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Plasma-enhanced deposition of antibacterial layers to inhibit biofilm formation

Amy C. Lee Wong[1, 2], Baiyan Dong[1, 2], Hongquan Jiang[1, 2], Sorin Manolache[2], Eileen B. Somers[1], Yingying Wang[1, 2], and Ferencz S. Denes[1, 2, 3]

[1]Food Research Institute, [2]Center for Plasma-Aided Manufacturing, and [3]Department of Biological Systems Engineering, University of Wisconsin-Madison, U. S. A.

Attachment of bacteria to surfaces can result in the formation of biofilms that create economic and health problems in many environments, including the food and medical industries. Biofilms can be broadly defined as bacterial cells attached to a surface, which are frequently embedded in a polymer matrix of bacterial origin. Biofilms formed on equipment surfaces, conveyor belts, floors, drains, and packaging materials in food processing environments are a potential source for food contamination, and can result in transmission of food-borne diseases and reduced shelf-life of food products. Biofilms developed on biomedical devices such as prostheses, catheters, and implants can result in infections and cause health problems. Development of new technologies to prevent or at least attenuate biofilm formation is highly desirable.

Cold plasma technology has been used to modify various surfaces for specific functions and to deposit coatings onto organic and inorganic materials to achieve desired properties. Our goals are to: (a) synthesize and deposit macromolecular moieties that will inhibit bacterial attachment and biofilm formation, and (b) deposit bactericidal agents onto surfaces of materials used in food processing, handling, and packaging.

It has been shown that poly(ethylene glycol) (PEG) functionalized on surfaces can reduce adsorption of macromolecules such as proteins and some bacteria. We employed three different approaches to deposit PEG-type structures onto stainless steel type 304 and silicone rubber surfaces: (1) deposit thin layer PEG-type networks from volatile compounds such as crown ether, tri(ethylene glycol) dimethyl ether [triglyme], and di(ethylene glycol) vinyl ether; (2) graft PEG molecular chains onto $SiCl_4$-plasma-functionalized surfaces; and (3) cross-link pre-deposited PEG molecules under plasma environments. Electron spectroscopy for chemical analysis (ESCA) showed the presence of PEG-type structures on both stainless steel and silicone rubber surfaces after plasma modification by all three methods. Results showed that >90% decrease in *Listeria monocytogenes* biofilm numbers could be obtained with these modified surfaces when compared to unmodified surfaces. We will determine the optimal conditions for the generation of more effective antifouling layers by varying plasma parameters, and using different monomers and PEG of different molecular weights. In addition to *L. monocytogenes*, other foodborne pathogens will be examined. The antifouling characteristics will be related to the chemical nature and morphologies of the PEG-type structures.

For the second approach to develop bactericidal layers, we have chosen silver as one of the starting materials. Silver and its compounds have been used as antimicrobial agents for many years. Currently, silver is used in medical applications and water treatment. It was recently approved for use a preservative in polymeric coatings for polyolefin films intended for use in contact with food. We have developed a plasma-mediated method for deposition of silver onto polymer surfaces. Our data indicate that $>10^5$ *L. monocytogenes* cells could be inactivated by exposure to silver coated silicone rubber surfaces. Conditions for generating high efficacy silver coatings will be optimized.