Project LaserImplant

D2.2 Images designed LIPSS patterns

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1. Goals

The deliverable D2.2 provides a collection of SEM images of designed LIPSS patterns on cylindrical Ti-based samples published on the **LaserImplant** web-site (www.laserimplant.eu).

2. Detailed Description

Introduction

Unarguably it is easier to fabricate the patterns on flat samples at the initial stage for laser texturing and for following biology assessment, especially when cells staining and fluorescence confocal microscopy studies concerned. However, it is essential to transfer these laser patterns onto cylindrical surfaces, eventually onto more complicated surface geometries, such as the screws with windings in question. The technical issues related to the laser patterns transfer from planar surface to cylindrical surface has been discussed in D2.1, such as surface curvature induced periodicity change and surface shading. Therefore, these issues are not the major concern of this deliverable. In this report, **UJM** illustrates cylindrical surface texturing with designed patterns that are potentially useful for osteoblast cells repellant or adhesion, or enhanced mesenchymal stem cells differentiation.

UJM

UJM worked on the deliverable D2.2 to create LIPSS patterns on cylindrical Ti-based samples and to image them using SEM. In order to do so, a non-anodized **HOFER** screw with a diameter of 3.5 mm and a length of 50 mm was used. In order to prepare the up-scaling process, working on a screw is more adapted compared to a smooth cylindrical surface. It will allow us to gain experience and visibility over the difficulties that we could face in the upscaling process of screws knowing that the surface topology won't be uniform with the presence of threads.

The choice of the designed patterns was based on current understanding and expected cells behaviours on these patterns. Laser Induced Periodic Surface Structures (LIPSS) of 350 nm periodicity (produced at 515 nm laser wavelength) is in the list of the choice because a higher degree of hydrophilicity was observed on these LIPSS compared to the LIPSS of 700 nm periodicity (produced by 1030 nm laser wavelength) – the higher degree of wettings helps spreading of the proteins on the patterned surface hence helping cells adhesion. An additional merit of LIPSS with 350 nm periodicity is that these LIPSS seem to repel some pathogenic bacteria commonly present in salivary glands, *i.e.* streptococcus, and s. mutans, although it is unclear at this stage if this functionality is useful or nor for the project. Nanospikes with hierarchical surface features is also in the list of choice. Here, the nanoscale features are the LIPSS with a 350nm periodicity. Ripples with a radial symmetry is also among the chosen designs based on the fact that these ripples are also resist to aforementioned saliva bacteria. There is an ongoing biology test preparation to combine micrometre scale of shallow craters with some of the above-mentioned nanostructures. But for this report combined features are not to be produced on cylindrical surfaces.

The screw was mounted on a motorized rotation jig, and was irradiated from the top as shown in Figure 1a. The laser used is a 515 nm laser (second harmonic generation of 1030 nm laser) exhibiting a 400 fs pulse duration and a repetition rate of 10 kHz.

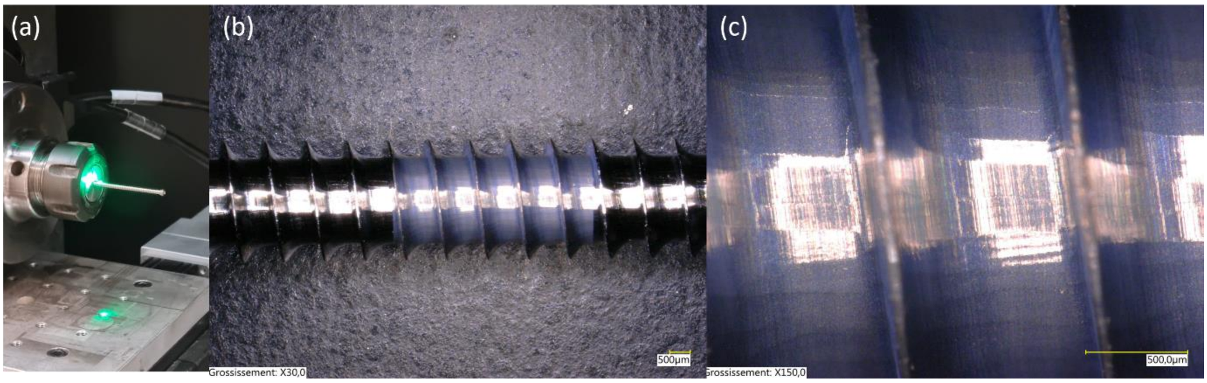

Fig.1: (a) A photo of the **HOFER** screw mounted on the rotating motor and being irradiated by the green femtosecond laser (b) Optical microscope photo of the HOFER processed screw (c) zoom in on the processed area

The screw was processed using a pulse energy of E=0.6 µJ, $2w_0$ = 30 µm, laser fluence Fpeak = 0.17 J/cm^2, translation speed of V_x=23 µm/s and a rotation speed of 2080 °/second, to create LIPSS in a homogenous way. Figure.1b shows the laser processed part of the screw under optical microscope where the difference between the processed area (blue coloration) and the unprocessed area (dark zone) is shown. Moreover, to better characterize the structures, SEM images were conducted on the screw and are shown in Figure 2. First of all, a low magnification image is acquired to show the difference between the laser processed area and the non-processed similar to what was done earlier using the optical microscope. Following that, a zoom in on the interface between the two pre-mentioned areas is performed as shown in Fig 2b. Finally, a big magnification image revealing the creation of LIPSS exhibiting a periodicity of around 350 – 380 nm on the screw in a homogenous way. The screw was processed using a pulse energy of E=0.6 µJ, translation speed of V_x=23 µm/s and a rotation speed of 2080 °/second, to create Laser Induced Periodic Surface Structures (LIPSS) in a homogenous way. Figure 1b shows the laser processed part of the screw under optical microscope where the difference between the processed area (blue coloration) and the unprocessed area (dark zone) is shown.

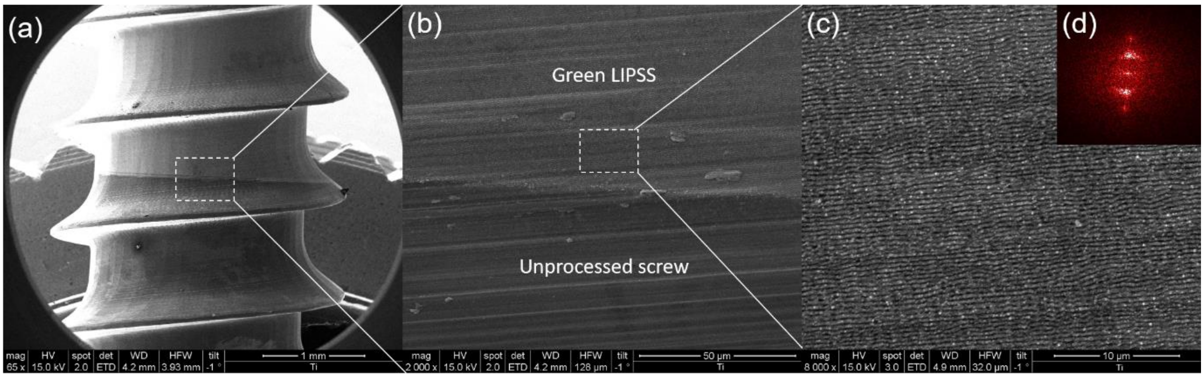

Fig.2: SEM images of the laser process screw with LIPSS generated with femtosecond laser pulses at 515 nm wavelength, (a) (b) low magnification images showing the interface between processed and non-processed areas (c) high magnification image showing the LIPSS (d) Fourier transform of (c).

Figure 3 illustrates the laser processed nanospikes on **HOFER** screws generated with femtosecond laser pulses at 515 nm wavelength. The pulse energy was 2.1µJ, and the spot size $2w_0$ = 23.5 µm, laser fluence Fpeak = 0.97 J/cm^2, 210 mW @ 100kHz, the distance between two successive laser pulses was 70 nm and the scan track spacing was 6.2 µm. The spikes are visibly smaller than the ones produced by **JKU** and **BAM** with 1030 nm wavelength femtosecond laser pulses, the LIPSSs which cover the spikes are smaller in periodicity as well.

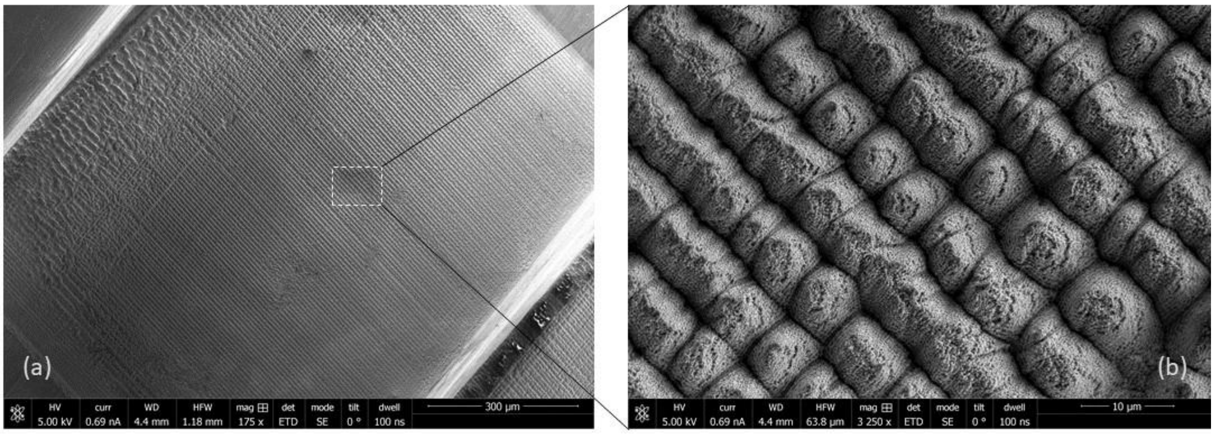

Fig.3: SEM images of the laser processed **HOFER** screw with nanospikes generated with femtosecond laser pulses at 515 nm wavelength, (a) low magnification image showing a textured cylindrical area between two successive screw windings (b) high magnification SEM image showing the hierarchical surface topographies with less than 10µm sized spikes and LIPSS covering the surface of the spikes.

Figure 4 shows radially aligned ripples produced on **HOFER** screws using 1030 nm wavelength femtosecond laser pulses with an Azimuthal polarisation configuration. For the preparation of such pattern, laser power was 70 mW @ 100 kHz, pulse energy 0.7 µJ, 5 pulses per impact and inter-spacing between impacts was 13 µm.

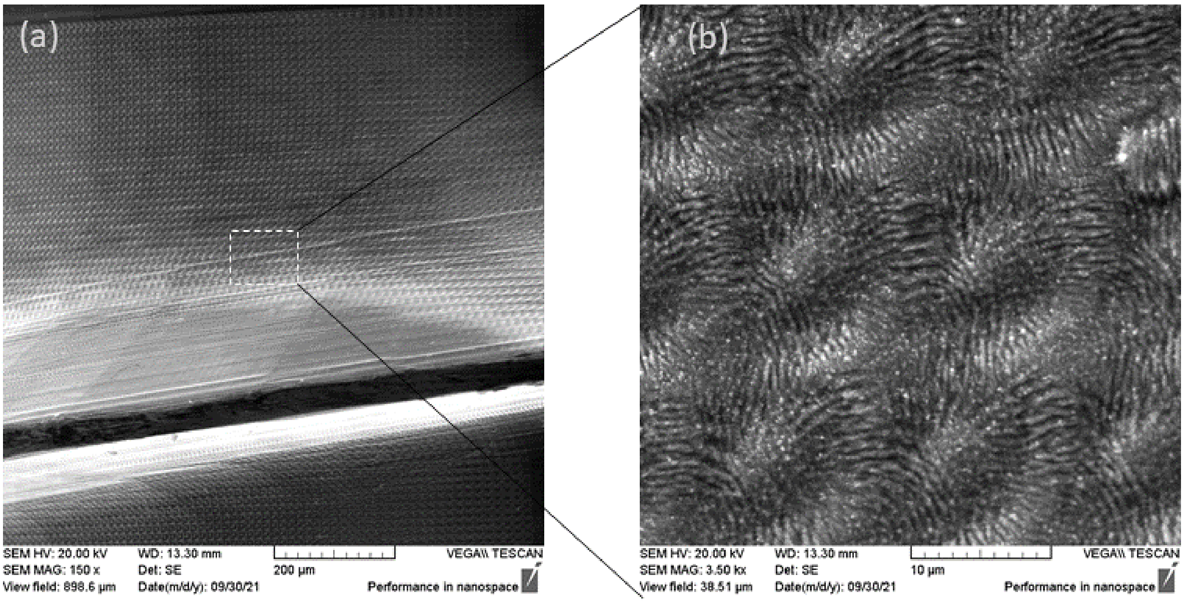

Fig. 4: SEM images of ripples with radial symmetry. (a) Such patterns imprinted on the cylindrical part of the screw, (b) higher magnification SEM micrograph to highlight the details of the ripples with radial symmetry.

As perspective, a series of newly designed patterns are being produced. This series consists hexagonally arranged µm-scale craters of 30 µm diameter and 3 µm pit depth. Firstly, the space between the pits remains polished surface condition before further nano-structuring. These µm-scale features render this surface template of an initial roughness Ra ~1 µm. The space between the pits is then imprinted with different nanostructures, namely LIPSS made with 1030 nm laser wavelength, LIPSS made with 515 nm laser wavelength, LIPSS with 257 nm laser wavelength, LIPSS with radial symmetry (as shown in Fig. 5), respectively. For this batch of flat samples, dedicated bio-assessment are envisaged (cells motion after 24 hours' culture, fibronectin and collagen study after 7 days' culture, mineralisation investigation after 3 weeks' culture, etc). The pattern with best performance will be reproduced on Ti screws.

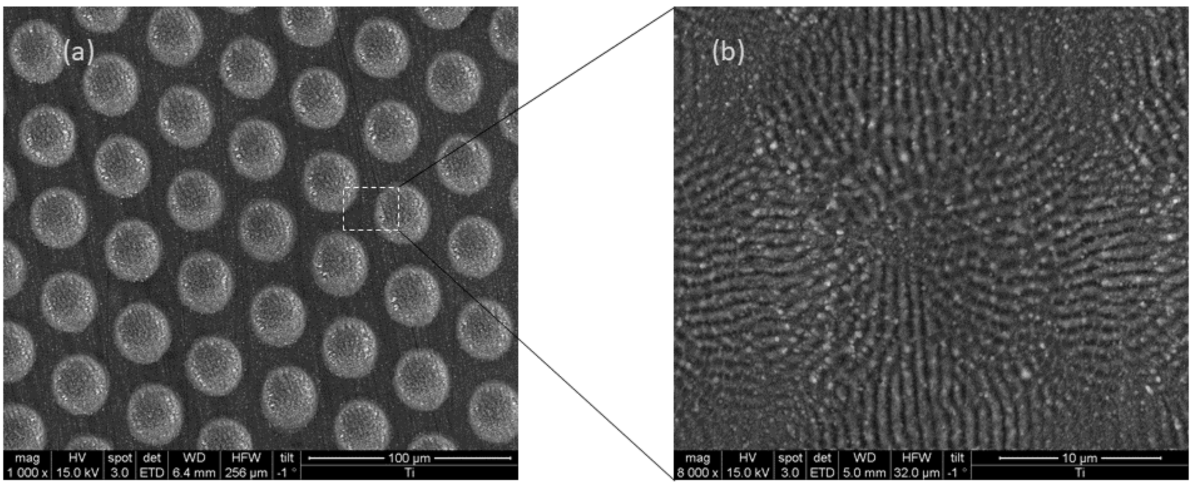

Fig. 5: SEM images of some designed patterns for mesenchymal stem cells culture and bio-assessment. These combined features are currently only fabricated on flat sample but could be produced on cylindrical surfaces if the bio-assessment came back with encouraging results.

3. Evaluation of Goals and Resulting Actions

The deliverable **D2.2 Images designed LIPSS patterns** was finalized in time by m9. A link to this report will be implemented into the Dissemination section of the **LaserImplant** web-site (www.laserimplant.eu).

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