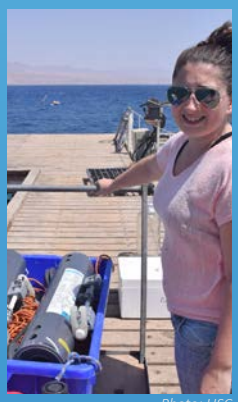
Summary description of project context and objectives

Biofouling has profound effects in different branches of maritime activities. It is the major cause for maintenance expenses of any (partially) submerged man-made surfaces, including ship transport, buoys, aquaculture, but also membrane bioreactors and desalination units, power plants' cooling water systems and oil-pipelines. It poses also a significant problem for all the aquaculture industry, the broadest and the most documented impact being in marine finfish aquaculture. The settlement of marine invertebrates or algae on the hulls of ships results in increased surface-erosion, reduction of speed, increased fuel consumption and therefore, increased air pollution and CO_2 emission.

Photo: TAU



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The main goal of the BYEFOULING project, supported in the framework of the Ocean of Tomorrow by the European Commission, is to design, develop and upscale novel low toxic and cost-efficient environmentally friendly antifouling coatings with enhanced performance compared to currently available products. The approach in BYEFOULING is to tackle different stages of the biofouling process using innovative antifouling agents, covering surface-structured materials, protein adsorption inhibitors, quorum sensing inhibitors, natural biocides and microorganisms with antifouling properties. Encapsulation of the innovative compounds in smart nanostructured materials will be implemented to optimize coating performance and cost all along their life cycle. A proof-of-concept for the most promising candidates will be developed and demonstrators will be produced and tested in the fields.

The specific objectives of BYEFOULING are:

- obtain coatings with extended service life;
- reduce VOC content in coating formulations;
- reduce fuel costs due to drag reduction in maritime transportation and fishing vessels;
- increase operation life of floating devices;
- reduce fish mortality as a result of conventional biofouling processes and respective control measures.
- reduce maintenance costs;

The project is organized in 8 work packages (WP) and is running from December 2013 to November 2017. BYEFOULING combines a multidisciplinary consortium involving 19 partners from SMEs, large companies, research organisations and universities in Europe, able to develop a full production line for new antifouling coatings. In WP1, the project is coordinated and directed according to a work plan. In WP2, novel compounds, development of interfacial microstructures, and preparation and growth of antifouling microorganisms are under development. In WP3 different tools are used to incorporate the new antifouling approaches into coating formulations, including encapsulation to protect compounds from the coating matrices and to enable controlled release of active species, preparation of functional fillers with hydrophobic and biocide-active functional groups, and development of waterborne coating formulations. In WP4, assessment of antifouling performance and benchmarking of the obtained systems with commercial and state-of-art technologies are carried out. Ecotoxicity tests are performed to investigate the effect of the developed materials in the laboratory and the field. In WP5, relevant parameters for application of coating formulations in subsequent stages are under testing and characterisation. In addition, fundamental studies on adhesion of fouling organisms and effects of fouling on biocorrosion are under investigation. In WP6, reliable methods for evaluation of drag resistance of vessel hull coatings and for the application of holistic and comprehensive assessment tools such as Life Cycle Assessment (LCA) are under development. In WP7, demonstration activities will be performed aiming at preparing three types of demonstrators, specifically for ships, aquaculture and buoys. To obtain enough paint and related components, up-scaling of the most promising technologies will be implemented. In WP8, the results are disseminated and exploited. SMEs and industrial partners will in particular use the developed technology to address new market areas.

Photo: USC

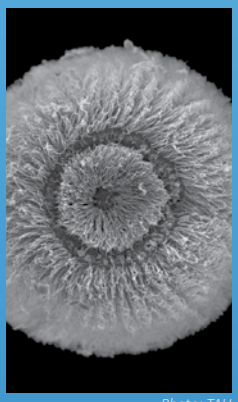
Photo: TAU


Photo: SMT

Description of work performed and main results

In **WP1**, an internal website (eRoom) was created for BYEFOULING partners with detailed information on the project (Deliverable D1.9 submitted 3. June 2014). It is only accessible from the project partners. A homepage address for public access is created (www. byefouling-eu.com). A routine for EB/MST meetings is established. A routine for partners and WP reporting is implemented. The 6M meeting was held on 27-28. May 2014 in San Sebastian and the MoM is available in the eRoom. The 6M report (D1.1) was submitted in the participant portal on 30. July 2014. The 12M meeting was held on 19.-20. November 2014 in Athens and the MoM is available in the eRoom. The 6M and 12M reports (financial and technical) have been assessed by the MST.

In **WP2**, studies on surface structuration, protein adsorption inhibitors, quorum sensing inhibitors, natural biocides and living active species have been carried out. For surface structuration, the feasibility of obtaining double wavelength wrinkled surface with labyrinth morphology has been demonstrated and the production of textured samples has started. Samples were sent for characterization. With respect to protein adsorption inhibitors, two types of systems are being studied: peptide-like and poly-zwitterionic materials. Different peptoids were successfully synthesized and the synthesis capacity increased; the set up and optimization of a testing protocol for zwitterionic materials under development is established and a robust protocol for the synthesis of different “zwitterionic polymers” launched. In terms of quorum sensing inhibitors and natural biocides, the main efforts have been focused on establishing the most suitable microorganisms and techniques for screening of the quorum sensing inhibitors and algae biocides. More recently, different QSI compounds/extracts described in the literature were tested and anti-algae activity of extracts of micro-algae assessed. Lastly, in the field of Living Active Species, freeze-dried cells of different bacteria strains have been produced and sent to several partners in WP3.

In **WP3**, synthesis and characterization of nanostructured inorganic, hybrid and polymeric materials that can be used as reservoirs for the encapsulation of active species has been initiated. Additionally, synthesis of fillers with functional groups attached to the surface to impart hydrophobic or biocide functionalities have been initiated. Attempts for encapsulation of living microorganisms prepared in the frame of WP2 have started and samples already sent for WP4 for assessment of antifouling activity.

In **WP4**, normalization of procedures to characterize antifouling systems has been completed and verified using commercial samples. Protocols are written for: laboratory tests on anti-microfouling efficacy, laboratory tests on anti-macrofouling efficacy, mesocosm efficacy tests of the antifouling paints and field efficacy tests of the antifouling paint prototypes. In addition, several cultures of model fouling organisms were set-up and antifouling and ecotoxicological studies initiated.

In the frame of **WP5**, data about surface characterization are collected. With respect to fundamental studies, partners have performed literature review, set up of experimental characterization techniques and cultures of bacteria have started to produce biofilms. The first experimental results on biocorrosion have been obtained.
In WP6, activities related to the development of the mathematical models for drag reduction prediction and activities related to LCA were performed.

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In **WP7** there were no activities planned in this period.

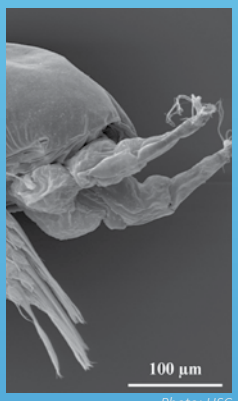

Photo: USC


Photo: USC


Photo: Jotun

In **WP8** several dissemination activities have been performed, including designing a logo, launching a user friendly website (www.byefouling-eu.com), preparing a leaflet published by the European Commission, promoting the project in local press, international journals and conferences as well as designing a poster and a Powerpoint presentation of the project. An outline of dissemination plan and activities was presented during the project kick-off meeting. Furthermore, the first internal training course was held for young researchers and the organization of the first BYEFOULING workshop (June 2015) has been initiated.

Expected final results and potential impacts

The BYEFOULING project addresses high volume production of low toxic and environmentally friendly antifouling coatings for mobile and stationary maritime applications. The technology will fulfil the coating requirements as a result of the incorporation of novel antifouling agents and a new set of binders into coating formulations for maritime transportation, fishing vessels, floating devices and aquaculture facilities. Readily available low toxic and cost-effective antifouling coatings will increase the efficiency of maritime industry and will facilitate technology for novel products.

The potential impacts of the project can be divided into internal and external ones. Internally, academic partners (universities, research institutes) participating in BYEFOULING will form young researchers in an interfacial field where knowledge on biology, marine sciences, chemistry, physics, materials science and engineering, and coating technology come into play to generate environmentally friendly and at same time high performance products. This is a strong positive point when considering high-level education and competitiveness of jobs in the global market. In addition, the generated knowledge will be reflected upon publications in journals of high impact factor, which is always one of the main factors for assessment of public institutions when looking for funding and high international standards. . From an industrial perspective, the involved SMEs and large industries provide a unique opportunity to establish transnational networking developing high-level products that can be distributed in the global market.

Externally, the impact of BYEFOULING can be detailed for different sectors. In the ship transport sector, BYEFOULING will offer more efficient and less toxic antifouling coatings, the operation and lifecycle costs will be significantly reduced, thereby increasing the efficiency and competitiveness of the ship transport industry. Furthermore, the project will reduce the negative impact on the marine environment and reduce CO_2, NO_x and SO_x emission. In the aquaculture sector BYEFOULING products will improve the performance of marine operations, with better growth rates, improved water quality and better control of disease vectors, reduce costs associated with copper waste disposal, enable lighter structures and improved resistance towards extreme weather and enhance the viability towards more stringent regulations on the use of biocides.

Finally, BYEFOULING is a project which opens new societal insights, taking into account national and transnational objectives within EU for the forthcoming years. Specifically, it pertains to several aspects of what is termed blue growth. In this sense, BYEFOULING is targeting the generation of new materials coming directly from marine renewable resources. On the other hand, the impact of antifouling coatings generated in BEYFOULING will have a profound impact on industrial activities directly related to the marine dimension.