Abstract

Laser micromachining is a well-established industrial processing technique. Due to the performance attainable with modern lasers, like high power, coherence, and monochromaticity, it has been utilized for cutting, welding, and engraving various materials, including metals, polymers, and composites. However, besides its traditional use, advancement in the laser technology has enabled a new perspective for laser processing towards advanced applications like surface functionalization, precision modification, and chemical alterations at the micro- and nano-scale. The applications for such material modifications include thin film dewetting, microfluidic channels, 3D optical waveguides, cell scaffolds, drug delivery systems, and solar and fuel cell applications.

Many of these advanced applications rely on ultrafast laser systems that use non-linear interactions to modify different materials in bulk with high precision. However, although several such applications have been demonstrated at a research level, an industrial-scale translation of these techniques has been dragging. That is due to the complexity, relatively slow processing, and expensive equipment involved with such ultrafast laser systems. On the contrary, long pulsed nanosecond lasers have been industrially established and could offer solutions to various advanced applications involving large-scale production.

This thesis focuses on the use of an industrial grade fiber nanosecond laser system to push the boundary of laser surface modifications on different materials: from metals to ceramics, from glass to polymers. Leveraging on the flexibility of

this approach and based on extensive research on the laser material interaction conducted during the development of the thesis, different applications are proposed here. Those applications include the fabrication of superhydrophobic/ superamphiphobic surfaces, surface texturing for improved functioning of solid oxide fuel cells, precision modification of microstructures and optics on bioresorbable glass, and ultrahydrophobic high gauge factor strain sensors based on reduced graphene oxide.

This research demonstrates that a high degree of control on the surface texture, like roughness or hierarchical structures, can be obtained by an accurate choice of laser parameters. For example, by appropriately adjusting the laser pulsewidth, aluminum can be made superamphiphobic. In another case, tunable surface roughness is achieved by varying the laser fluence obtaining an improved solid oxide fuel cell interconnect with the oxide glass sealant. Promising results have also been obtained by modifying glasses of biomedical interest like bioresorbable calcium phosphate glass. Indeed, in those glasses, the heat affected zones (HAZ) generally associated with nanosecond lasers can be reduced the resulting inverse Marangoni flow of the locally melted glass can be controlled to obtain microtextures on the glass surface. That enables to obtain e.g. micro-optics structures in the form of hyperbolic and spherical microlenses or diffraction gratings.

In addition, this thesis's work explored combining laser texturing capabilities with chemical surface treatments. Besides obtaining superamphiphobic surface with fluorosilane coatings, an eco-friendly rapid chemical treatment was developed using vegetable oil on the laser treated surfaces to achieve superhydrophobicity.

Finally, even though nanosecond laser micromachining can't reach all the capabilities offered by ultrafast lasers, several applications could use this former as a powerful tool towards industrial scale processing for advanced applications and novel functional surfaces.