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Full Length Article

Laser texturing of stainless steel under different processing atmospheres: From superhydrophilic to superhydrophobic surfaces

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ABSTRACT

Wettability plays a major role in a variety of surface related phenomena, as corrosion, heat transfer or tissue adhesion on implants. Consequently, great research effort is being devoted to control the wetting degree of functional surfaces. Pulsed laser texturing at micro/nanometric level has been widely used for that purpose as a precision/time efficient technique. This work studies the role of the processing atmosphere in controlling the wettability of commercial AISI 304 by laser texturing. A pulsed laser source (λ = 532 nm) working at the nanosecond regime was employed and five different atmospheres were tested (i.e. O_2, Air, CO_2, N_2, Ar). The results show clear differences in the wetting behaviour depending solely on the processing environment, ranging from hydrophilicity (31°) to hydrophobicity (125°). Those differences in wettability were found to be a consequence of changes in surface chemistry between samples processed under the various gases. The laser processing parameters showed a capability to tune the final wetting behaviour by controlling the topography and modulating the chemical composition given by the processing environment. It is demonstrated how the effects of the atmosphere can be exploited to tailor the wettability of the untreated surfaces (θ = 88°) up to the desired value, ranging from superhydrophilicity (θ = 0°) to superhydrophobicity (θ = 152°).

1. Introduction

Wettability is a crucial surface property governing diverse phenomena like corrosion [1], cell adhesion [2,3] or heat transfer [4], among others. Then, the control of the wettability of functional surfaces has a tremendous potential benefit in the performance of engineering devices. For that reason, the fabrication of surfaces with extremely low wettability, designated as superhydrophobic, or with extremely high wettability, also known as superhydrophilic, has been actively researched [5,6]. Such surfaces make possible the development of water harvesting systems, controlled drug release devices or low drag surfaces for maritime transports [7,8].

The wetting behaviour of a surface is governed by the interactions between the solid phases and the liquid at molecular level. Changes in the chemical composition of the surface and/or in the surface roughness modify its intrinsic wettability degree, as described by the classic models of Young [9], Wenzel [10] and Cassie-Baxter [11,12]. On that basis, methods for modifying the wettability require the control of both surface chemistry and topography, being plasma etching, sol-gel modification, or hydrothermal reaction some examples of the most used ones [7].

Laser texturing based on short/ultrashort pulses, i.e. with ns/ps-fs laser pulses, has proved to be a useful tool to modify the surface topography at micro/nano scale over a wide area of material within a relatively short time, which makes it a precision/time efficient technique. The lack of special requirements like vacuum environment or chemical coatings, together with its adaptability to different materials have already foster its use to tune the wettability of metals [13], polymers [14], ceramics [15] or natural stones [16].

Regarding metals, wettability modification by pulsed laser texturing entails topography changes based on melting/evaporation processes, which can be controlled by the processing parameters to tune the size and period of the generated structures [17,18]. Interestingly, a wettability transition from highly hydrophilic freshly processed surfaces towards hydrophobic values as time is elapsed from processing has been reported and studied in many publications to this day, irrespective of the irradiated metal [13,19–24]. Despite the mechanism is not totally clear, generally it is accepted that high energy metal oxides are generated during laser processing, giving its initially hydrophilic behaviour to the surface. Those oxides are highly active and tend to react with surrounding molecules over time, decreasing the surface energy and the wettability in consequence [20,22].

Most of the current works have only explored tuning the wettability

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