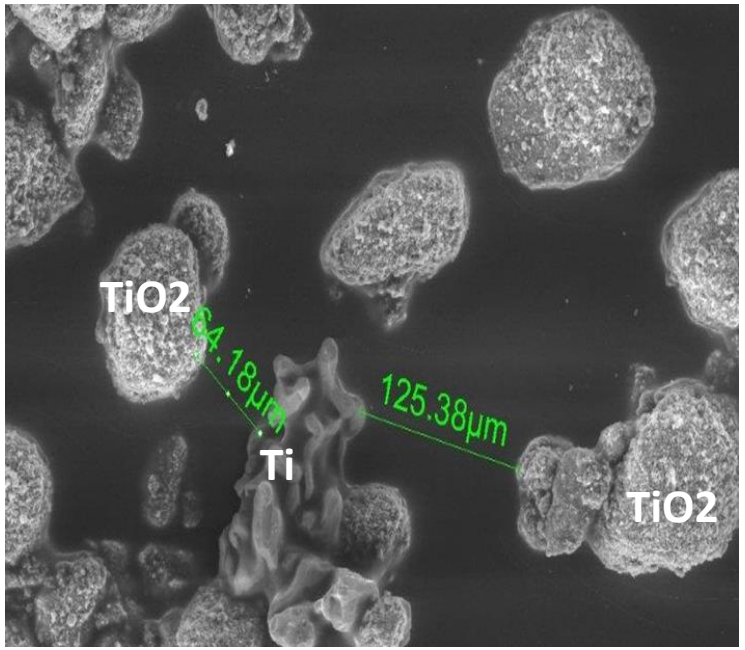
Cladosporium cladosporioides

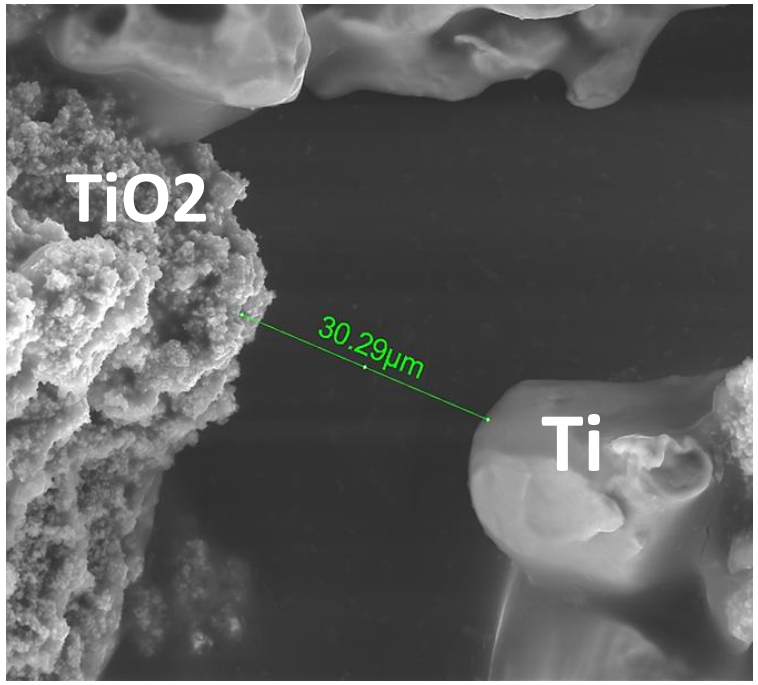


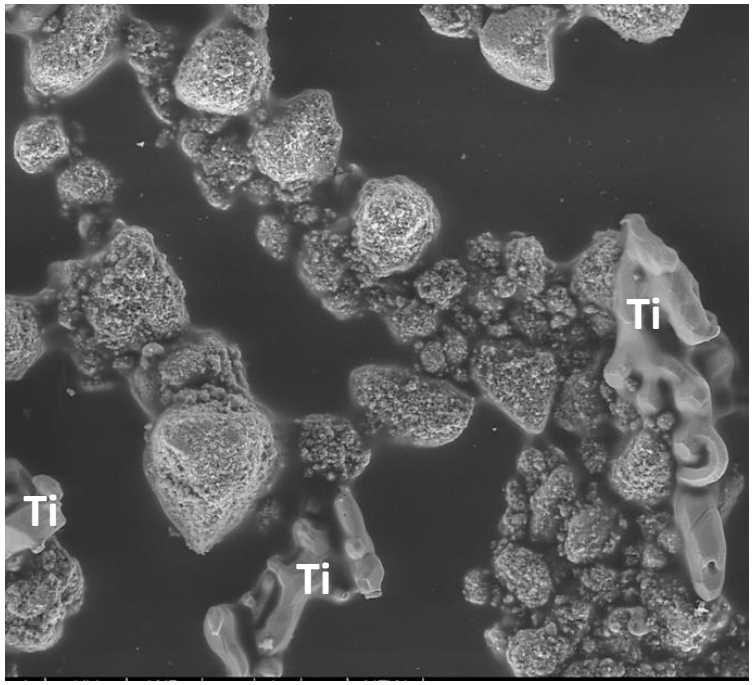
Trichoderma viride xeni

Galvanic anti-fungal effects must be distinguished from the well known anti-fungal toxicity of metals that form electrodes. This toxicity is noticeable primarily with the Cu 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.



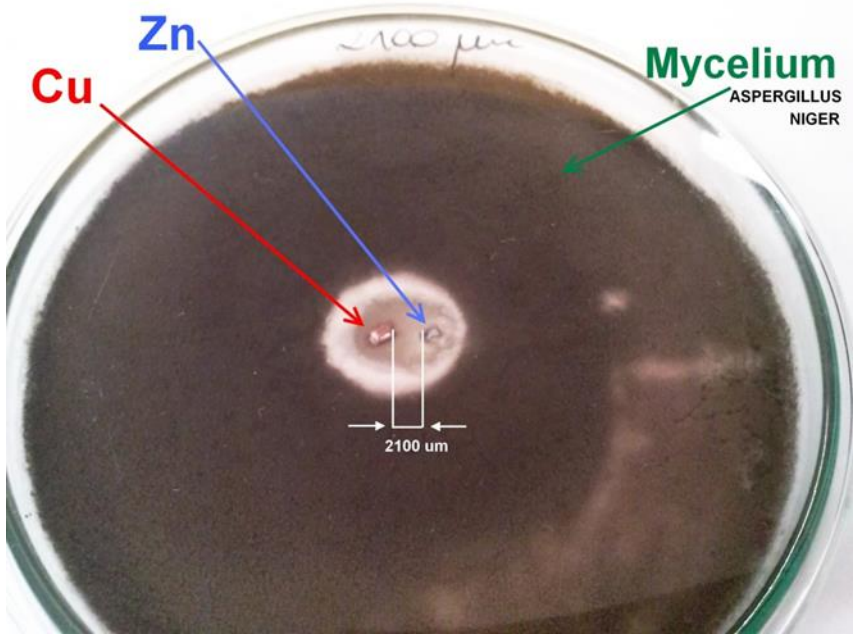


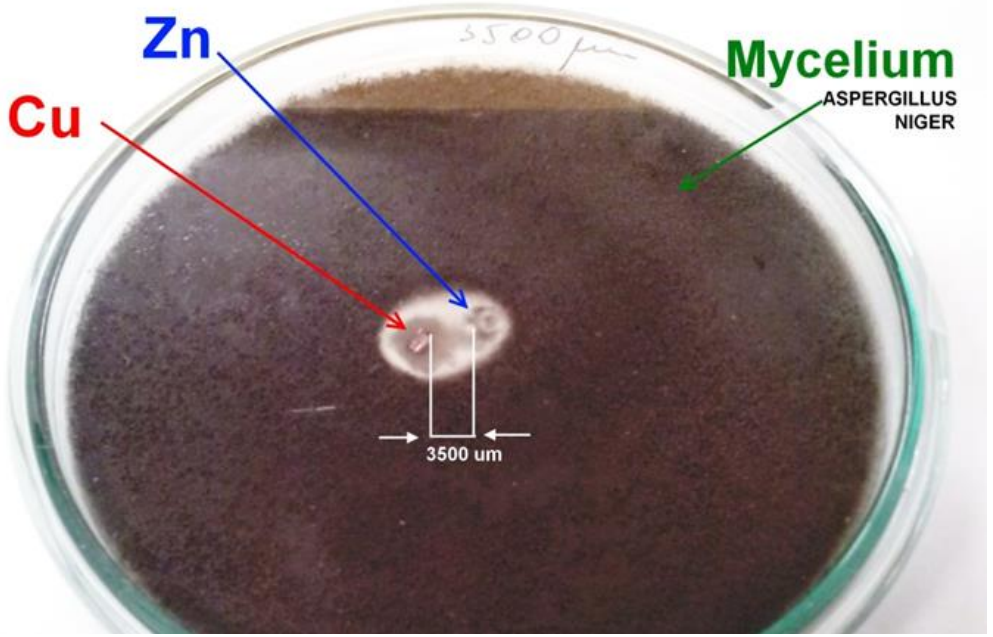


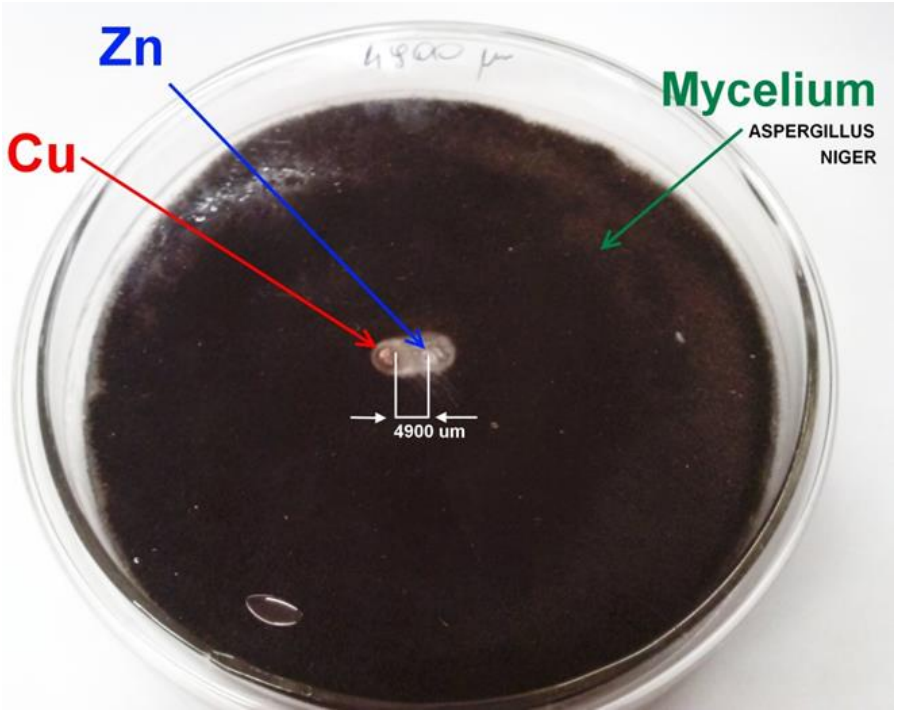


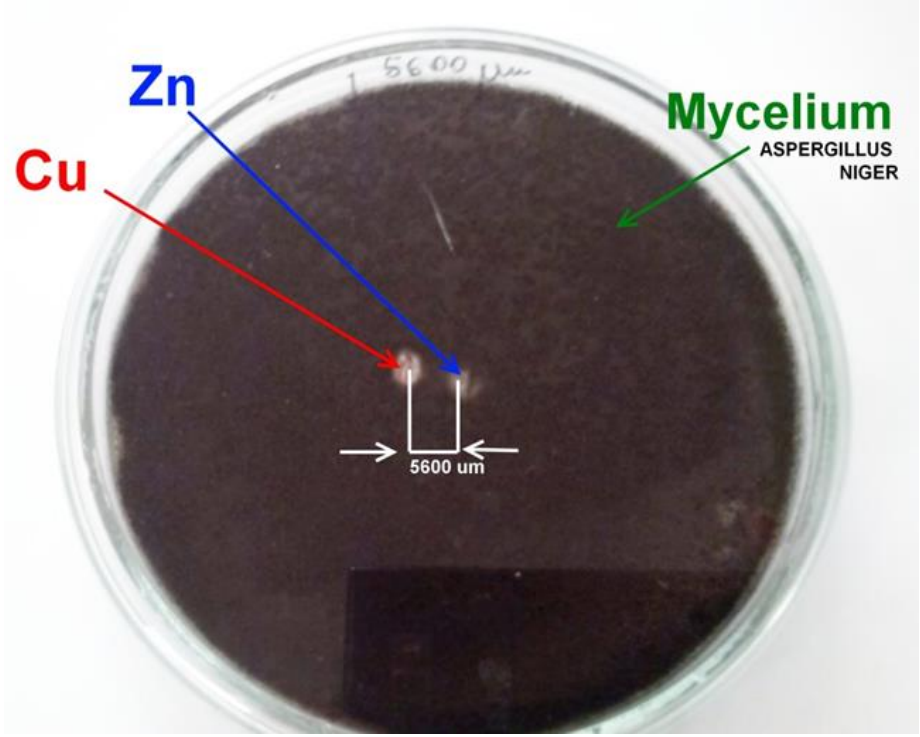
We show that the flow of galvanic ions can effectively inhibit Biofilm formation.

Here, incubation of *Enterococcus faecalis* **cultures, with galvanic ion currents produced from Ti – TiO_2 electrodes for 4 days cause significant prevention of biofilm development.**





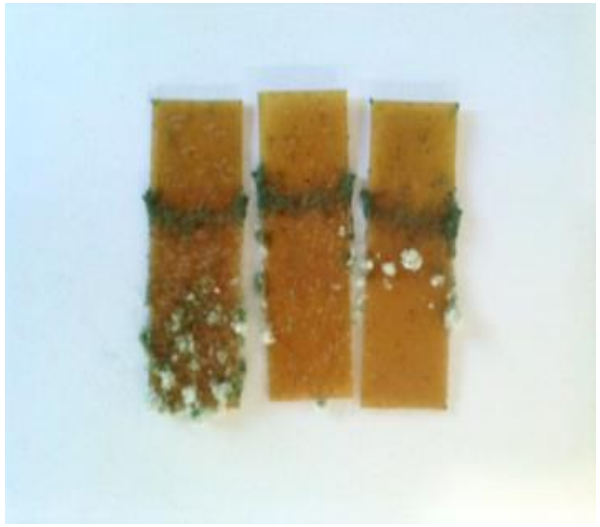




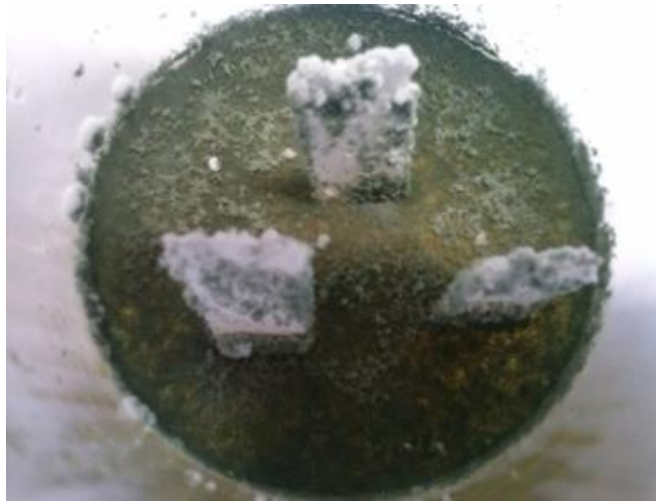
Analyses of parameters that affect the potency of anti-fungal activity of galvanic currents, utilizing cells with Cu-Zn electrodes.
Evaluation of the effects of the distance between electrodes on the the anti-fungal efficacy of the cell.

It can be seen that alteration of the distances between the electrodes modulates the antifungal activity of the galvanic currents. The shortest the distance between the electrodes, the larger is the halo, fungus-free zone around the electrodes.

Control



Biosan: paint with triclosan



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SUMMARY:

We have found that galvanic currents can generate anti-microbial activities that result in prevention of biofilm formation.

Biofilms from bacteria and fungi are equally affected by galvanic currents.

Various metal electrodes differ in the 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 the electrodes. The shorter the distance between the electrodes, the larger is the diameter of the fungus-free zone surrounding the electrodes.

The utilization of galvanic cells has already proven itself to be useful in preventing fungal contaminations of paints. We now believe that they may also be useful in preventing biofilm formation on indwelling medical devices. We now aim to address this medical indication and develop the required technology to implement it.