Applications of Energetic Materials and Copper Oxide Nanorods for Decontamination

Rajagopalan Thiruvengadathan[1], Byung Doo Lee[2], Brandon Smith[2], Shramik Sengupta[2], Luis Polo-Parada[3], Shubhra Gangopadhyay[1], and Keshab Gangopadhyay[1,4]

[1]Department of Electrical and Computer Engineering, University of Missouri, Columbia, Missouri 65211.
[2]Department of Biological Engineering, University of Missouri, Columbia, Missouri 65211.
[3]Department of Medical Pharmacology and Physiology, University of Missouri, Columbia, Missouri 65211.
[4]NEMS/MEMS Works, LLC. 4302, South Lenoir street, MO 65201

We demonstrate the potential of nanoenergetic coatings and CuO nanorods to decontaminate surfaces infected with bacteria. The methods of decontamination include (i) fast combustion of an energetic paint applied on contaminated surfaces and (ii) exploitation of biocidal activity of copper oxide. The success of the first method depends mainly on effective heat transfer to the contaminated surface. For this to happen, the substantial heat produced during the combustion of the energetic coating needs to be sustained for sufficient duration. At the same time, it is necessary to ensure that the contaminated surfaces are not damaged. Our research group has developed suitable energetic composition to realize this goal.

A stainless steel substrate contaminated with cultured bacteria grown in standard conditions was spray coated with a thick film of the paint (composed of appropriate weight percent of Al nanoparticles dispersed in a fluoropolymer, THV 220A). After a short drying period, the paint was ignited which self propagated across the substrate typically in few milliseconds. A swab of the remaining ash was taken and an LB agar plate was prepared. The plate was incubated at 37℃

for 72 hrs with inspection after every 24 hours. No bacteria had grown after 72 hrs indicating the successful destruction of bacteria. Applicability of this method was further extended to removal of biofilms from different substrates.

For certain optimal compositions of the energetic formulations, the flame propagates extremely rapidly across the rest of the surface (in tens of milliseconds on 1” x 3” test surfaces) without damaging the surface and leaves behind charred remains of the biofilm that can be wiped / air blown away. We believe that the flame propagates through a series of events in which nano-particles ignite and reach high temperatures as they burn. The high local temperature destroys the biofilm in its immediate vicinity and also helps to ignite other nanoparticles nearby. However, since the amount of heat released is comparatively less, the underlying material surface remains relatively undamaged.

Complete destruction of bio-film with no damage to the underlying material can be achieved only for certain optimal values of nanoparticle size and concentration in the organic solvent, and for certain compositions of the solvent itself. We have been able to successfully formulate such blends. Such blends were used to treat biofilm harboring ~ 10^7 bacteria / cm^2. A burn lasting <1 s reduced the number of bacteria to less than our detectable threshold of 2 bacteria / cm^2. We would like to use the technology to remove biofilm formed on the surface of heat exchangers. Biofilm buildup causes the efficiency of heat exchangers to drop by ~30%, and costs associated with taking the exchangers offline and cleaning them accrue to billions of dollars each year. Our initial results from the testing on the biocidal activity of the filtrates consisting of copper and chlorine ions obtained during the production of CuO nanorods shows that the contaminated surfaces can be cleaned effectively.

Acknowledgement: We acknowledge the financial support provided by the Leonard Wood Institute (LWI).