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# The Challenge of Non Fouling Surfaces: Polymers could be the Answer

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**ABSTRACT**

Immersion of engineered materials in water environments such as industrial waters, sea water, body fluids etc., is often followed by an aggregation and colonization of their surfaces with water-born organism and biological matter. This method is also known as biofouling, affects performance in many applications to the detriment of the materials and related devices. Biofouling of ship hulls, for example, causes ship speed reduction and increases fuel consumption by up to ~40% higher than non-fouled ships. In addition, the production of greenhouse gas rises, and the generated biofilms disperse the water-born organism across the planet – a process that could disrupt the balance of sensitive ecosystems. Biofouling of measuring instruments used at oceans, sea and on the coast may significantly affect the quality of data and the performance of the instruments.

Biofouling also causes issues in industrial applications, such as heat exchangers, where heat transfer levels are decreased by 20 to 50 percent due to the formation of biofilms. This results in a rise in global investment to tackle the problem by ~ $15 billion annually. Biofouling is the primary restriction to expand the use of membrane technology, microfiltration and ultrafiltration membranes for the processing of drinking water and treatment of waste water. The explanation is that the formed biofilms significantly reduce the permeating flux, increase energy consumption and may contribute to filtered water pollution. Biofouling is also an important issue for biomedical implants and appliances. Biological fluids are abundant in proteins, cells, and so on, and may also be infected with pathogens. Both of these organisms may bind strongly to the surfaces of the biomaterials, causing biofouling and dramatically altering the original characteristics of the surfaces, thereby degrading the performance of the biomaterials. For example, catheter microbial colonization often results in infections of the urinary tract which makes the latter the most common infections acquired by the hospital. Certain biodevices that biofouling may adversely affect include prosthetic implants, biosensors, dental implants, and medical equipment. The unwanted biofouling may cause implant rejection, spread of infectious diseases and biosensor malfunction.

Nowadays, two main techniques are used to counter biofouling, namely: (I) release of bioactive compounds, and (ii) alteration of surface chemistry / micro topography. The first takes advantage of small molecules of e.g. biocide activity that are released in the atmosphere, while the second is surface alteration of the biomaterials. For example, using non-fouling polymers and related materials (physico-chemical approach) and/or imparting a suitable surface topography (physical approach). In addition, both methods are taken from nature, as these are the natural ways to fight / prevent biofouling. Many marine organisms have complex topography on their bodies, like sharks, skates, and rays – placoid scales, known as dermal denticles. The latter consists of a

dentine vascular nucleus surrounded by an acellular "enamel" layer, similar to human teeth. This unique topography protects aquatic species from ectoparasites in addition to the strictly mechanical functions of these denticles such as reduction of mechanical abrasion and hydrodynamic drag. A combination of grooves and ridges is likewise a way of preventing biofouling on e.g. dolphin and whale skins, musk shells, etc. Biofouling of implants and devices in living organisms starts with the protein adhesion on the surfaces of the biomaterials – a process that happens very rapidly within the first few seconds to minutes after the immersion in the body is anticipated. The change in the conformation of the adhered proteins is essential for the further biofouling process as it is that which could cause the cell (e.g. macrophages) attachment. The macrophages which are attached fuse and form the giant cells, beginning to release inflammatory cytokines at the same time. These reaction cascades are part of the foreign body reaction normally occurring when foreign body is introduced into mammals. The final result is the formation of an impermeable or hypopermeable dense fibrous capsule around the implant or system implanted in vivo into the mammals which isolates it from the rest of the body and hinders its final efficiency. The answer of foreign bodies is difficult to overcome and while several different biomaterials have been tested, the development of a stealth material that circumvents the ability of mammalian surveillance systems to differentiate between foreign and self is still a major challenge.

The problem remains for the non-biofouling behavior of the materials and designs used in the water system, which is why many researchers from various fields are working on it in many different applications. Given the different methods used, polymers are the main players in their efficient solution, as they have a combination of appropriate surface chemistry and the possibility of regulated surface micro topography, as learned from the lessons of nature. Zwitterionic polymers are the rising star in the field but, as the challenge is immense, we should expect another serious competitor soon.

Keywords: Biofouling; Ultra filtration; Bio materials; Micro topography