

## Nanostructures take on biofouling organisms

Thirty one members from the European Union (EU) have come together to develop nanostructured surfaces that could be the answer to that age-old problem of aquatic biofouling.

The marine industry is plagued by the presence of barnacles, bacteria, and algae that stick onto the surfaces of vessels and equipment. In fact, it is estimated that the extra weight on ship hulls and increased drag caused by these organisms results in the consumption of an extra 300 million tons of fuel per year, worldwide.

So far, the answer to biofouling has been in the form of protective coatings consisting of components such as tributyltin (TBT). However, these coatings have become increasingly restricted by the International Maritime Organization because they are toxic. A concerted effort funded by the EC Framework 6 Integrated project AMBIO (Advanced nanostructured surfaces for the control of biofouling, <http://www.ambio.bham.ac.uk/>), coordinated by Prof. J.A. Callow (University of Birmingham) is focusing on engineering new protective coatings that do not contain TBT and researchers are looking to nanomaterials to provide all the key elements necessary for an ideal antifouling material.

“Adhesion involves interfacial interactions between the living organisms and the marine structure, which occur within a few nanometers of a surface,” says Axel Rosenhahn of the University of Heidelberg in Germany. “The research on nanoscale interfacial properties and how organisms adhere will allow understanding how anti-biofouling or easy to clean systems work. This will trigger the development of future industrial applications.”

The development of nanostructured coatings that can tackle biofouling relies on several key aspects. Firstly, the creation of models that will help scientists understand the factors involved in biofouling and provide an insight into the approaches required. Secondly, the formation of coatings that organisms cannot adhere to, and thirdly, identifying the tools required to analyze the resulting nanostructured surfaces in detail and under seawater. A film can swell upon immersion in water, resulting in structural rearrangement. Therefore, it is important to characterize the film both before and after immersion.

Coatings have a variety of physicochemical properties, such as elastic modulus, surface charge, surface free energy, and topology which all affect their effectiveness as antifouling treatments. Model surfaces are used to test variables in surface chemistry that may have an influence on whether organisms adhere to a material or not.

One approach to such model systems is the formation of self-assembled monolayers (SAMs), layers of molecules that assemble on surfaces in a highly-ordered fashion. The studies show that there is a marked difference in antifouling properties between SAMs that have an exposed hydrophobic group and those with a hydrophilic functional group. Surfaces coated with hydrophilic molecules are far more resistant to settlement by algae.

Topology of coatings on the nano- and micrometer scale can change the materials` biofouling properties significantly. For a selected class of marine biofoulers, carbon nanotube-filled silicone coatings and amphiphilic block copolymer coatings that exhibit a self-assembling nanoscale surface morphology after immersion, show a marked improvement in antifouling or foul release properties.

When tested on different biofouling organisms, introduction of such nanostructures into the matrix has an adverse effect, so clearly generalization is not yet possible. Feedback from researchers of both positive and negative results will be of the utmost importance to the scaling up and commercialization of novel products. “Innovation is vital to coatings manufacturers who constantly reformulate their products to differentiate themselves from market competitors,” says Rosenhahn. “Innovation is especially important in the current legislative climate in which environmentally-benign products are increasingly sought. Emerging technologies, such as nanostructuring of coatings, will provide such a source of innovation.”

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**“Advanced nanostructures for the control of biofouling: The FP6 EU Integrated Project AMBIO“**, Axel Rosenhahn, Thomas Ederth, and Michala E. Pettitt