Project No. NMP4-CT-2005-011827

AMBIO

ADVANCED NANOSTRUCTURED SURFACES FOR THE CONTROL OF BIOFOULING

Instrument Type:	Integrated Project
Priority Name:	Nanotechnology and nanosciences, knowledge-based multifunctional materials and new production processes and devices (NMP)

Publishable Executive Summary: Period 2

Period Covered: from	March 1st 2006	to	Feb.28th 2007	Date of preparation	April 14th, 2007
Start Date of Project:	March 1st 2005			Duration:	5 Years

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PUBLISHABLE EXECUTIVE SUMMARY

AMBIO- a nanotechnology project funded by the European Commission to study and develop new coating materials for the control of biofouling in aquatic environments.

http://www.AMBIO.bham.ac.uk

EU companies are world-leaders in anti-biofouling[1] coating technology with 70% of the global market share. However, many of the technologies in use are subject to restrictions due to novel and more stringent environmental protection criteria that will eliminate many of the currently-applied biocides[3]. Nowadays, there are no overall suitable alternative non-toxic coating technologies, so that new research is needed to overcome this technology gap and to provide EU companies with the fundamental science necessary to maintain their position at the forefront of the marine coating market. This is the raison d'être of AMBIO[2], an Integrated Project[3] funded by the European Community in its 6th Framework Programme of Research and Technological Development[4].

Ship hull fouled by barnacles (Akzo-Nobel)

Biofouling is caused by the adhesion of organisms such as bacteria, barnacles and algae to a surface. It generates large economic costs due to clogging of water pipes (e.g. in cooling installation), increase of mass on boats and marine structures, etc. This adhesion involves interfacial interactions, between the living organisms and the marine structure, which occur within a few nanometres of a surface. The aim of AMBIO is to study and develop different types of nanostructured surface[5] to avoid the adhesion of marine fouling organisms. The research on nanoscale interfacial properties of different surfaces and how organisms adhere will allow understanding how anti-biofouling systems can work, starting at the nanoscale to scale-up to future industrial applications.

The AMBIO project integrates industries, universities and research organisations into a coordinated, interdisciplinary research incorporating all the necessary elements from nanomaterials engineering technologies to biological evaluation and end-user trials. The 5-year project has a total budget of € 17.9 million of which € 11.9 million is funded by the European Community.

New Materials and Improved Understanding:

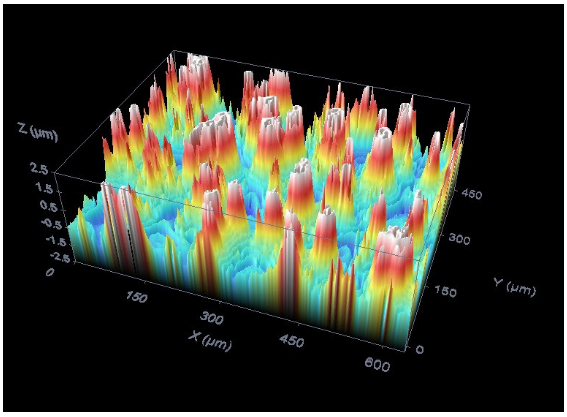
1 Biofouling: the process by which any surface in a marine or freshwater environment acquires a growth of organisms of different types. This problem has traditionally been controlled by incorporating 'biocides' (chemicals that kill organisms) into coatings.

2 AMBIO: "Advanced Nanostructured Surfaces for the Control of Biofouling."

3 An Integrated Project aims at generating new knowledge in a particular research topic by integrating the critical mass of resources and expertise.

4 The Sixth Framework Programme: financial plan for the years 2002-2006 of EC research funding, playing a key role in the creation of an internal market for science and technology, which constitutes the main objective of the European Research Area (ERA).

5 Nanostructured surfaces: surfaces or coatings, the physical and chemical properties or features of which are on a scale <10-9 metres.



In Phase 1 (Years 1-3) a range of surface nanostructuring methods are being used to create experimental test surfaces with controlled and well-characterised physical and chemical properties at the nanoscale. Surfaces are evaluated by rapid, laboratory-scale adhesion and biofouling assays with different types of biofouling organism. Theoretical and experimental studies on dynamic interfacial properties of test surfaces are integrated with biological adhesion assays to provide a critical understanding of how anti-biofouling surfaces work at the nanoscale.

Left: Nanostructured surface under water, viewed by confocal microscopy (courtesy TNO)

New Products:

In Phase 2 (Years 3-4), the most promising test surfaces will be selected for scale-up and development as practical coatings. In Phase 3 (Year 5) the most promising coatings will be evaluated as possible prototypes through quantitative, comparative field trials involving a minimum of 7 end-uses where biofouling is a problem; including, ship hull and pleasure craft coatings, membrane filters, aquaculture equipment, instrumentation, water-inlets, and heat exchangers.

The Environment:

All AMBIO technologies are designed to be environmentally benign since none contain biocides that would require registration under the Biocidal Products Directive. Surfaces containing covalently linked nanoparticles (such as carbon nanotubes) should not release nanoparticles to the environment. Once technologies have been selected for scale up and real-scale application trials, an impact analysis will be conducted in the light of regulations at the time to identify any possible risks that would need to be addressed before wide utilisation.

Project Partners:

The consortium of 31 Partners has 15 companies (including 9 SMEs), 10 universities and 6 research organisations. Twelve EU Member States are represented as well as Turkey, Israel and Norway.

Research institutions
University of Birmingham, UK; University of Pisa, Italy; TNO, Holland; University of Dundee, UK; Newcastle University, UK; Gebze Institute of Technology, Turkey; CIDETEC, Spain; University of Mons-Hainaut, Belgium; Linkoping University, Sweden; Institut National Polytechnique de Lorraine/CNRS, France; Institute of Metals & Technology, Slovenia; , Technion, Israel; Institut für Polymerforschung Dresden, Germany; Corrosion Institute (KIMAB), Sweden; University of Heidelberg, Germany; Ship Design and Research Center, Poland.

Technology Companies
International Paint Ltd. (part of Akzo-Nobel), UK; BASF, Germany; Polymer Laboratories, UK; Biolocus, Denmark; Argus Chemicals, Italy; Laviosa, Italy; TEER Coatings, UK; Nanocyl, Belgium; SusTech, Germany;

End-User companies
Wallenius Marine, Sweden; KEMA, Holland; Marina Port Zelande, Holland; OCN,
Holland; VAL VGS, Norway; Zenon, Hungary.

Progress in Year 2

The project has made further good progress towards its technical goals in Period 2. A wide variety of experimental nanostructured coatings has been produced and in many cases their physico-chemical properties have been characterised at the nanoscale. The coatings have been evaluated for performance in lab-based assays against a suite of fouling organisms and selected coatings are proceeding to the first round of testing in the field. Examples of important advances include:

- Silicones in which nanostructuring through incorporation of carbon nanotubes and other nanofillers, or certain block co-polymers, provides good fouling-release performance combined with significant shear thinning behaviour. These offer good prospects for improved composite materials for use as fouling-release coatings and a provisional US patent has been filed.
- Fluorinated polymers and block co-polymers as candidates for fouling-release coatings in which self-assembly, phase segregation and nanostructuring affect surface energy and topology. These coatings show good fouling-release performance in laboratory tests.
- PEGylated and other hydrogel-type of amphiphilic materials that have some history of application as antifouling surfaces in biomedicine but which have not been systematically investigated for marine antifouling, show some effectiveness against marine and freshwater bacterial biofilms.
- Superhydrophobic polymers and their blends, the morphology and topology of which can be adjusted by deposition techniques show good fouling-release properties against marine algae. Thicker coatings of this type have yet to be evaluated for release of barnacles.
- Nanocomposite coatings, in which the length scale of surface topology can be controlled by the sol-gel chemistry of the cure reaction and the chemical functionalisation of the nanoparticles are effective against some of the fouling organisms tested.
- Hydrophilic polymer coatings containing proteolytic enzymes that may serve to destroy the biological glues that hold organisms to surfaces. Polymer coatings based on maleic anhydride copolymers are being prepared and subsequently decorated with a serine protease by covalent binding. The immobilized enzymes are being thoroughly characterised with respect to the amount of immobilized enzymes, enzyme conformation availability and function. The enzyme-containing coatings have yet to be studied against fouling organisms.
- Ultra-thin, low surface energy metal-polymer nanocomposites deposited through vapour deposition and plating techniques that resist biofilm formation and adhesion. Clear trends have been detected in the influence of surface nano-scale properties on the adhesion of fouling organisms.
- For several types of coating extensive in situ characterisation by spectroscopy, AFM, SEM, confocal microscopy, acoustic and electrokinetic methods is improving our understanding surface and bulk properties and how coatings reorganize under water. This information is crucial to understanding how coatings work.

Other fundamental advances in the project follow from the use of controlled, well-characterised model nanostructured surfaces (prepared for example by 'soft' lithography and self-assembly) that vary systematically in properties such as surface energy, charge density and topology. For example, protein-resistant surfaces based on hydrophilic materials such as oligoethyleneglycols, and certain saccharides exhibit remarkable antifouling characteristics against two types of algae. Such model surfaces, coupled with the use of a novel holographic microscope for tracking individual, motile cells of fouling organisms as they interact with surfaces, are advancing our understanding of how antifouling surfaces work.

Contact for further information

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