

## LASER PROCESSING AND SYNTHESIS OF MATERIALS AT MICRO- AND NANOSCALE

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The successful application of laser technologies to process a broad diversity of materials can only be understood after the recent development of a likewise broad range of laser sources. Thus, the selection of the laser wavelength, laser pulse energy and duration is a key factor for the development of new processing techniques. Figure 1 enumerates the laser techniques in relation to laser-material interaction time.

These laser based techniques can be classified in different groups as a function of their objective. Hence, there are techniques whose purpose is the production of a coating onto a substrate, such as the Pulsed Laser Deposition (PLD) and laser cladding. Our innovations in the field of these techniques start with the production of biocompatible coatings such as hydroxyapatite or bioactive glasses onto metal substrates for implants. More recently, the capabilities of laser cladding have been stretched with our development of an unique facility for microcladding. Laser microcladding of metallic alloys onto metals and copper onto crystalline silicon are some examples of the potential of this technique.

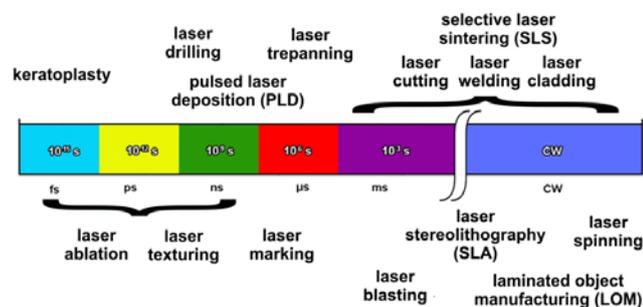


Fig 1. Laser assisted processes as a function of pulse duration.

On the other hand, we have available laser based techniques related to surface modification of materials, such as laser marking, laser texturing or laser blasting. The main purpose of laser texturing and laser blasting is to change the surface roughness and wettability of materials we stretched. Although recent research covers biocompatible polymers (see figure 2), these techniques have been applied mostly on metallic implants such as titanium and titanium alloys.

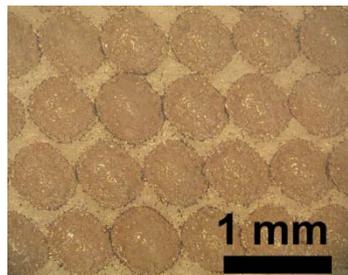
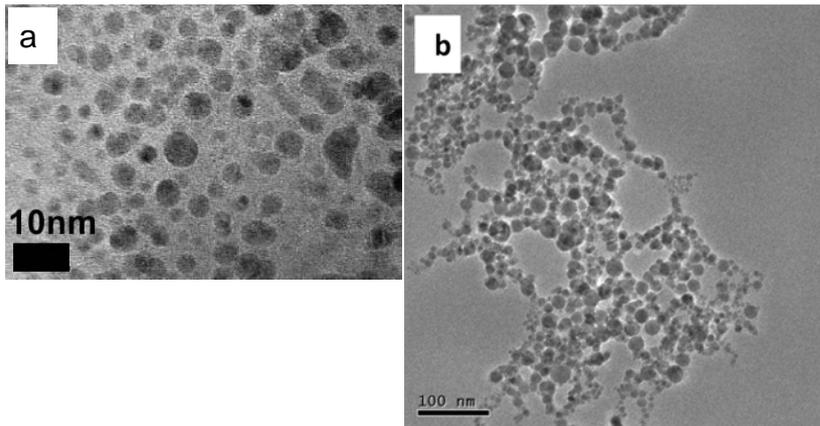


Fig. 2. Laser texturing of PEEK.

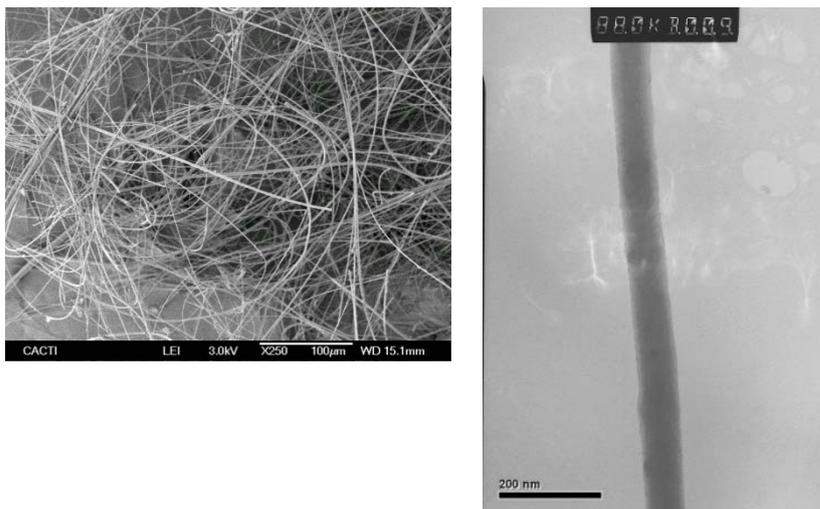
Techniques aimed to produce three dimensional structures are classified into additive manufacturing procedures. Here we can include all laser based rapid prototyping techniques such as Selective Laser Sintering (SLS), Laser Stereolithography (SLA), and Laminated Object Manufacturing (LOM).

Referring to the capability of lasers to synthesize nanomaterials, we can highlight two techniques: laser ablation for production of nanoparticles and laser spinning that has been recently introduced for the production of glass nanofibers.  $\text{TiO}_2$  nanoparticles with controllable average diameter have been obtained by Continuous Wave (CW) laser ablation of metallic Ti submerged in water. The use of a CW laser contributes to a complete reaction between the metallic species and the evaporated liquid due to long interaction time. Obtained nanoparticles are almost perfect spheres in shape with a stoichiometric composition corresponding to  $\text{TiO}_2$ . Furthermore, this technique has been probed to produce hydroxyapatite nanoparticles by laser ablation in ambient conditions. Figure 3.a shows a sample of these hydroxyapatite nanoparticles, while figure 3.b shows the titanium oxide nanoparticles.



**Fig. 3.** TEM micrographs showing a) HA and b) TiO<sub>2</sub> nanoparticles produced by laser ablation.

Laser spinning is a new technique which allows the production of ultralong glass nanofibers. This technique opens up new possibilities to produce glass nanofibers that have not been obtained with other methods. Figure 4 shows 45S5 Bioglass® nanofibers produced by Laser spinning. This bioactive glass nanofibers can be employed to build scaffolds for tissue engineering. Additionally, their application for bone defect filling is advantageous compared to granules, thanks to their high length, flexibility and mechanical resistance which make possible to adapt them to any form and insert or remove easily. Also, nanofibers of different functional compositions such as aluminosilicates for refractory applications or lithium silicates for carbon capture have been produced.



**Fig. 4.** SEM and TEM micrographs showing and overall view and a detail of the micro- and nanofibers of 45S5 Bioglass® produced by Laser spinning.

In summary, lasers are available today to treat, process, or synthesise many micro- and nanomaterials, opening a broad field of possibilities worth to be explored and applied.