NOVEL MATERIALS FOR MITIGATION OF DIATOM BIOFOULING ON MARINE SENSORS

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Abstract - Biofouling, the attachment and growth of organisms on hard surfaces, represents one of the main challenges to long-term autonomous deployment of marine sensors and sensor networks. Unmaintained or unprotected sensors rapidly experience data loss or drift unless some mechanism of biofouling prevention, or antifouling, is employed. In this paper, we present the results of our research into the basic mechanisms of marine biofouling, with particular emphasis on the surface factors that influence the attachment of benthic diatoms (Bacillariophyceae) in the early stages of the biofouling process. We present the results of our research into the influence of engineered surface topography (EST) on diatom adhesion and removal in the field, and demonstrate how careful control of surface topography and texture can be employed to produce novel means of mitigating diatom biofouling and thus increase sensor lifetimes. We demonstrate that surface topography feature spacing and orientation are vital cues for attaching diatoms, subject to species and attachment strategy. In addition, we present the results of our field trials of environmental monitoring sondes equipped with novel antifouling materials at Ireland's only statutory marine reserve, Lough Hyne, This interesting and dynamic site offers many challenges with regard to long-term sensor deployment due to biofouling.

Keywords - Biofouling, sensors, antifouling, topography, diatoms

1. INTRODUCTION

Biological growth and attachment to sensor components leads to costly maintenance and removal strategies and if these are not completed then data quality will be compromised. Traditionally, biofouling was prevented by the use of toxic broad action biocides such as tributyltin (TBT). However, since many of these compounds including TBT have been discovered to be environmentally damaging and have subsequently been banned in many areas of the globe, a need has arisen for the development of non-toxic alternatives. Fundamental to the development of these alternatives is an understanding of the physical and chemical parameters of substrate that is to be exposed, and the chemical and physical parameters that can be optimised for fouling reduction. Surface roughness and the topography nature of the surface or material are fundamental in this respect as they significantly influence the growth rates and attachment strength of marine organisms. In addition, careful control of the physical nature of the surface alters the chemical properties of that surface once immersed.

Benthic diatoms (Bacillariophyceae) are an important component of marine biofilms and are commonly found as part of the biofouling community on environmental sensors. Additionally, these organisms passively contact a potential settling surface and subsequently become motile and explore the surface before permanent colonisation. It is understood that surface crevices and niches provide protection from hydrodynamic shear forces and significantly affect surface adhesion and ecological community of attached diatoms. However no detailed results of field studies into the effects of carefully dimensioned engineered surface topography on diatoms have been published.

2. MATERIALS AND METHODS

A number of engineered surfaces have been produced in the elastomer, poly(dimethyl)siloxane (PDMSe) using photolithographic techniques. These surfaces exhibit a range of topographic patterns and feature spacing designed to test several of the common models developed for surface topographic inhibition of biofouling. Surfaces were exposed in the marine environment on environmental sensors for varying periods of time. Samples were then removed and preserved for analysis. Adhered cells were enumerated and identified using a combination of scanning electron microscopy (SEM) and light microscopy (LM).

3. RESULTS

Variation in the colonisation rates and species were seen on deployed engineered surfaces, implying that surface topography directly affects marine biofilm composition and subsequent biofouling community development (Fig. 1.). A relationship between species composition, based on cell size and adhesive mechanism, and surface topography type were observed. However strongest affects of surface topography were only seen in the initial stages of biofouling development, implying that other factors such as the settlement of a bacterial biofouling community and alteration of the topographic nature of the substrate subsequently reduce the influence of topographic patterning on diatom adhesion.

4.CONCLUSIONS

Carefully engineered surface topography influences the adhesion of marine diatoms in the natural environment and this in turn has implications for the development of novel non-toxic methods of biofouling prevention. Control of surface topography is vital in the development of new methods of biofouling prevention, and while creation of such topography on large surface areas may be economically unviable given current methods of topography production, there is significant scope for the application of surface topography to the improvement of the lifetimes of environmental sensors, given the smaller surface areas involved.

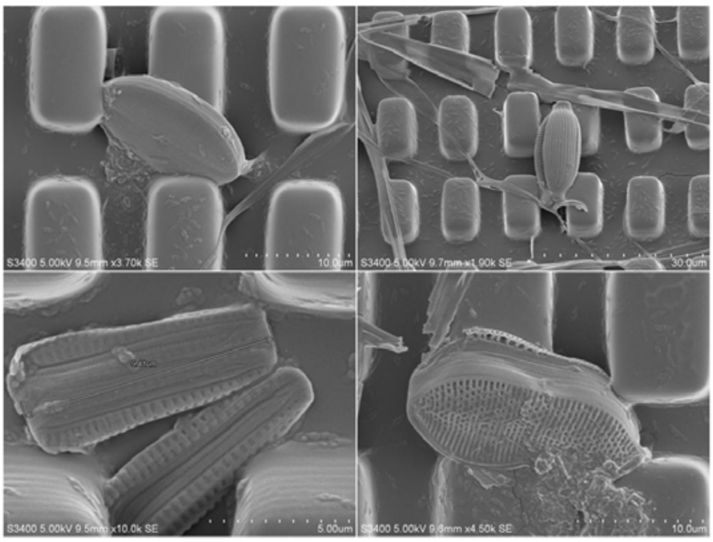

Fig.1. Scanning electron micrographs of the adhesion of pennate diatom cells to surface topography created in PDMSe. Smaller cell types of a certain minimum size are unable to contact the surface completely and thus exhibit fewer focal adhesion points to the elastomer surface. This means that cells are easily removed and are less likely to undergo permanent adhesion to the surface.