FP7-OCEAN-2013.3

Grant Agreement Number 614034

SEAFRONT

Synergistic Fouling Control Technologies

Deliverable 1.14: Production of textured coatings/foils and delivery to other partners

Delivery date: June 2016

Table of contents

1 Introduction

WP1 is dedicated to the development of surface structure based biofouling control technologies. This concerns strategies of which the working principle is based on surface properties of antifouling coatings such as the surface texture, the surface energy and the surface wettability. Two different technology vectors will be investigated within this concept; the work carried out for this deliverable belongs to the first:

Textured coatings – drag reduction coupled with an antifouling effect.

This task is concerned with the influence of the surface texture and coating chemistry of antifouling coatings on biofouling and hydrodynamic drag. It is known from nature that coatings with a nano/micro-structured surface topography are effective in preventing settlement of biofoulants and in reducing the skin friction (e.g., the skin of a shark), although their working principle is not yet fully understood. It is commonly believed that the antifouling principle originates from a reduction in possible surface attachment points for biofoulants as compared to a smooth surface and drag reduction brought about by modulation of the near-wall turbulence structure and dynamics in the turbulent boundary layer.

Studies have investigated topographies of different geometries and dimensions for antifouling properties and first products using this technology are commercially available for use in non-marine environments such as hospitals for bacteria resistance (e.g. Sharklet AF). Nevertheless, most of the developments are on a lab-scale and biofouling tests are mainly performed with single organisms like algae spores, so it is thought that a single topography alone is unlikely to be resistant to all marine fouling species. Despite topography having potential to deliver an anti-fouling effect, the antifouling performance of structured surfaces remain in the most part dependent on the surface chemistry, with the structure best being used from its proven drag reduction effect.

The biomimetic shark-skin surface texture, the so-called Riblet structure, is one of the most prominent examples of a topography capable of reducing the frictional drag on aircraft and ship hulls. Although it is capable to a very limited degree of influencing fouling settlement, it is not considered to be fouling deterrent and has no foul release properties what so ever. The technological challenge of this WP is to develop novel bio-inspired coatings with a structured surface topography optimized to reduce hydrodynamic drag and a surface chemistry and modulus for broad-spectrum biofouling control.

Often expensive techniques like photolithography are used to prepare surfaces with a desired topography which thus limit sample size, can affect the surface chemistry, and cannot be easily adapted to ship application.

Fraunhofer IFAM developed a continuous embossing-curing method for paints (see. Fig. 1) with which large areas of coating with a riblet structure can be produced in an industrial environment, thus facilitating field testing and demonstrating scalability. A transparent silicone film is used as an embossing tool exhibiting the negative of the desired nano/micro-structure. It is placed on the wet film and the structure is fixed by curing the coating via UV light. The paint formulation is based on a combination of two separate curing mechanisms. To fix the nano/microstructure UV-curable acrylate binders are used, and to approach a good wear resistance polyurethane components are integrated for a post-curing step. Removal of the embossing tool then reveals the desired well-resolved structure transferred to the coating. After initial development for aerospace applications, the riblet technology was adapted to marine applications in the nationally funded HAI-TECH project. In addition to the investigation of drag reduction in the aqueous environment and the development of a prototypic applicator for ship hulls; the fouling control of riblet coatings was studied and found to be unsatisfactory and a significant reduction in fouling settlement could not be achieved.

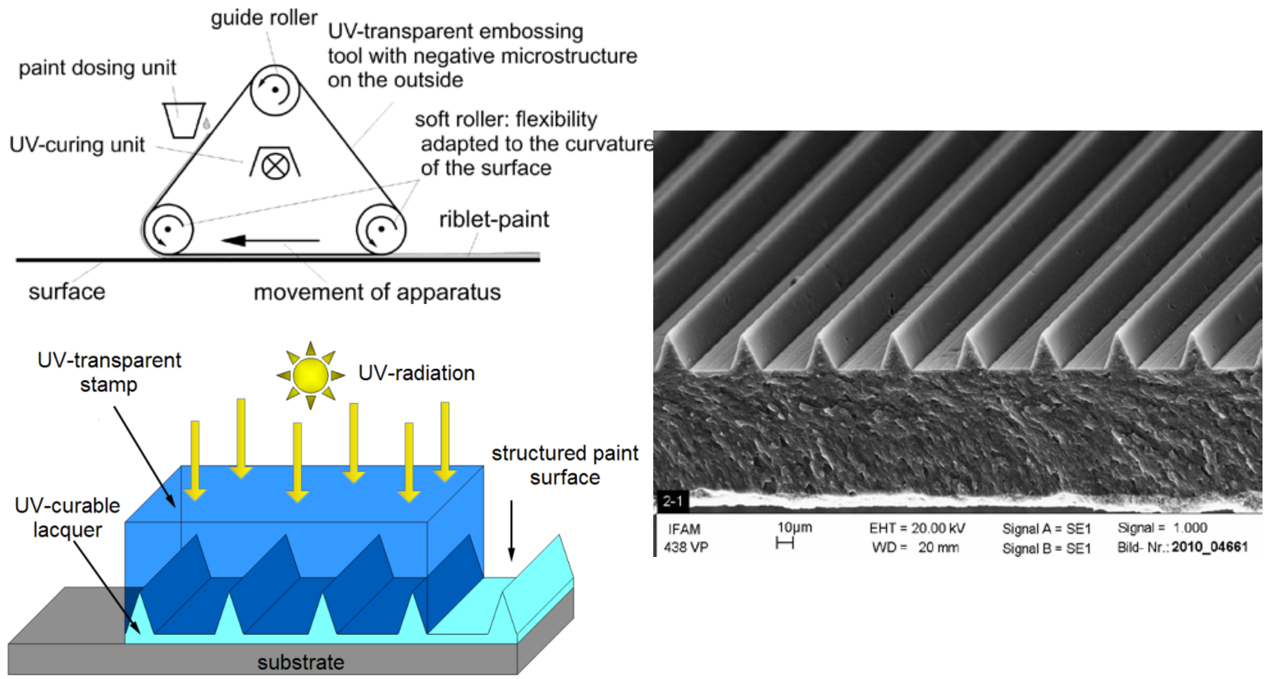

Figure 1: Schematic of the continuous embossing-curing technology developed by Fraunhofer IFAM: Principle of the automated application device (top left), schematic of simultaneous embossing and curing mechanism (bottom left); REM image of resulting riblet-textured coating (right).

Building on the demonstrated drag reduction of the riblet geometry, Fraunhofer will prepare riblet patterns using the foul release formulations of AkzoNobel. The antifouling performance and drag reduction of the different riblet geometries in combination with different foul release formulations will be assessed to identify relationships between topography and surface properties like modulus and surface energy and polarity. Foul release formulations were supposed to be modified so as to facilitate their curing by UV light and formulated so as to have the correct rheological properties to enable embossing with a high degree of pattern transfer fidelity. Partner TU Delft will perform a detailed assessment of the hydrodynamic behaviour of the developed coatings.

2 Partners involved

- Fraunhofer IFAM: Dorothea Stübing, Kerstin Eiben – Adaptation of the embossing technique to the elastomeric chemically cured coating system, preparation of samples for hydrodynamic and settlement testing.
- AkzoNobel: Kevin Reynolds, Clayton Price – Development, adaptation, and provision of the elastomeric fouling release coating system.
- TU Delft: Wim-Paul Breugem, Henk Benschop: Provision of T/C cylinders, hydrodynamic testing.

- Newcastle University – Marine Science and Technology: Tony Clare, Andrew Guerin, Nick Aldred – Biological testing of the delivered coated materials.

3 Description of technology delivered

The aim of D1.1 is to prepare riblet-textured samples and provide them to TU Delft for hydrodynamic testing and to UNEW-MST for settlement testing

3.1 Preparation and delivery of coated Taylor-Couette cylinders for hydrodynamic testing

Applying the riblet embossing technology adapted within task 1.1.2, six cylinders have been prepared (see also Fig. 2) and delivered to TU Delft for hydrodynamic testing:

- riblet-structured dual cure paint system from Fraunhofer (shipped in May 2015),
- riblet-structured solvent-free IS 1100SR from AkzoNobel (shipped in May 2015), and
- smooth solvent-free IS 1100SR (shipped in August 2015).

The riblet dimensions are 48:96 µm (riblet height : tip distance). Two replicate cylinders were prepared for each coating type.

Figure 2: Photos of the three types of coated cylinders for Taylor-Couette testing in WP1.1.3: Riblet-textured dual-cure paint from Fraunhofer IFAM (left), riblet-textured solvent-free IS 1100SR provided by AkzoNobel (centre), and smooth solvent-free IS 1100SR (right). For each type, two replicates were manufactured and provided to TU Delft.

Details on the adaptation process of the embossing method as well as on the application of the coatings to the cylinders are provided in the First Periodic Report. The results of the hydrodynamic tests will be reported in D1.2.

3.2 Preparation and delivery of coated Plexiglas panels for water tunnel testing

Furthermore, test specimens were equipped with riblet-textured coatings for water tunnel testing. Four Plexiglas plates of 2 m x 0.3 m were provided by TU Delft; two replicates for solvent-free IS 1100SR (Fig. 3) and two for the dual cure system. The plates were directly coated in order to avoid the disadvantages of the adhesive foil (i.e. difficulty to apply the foil to the substrate without entrapping air, risk of delamination under hydrodynamic shear).

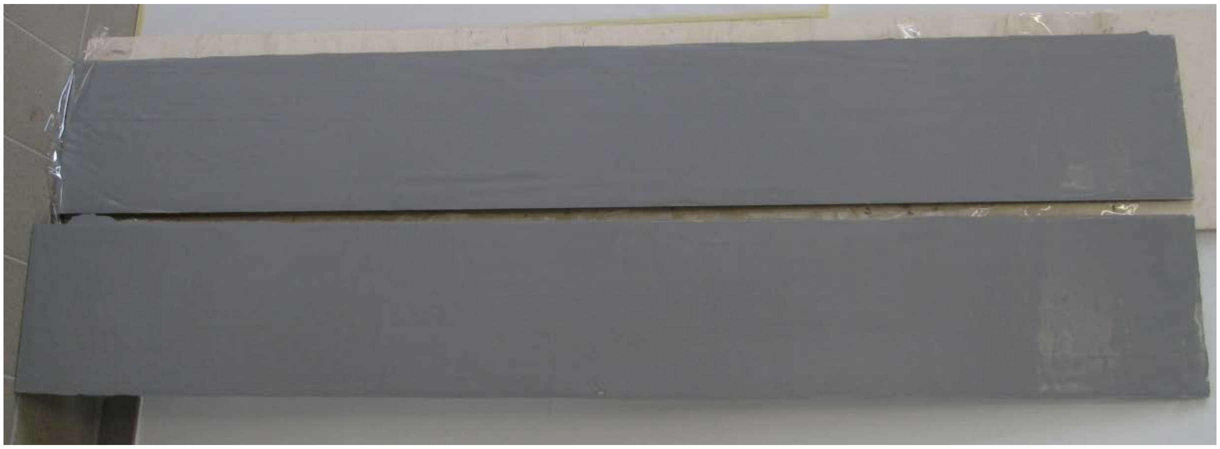

Figure 3: Photo of the two Plexiglas plates equipped with smooth solvent-free IS 1100SR for water tunnel testing.

3.3 Preparation and delivery of coated microscopic glass slides and PVC substrates for settlement assays

A set of microscopic slides has been prepared in order to investigate i) whether the modified solvent-free version of IS 1100SR is directly comparable to the standard IS 1100SR in terms of antifouling performance and ii) the influence of the riblet structure on antifouling performance. The following slides were prepared and shipped to UNEW-MST for settlement testing:

- 13 (plus some spare) slides with smooth solvent-free IS 1100SR (for barnacle and diatom assays), shipped in October 2015;
- 13 (plus some spare) slides with riblet-textured solvent-free IS 1100SR; riblet geometry 48:96 µm, riblet orientation along the length of the microscope slide (see Fig. 3 top) (for barnacle and diatom assays), shipped in October 2015;
- 7 (plus one spare) slides with riblet-textured solvent-free IS 1100SR; riblet geometry 48:96 µm, riblet orientation perpendicular to the length of the microscope slide (see Fig. 3 bottom) (for diatom assays), shipped in November 2015,
- 8 microscopic slides each with smooth and riblet-textured (both riblet orientations, as described above) solvent-free IS 1100SR for testing of slime settlement, shipped in July 2016.

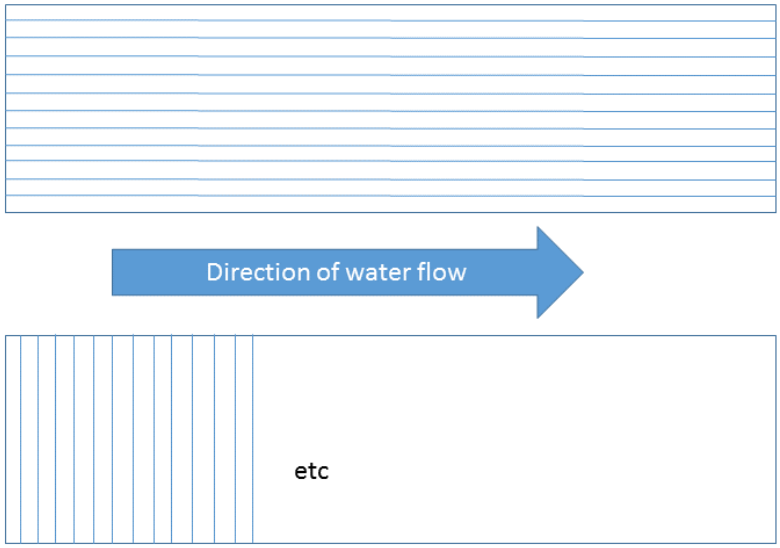

Figure 4: Illustration of the two different riblet orientations prepared on the microscope slides. The arrow indicates the direction of the water flow in the test facility for diatom removal.

The purpose of investigating the two different riblet orientations is to obtain information on potential differences of the percent removal of diatoms in the flow cell facilities of UNEW-MST.

The results of the settlement tests will be reported in D4.14.

Additionally, a set of PVC samples (7.5 x 7.5 cm) was coated with smooth (12 samples) and riblet-textured (24 samples) solvent-free IS 1100SR for field testing of anitfouling performance by AkzoNobel (Fig. 5; shipped in July 2016).

Figure 5: Photo of two PVC plates coated with solvent-free IS 1100SR with a shiny smooth (left) and an opaque riblet-textured surface (right).

4 Conclusions

Riblet-textured samples of different sizes and chemistries have been successfully prepared and delivered to WP1 and WP4 partners for further analyses. From a hydrodynamic point of view the currently used 48:96 µm geometry is of highest benefit for the targeted Reynold's numbers but if other geometries become of interest these can also be provided.