Highlights

RESEARCH AREA 2 - **Functional and Complex Materials for Innovative Electronics and Sensing** - 2022

"Ultrafast laser surface irradiation of silicon: Effects of repetition rate in vacuum and air"

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Ultrashort pulse lasers offer many possibilities in applications related to the processing of a solid target surface, such as materials drilling, cutting, marking and texturing. They have also been able to impart new functionalities to a material surface through the generation of laser induced periodic surface structures (LIPSS), e.g. and studies exploiting energetic laser pulses of few tens of μJ, at repetition rates of tens to hundreds kHz have shown new features of fs laser surface irradiation and texturing processes. Our study reports a thorough investigation on the crater morphology and surface texture of silicon irradiated with fs pules in air and vacuum, at various repetition rates. The subject is of particular interest, and great practical impact, since in many applications the process occurs at atmospheric pressure and our previous experimental findings evidenced a clear variation of the features of the irradiated samples at about 10 kHz, that was ascribed to plume shielding induced by the confinement of the ablated material at atmospheric pressure. Hence, we were stimulated to analyse the effects of surface irradiation of a silicon target also in vacuum conditions, at repetition rates varying from 0.01 to 200 kHz, and in static conditions. The outcomes were compared with results obtained in air in similar experimental conditions. Both the threshold fluence for the formation of a shallow crater, and the morphological characteristics of the surface structures generated inside the crater were analysed, for a fixed sequence of *N* laser pulses, as a function of the pulse repetition rate, f_p. Strong differences were observed for processing in vacuum and air, that allow also addressing the change in laser-target energy coupling in the two cases, at repetition rates larger than 10 kHz. The observed behaviour was eventually rationalized in terms of the different effects of the nanoparticle debris covering the target surface, and of the occurrence of plume

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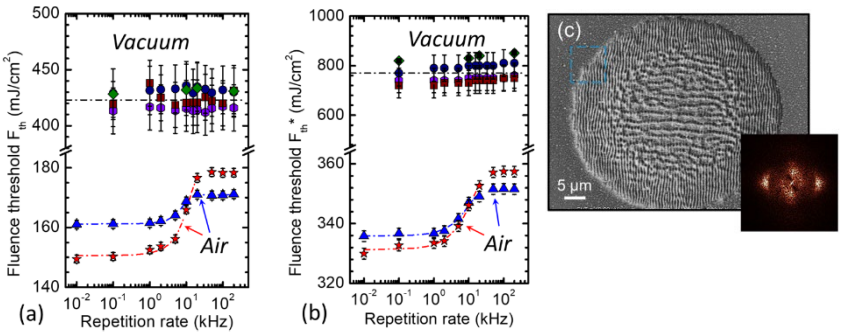

Fig. 1. Variation of the threshold fluences F_{th} (a), and F^*_{th} (b) as a function of the repetition rate, for irradiation in air, with a sequence of N = 100 (triangles), and N = 200 (stars), at a laser peak fluence F_p = 0.84 J/cm^2, and in vacuum, for ^{N} = 100, at four different values of F_p, namely 0.78 (hexagons), 0.84 (squares), 0.91 (circles) and 0.97 (rombs) J/cm2. The lines are guides to the eye. The panel (c) displays an example of the surface structures formed in the crater for irradiation in air at 1 kHz and its inset shows the 2D-FFT spectra generated from the SEM image.