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Contents

The main objective of the FemtoSurf project is to develop, test, and demonstrate industrial-grade solid-state 2-3 kW-level fs laser with parameters suitable for metal surface patterning applicable in industrial settings. FemtoSurf industrial-grade 2-3kW-level fs laser will be integrated into a propose-built optical chain enabling multi-beam processing (100+ simultaneous beams) with individually tailored spatial distributions in each laser spot, integrated into a fully automated processing setup for efficient patterning arbitrary shaped metal components with sizes exceeding several meters while retaining micrometer level precision and on-the-fly quality assessment (zero faulty parts delivered).

1 Introduction

The present document is a deliverable "D6.2 – Pilot testing with maritime applications" of the FemtoSurf project (Grant Agreement No.: 825512), funded by the European Union's Horizon 2020 Research and Innovation program (H2020).

The purpose of the DELIVERABLE is to provide a document that describes the development and testing process for maritime applications. In this document required information will be provided about the laser fabrication process, predetermination of texture patterns, fabrication, testing, and results for maritime applications, specifically to control and reduce the anti-fouling process on ships. Materials for samples were supported by end-user, ROLLA to Femtika for laser texturing. Prepared samples were sent to ROLLA for testing on the formation of biofilms on fabricated samples. Whole fabrication and testing were made in several iterations.

The following document made use of the HORIZON 2020 FAIR DATA MANAGEMENT PLAN TEMPLATE and was written with reference to the Guidelines to FAIR (Findable, Accessible, Interoperable, and Reusable) data management in Horizon 2020.

2 Texture predetermination and fabrication

2.1 Texture pattern predetermination

Anti-fouling on ships begins now then it is rinsed into water. At the first step, organic compounds with bacterial attachment to the surface. Then further layers start to build like microorganisms and small mammals leading to a fully fouled surface. To control and reduce the fouling process it is important to minimize organic compounds and bacterial attachment to the surface. One of the solutions is chemically inactive and has low surface energy exhibiting surface. The chemically inactive surface would not reach organic compounds and would not form clusters of organic compounds leading to the attachment. Low surface energy surfaces tend to be less wettable by liquids because of the interaction of molecules or atoms at materials' surfaces, and it is known that water is an essential resource for the organism. So, by reducing humidity, and wetting, bacterial growth is also reduced. Another way to possibly reduce bacterial growth is to reduce attachment to the surface, for this material should have a specific surface, for example, micro and nano size geometries like spikes, groves, and spheres could reduce attachment area for a variety of different sizes microorganisms, including bacterial. Based on known information we could start to predetermine surface texture which later would be tried to recreate. So, the surface must have hierarchical patterns, micro, and nano size geometries, the theoretical surface is shown in Figure 1 [1]. Also because of surface geometries rinsed surface in water would trap air, which would act as a barrier that would reduce bacterial and microorganism attachment to a surface. This means that produced superhydrophobicity could be one of the key elements in fabricating an anti-fouling surface.

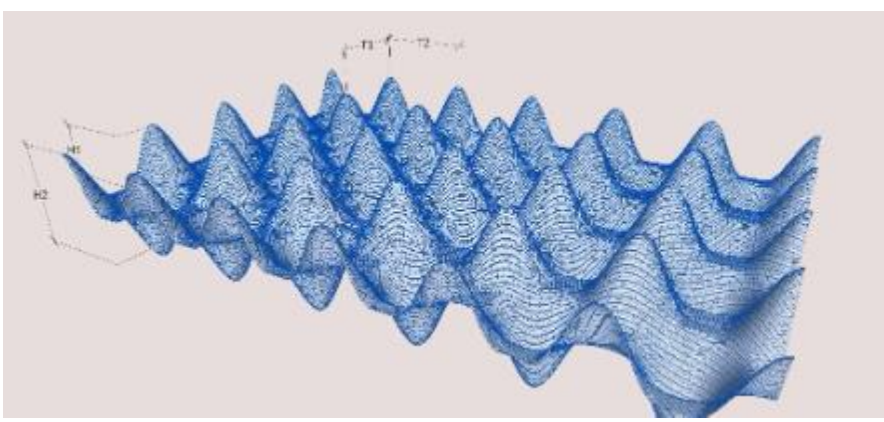


Figure 1. Theoretical surface geometry for anti-fouling experimentation.

From Figure 1. it seems that surfaces are described by parameters, height between upper peak and lower peak, height between upper peak and midpart, and the distance between peaks in both directions (X and Y). Multiple texture patterns were fabricated on sample materials, by trying to replicate theoretical surface geometry and other patterns which would later be tested for biofilm growing.

2.2 Samples preparation and fabrication

Disk shape materials samples (AISI2250 and CU3)) were provided by ROLLA. Each sample was fabricated using a femtosecond laser, forming a specific surface pattern. At first, multiple textures were fabricated using different laser parameters, and then pattern formation was observed. For the first iteration, from previously obtained results several patterns were selected, also laser parameters were adjusted for new samples fabrication. After fabricating samples from both sides were cleaned into isopropanol using an ultrasonic bath and then heat-treated at 60 °C for 24 hours. After heat treatment majority of textures exhibited superhydrophobic properties. Images of several patterns were made with SEM (scanning electron microscope) and are shown in Figure 2.

As it seems from Figure 2, samples are fabricated with different patterns from LIPSS (laser-induced periodic surface structures) to hierarchical structures. Fully prepared samples were sent to ROLLA for antifouling testing. Send samples are shown in Figure 3.

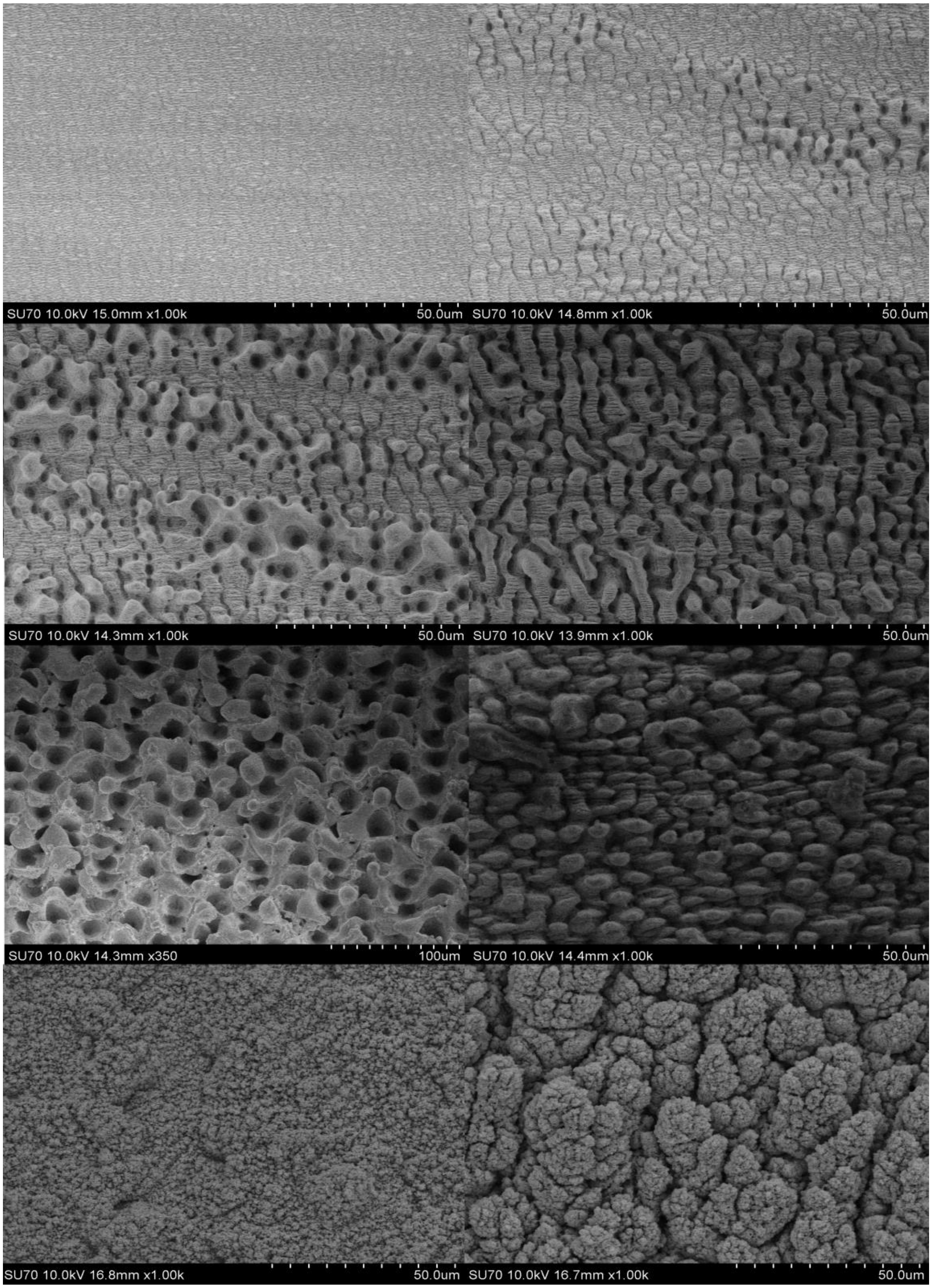


Figure 2. SEM images of several patterns.

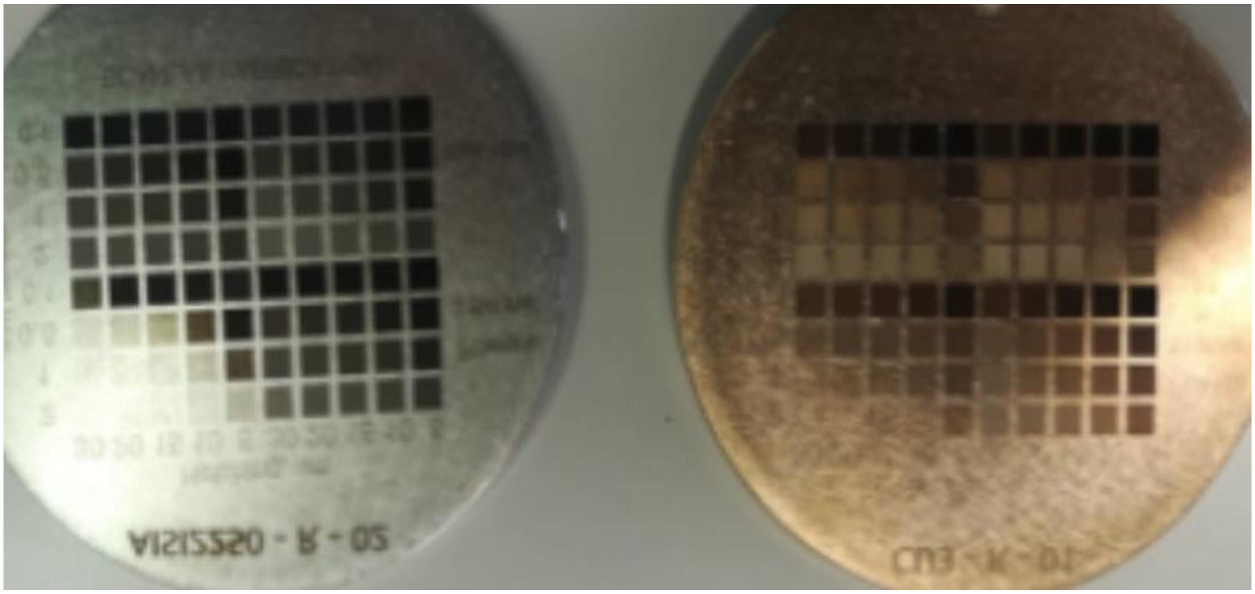


Figure 3. Fabricated samples picture.

Another iteration was started after primary antifouling results. At this iteration was decided to fabricate larger areas because it would help to decide which texture pattern affects fouling. Two disks of each material (stainless steel and Nibral) were fabricated with 4 textures on one side of the samples, a total of 8 different textures for both samples of each material. Another side of samples was used for texture testing and development. Samples are shown in Figure 4.

An identical laser parameter set was used for the A and C samples and another parameter set for the B and D samples. As it seems from Figure 4, there are quite some visual differences between materials. After fabrication, each sample was heat-treated at 60 °C for 24 hours. After heat treatment samples wettability was tested and most textures showed superhydrophobic properties. Pictures of each material texture were taken using a scanning electron microscope (SEM) and pictures are shown in Table 1 as wettability results.

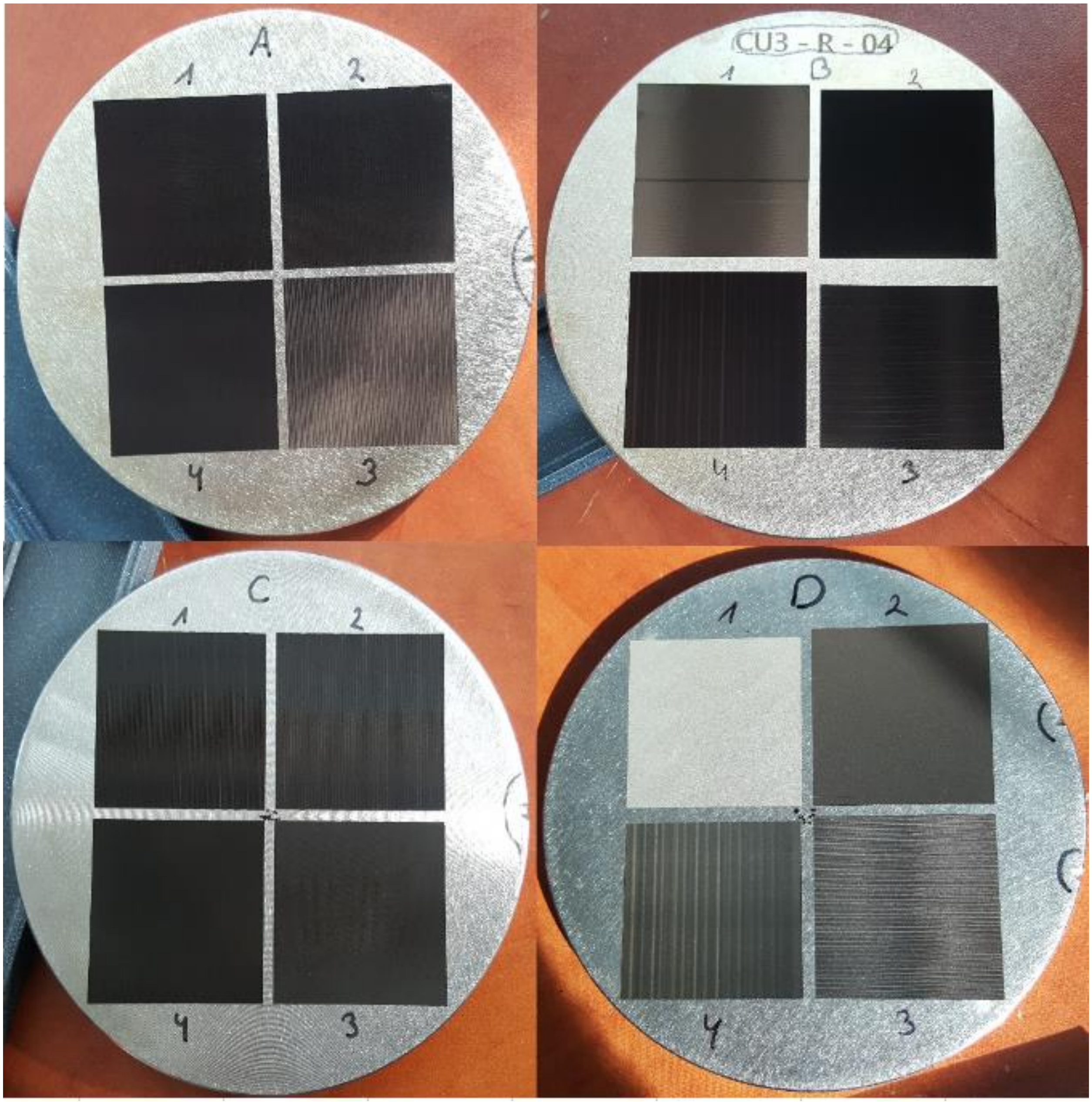
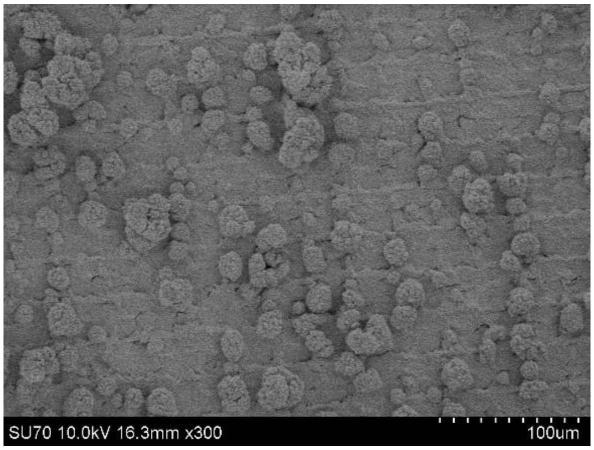
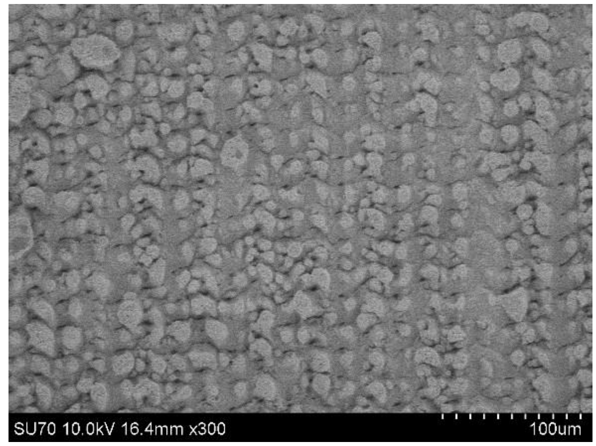
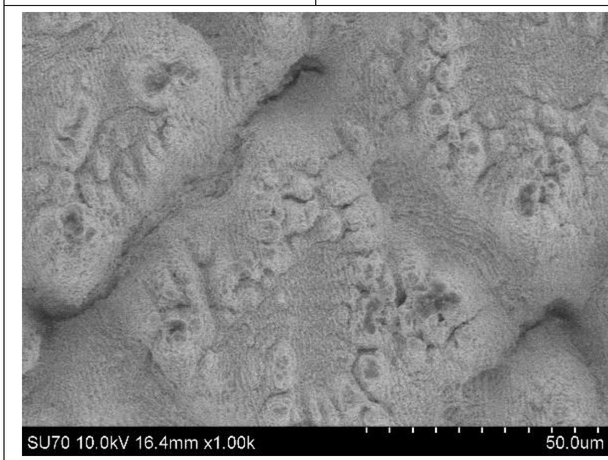
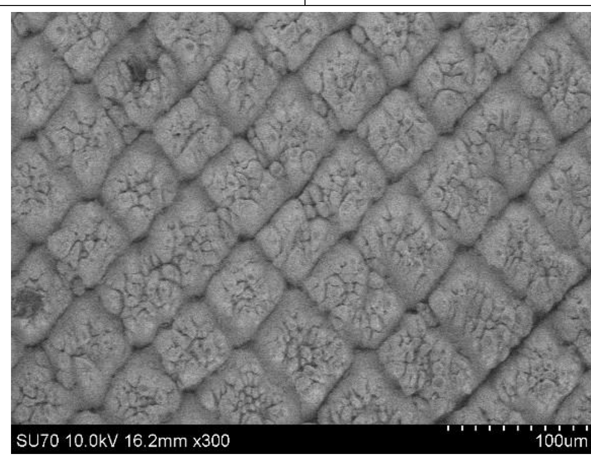
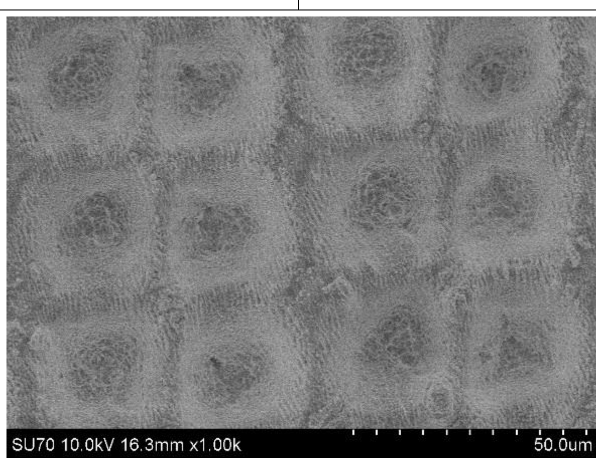
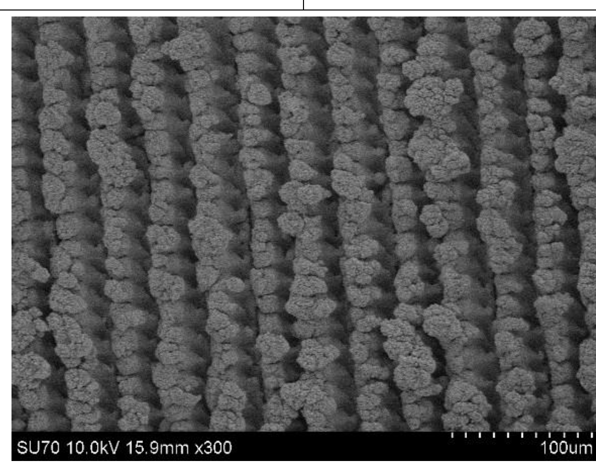
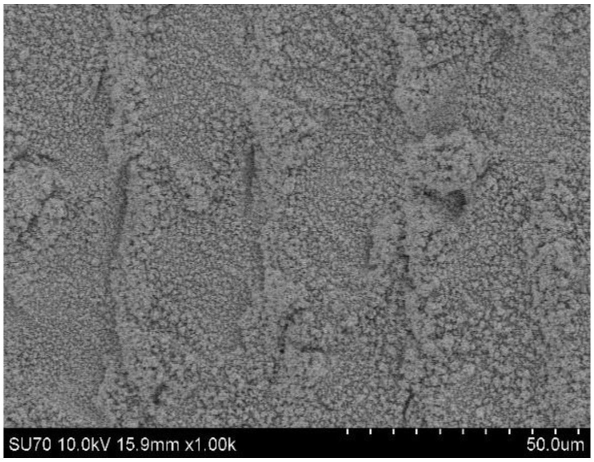
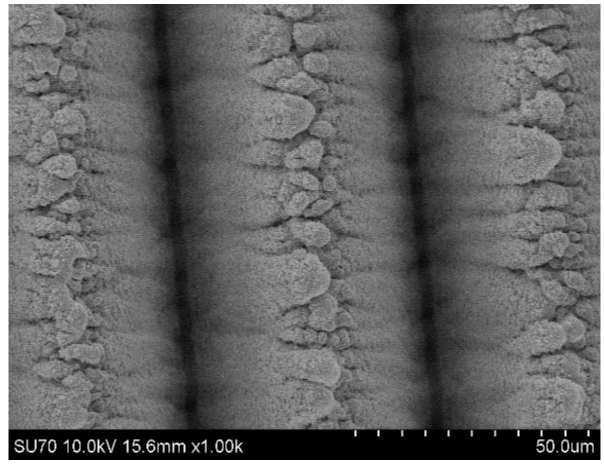
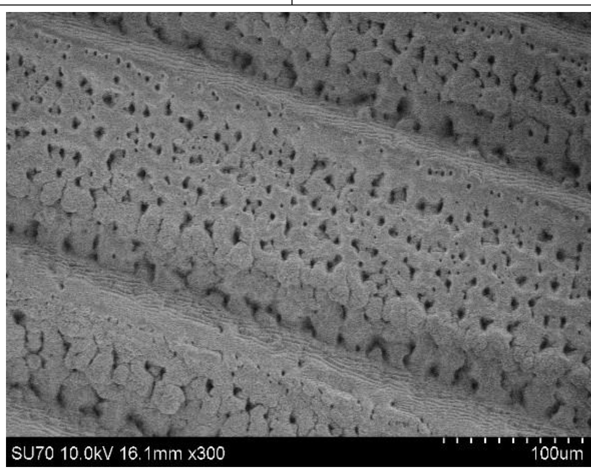
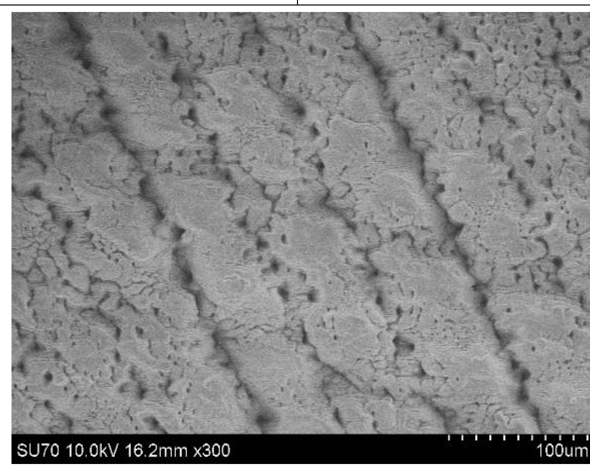
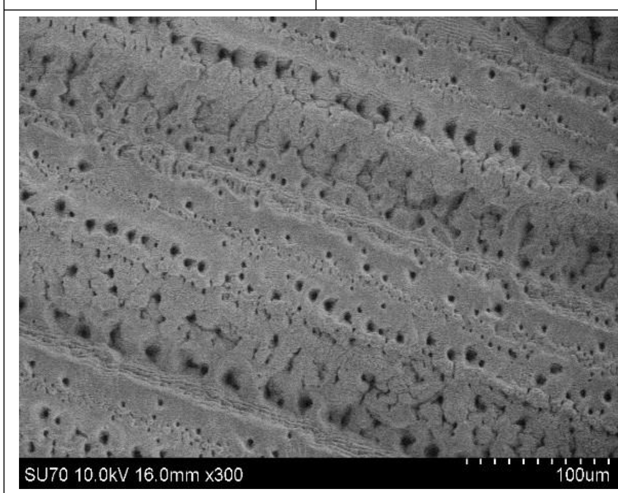
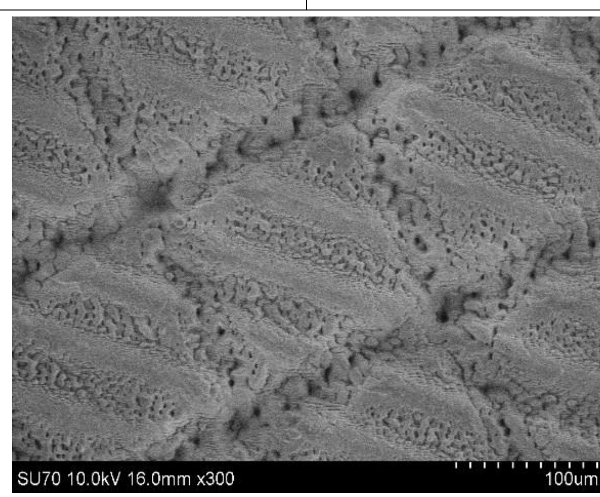


Figure 4. Second iteration samples. A and B are CU3 C and D are AISI2250.

Table 1. Wettability results from the current texture.

A1 texture	CA = 152°	A2 texture	CA = 140°
			
A3 texture	CA = 152°	A4 texture	CA = 140°
			
B1 texture	CA = 155°	B2 texture	CA = 150°
			

B3 texture	CA = 160°	B4 texture	CA = 2°
			
C1 texture	CA = 150°	C2 texture	CA = 140°
			
C3 texture	CA = 160°	C4 texture	CA = 165°
			

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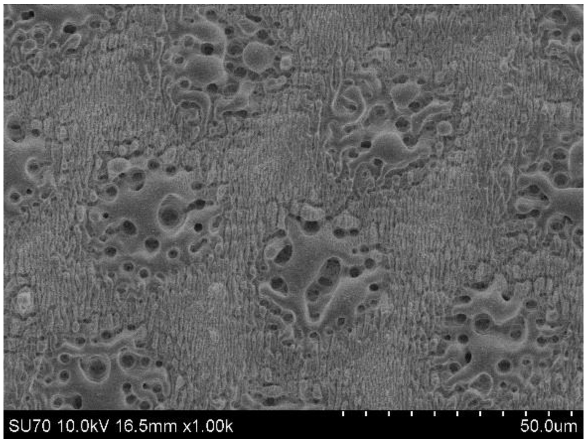
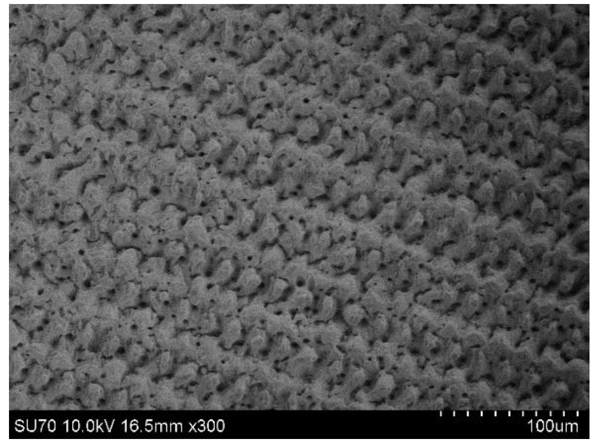
<tr><td>D1 texture</td><td>CA = 150°</td><td>D2 texture</td><td>CA = 150°</td></tr>
<tr><td colspan="2">
</td><td colspan="2">
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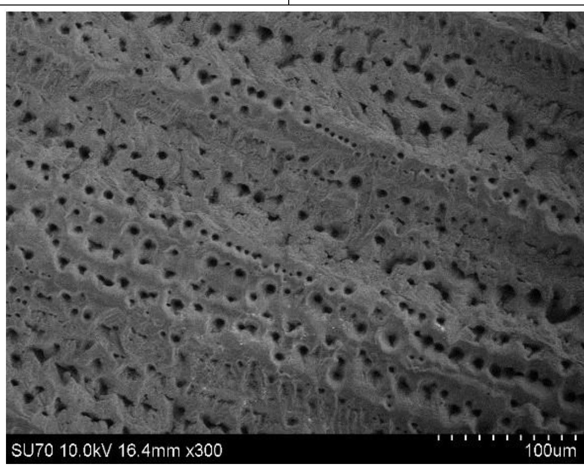
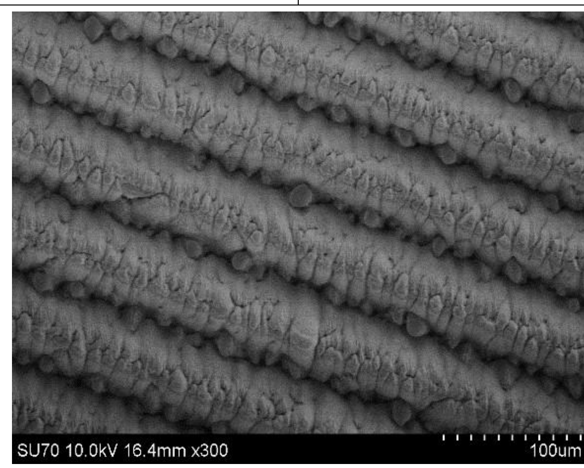
<tr><td>D3 texture</td><td>CA = 160°</td><td>D4 texture</td><td>CA = 1°</td></tr>
<tr><td colspan="2">
</td><td colspan="2">
</td></tr>
</table>

Most laser textured surfaces after heat treatment show superhydrophobic properties. Both materials (AISI2250 and CU3) were fabricated with the same laser parameters set, however as it seems from SEM pictures, obtained textures are different.

3 Outlook

The current laser texturing solution for laser textured surfaces to present fouling was overviewed. We have analyzed literature about fouling processes, possible antifouling properties of a textured surface, its mechanisms, and factors that would lead to the prevention of fouling. Possible pre- and post-treatment were analyzed leading to increased longevity of textured surface and prevention of wetting, which might be a major factor in the fouling process. After analysis of fouling results, further steps would be adjusted, texture structures were measured using "Heliotis" devices and from all results, it is the plan to fully texture the propeller.

4 Confidentiality

FemtoSurf partners must retain any data, documents, or other material as confidential during the implementation of the project. Further details on confidentiality can be found in Article 36 of the Grant Agreement along with the obligation to protect results in Article 27.

5 Conclusions

From the first two iterations of testing, if laser textured surface could prevent, two things were noticed: the first one that on CU3 fouling are slower and the second that some laser textures also reduce fouling process. Pre- and post-processes could change material chemical composition, forming oxides that might affect fouling. However, more tests need to be done and from this found a better method or chemical functionalization leading to a decrease in wetting and microorganism adhesion to the surface.