Fundamentals of surface modification after irradiation of silicon with ultrashort laser pulses

G. D. Tsibidis[1*], P. A. Loukakos[1], E. Stratakis[1,2], C. Fotakis[1,3]

1) Institute of Electronic Structure and Laser (IESL), Foundation for Research and Technology (FORTH), N. Plastira 100, Vassilika Vouton, 70013, Heraklion, Crete, Greece

2) Department of Materials Science and Technology, University of Crete, 710 03 Heraklion, Crete, Greece.

3) Physics Department, University of Crete, Heraklion 71409, Crete, Greece

** tsibidis@iesl.forth.gr, phone: 00302810391912, fax: 0030-2810391569*

Material processing with femtosecond (fs) pulsed lasers has received considerable attention over the past decades due to its multiple diverse applications ranging from micro-device fabrication to optoelectronics, microfluidics and biomedicine. Rapid energy delivery and reduction of the heat-affected areas are the most pronounced advantages and in view of the abundant applications a thorough knowledge of the fs laser interaction with the target material is required for enhanced controllability of the structuring process. The fundamentals of the physical mechanisms and simulation techniques are employed to conduct a thorough investigation of ultrashort pulsed laser induced surface modification due to conditions that result in a superheated melted liquid layer and material evaporation. The novel proposed theoretical model aims to address the laser-material interaction in conditions which lead to mass removal in combination with a hydrodynamics-based scenario of the crater creation and ripple formation following surface irradiation (Fig.1a) with single and multiple temporal separated pulses [1, 2]. The development of periodic structures (Fig.1b) with an orientation perpendicular to the electric of the laser beam is based on a synergy of electron excitation and capillary wave solidification and the interference of the incident wave with a surface plasmon wave [3]. The theoretical framework aims to offer a thorough elucidation of laser-matter interaction fundamentals and facilitate production of well-defined micro/nanostructures (Fig.1c) with preferable optical properties.

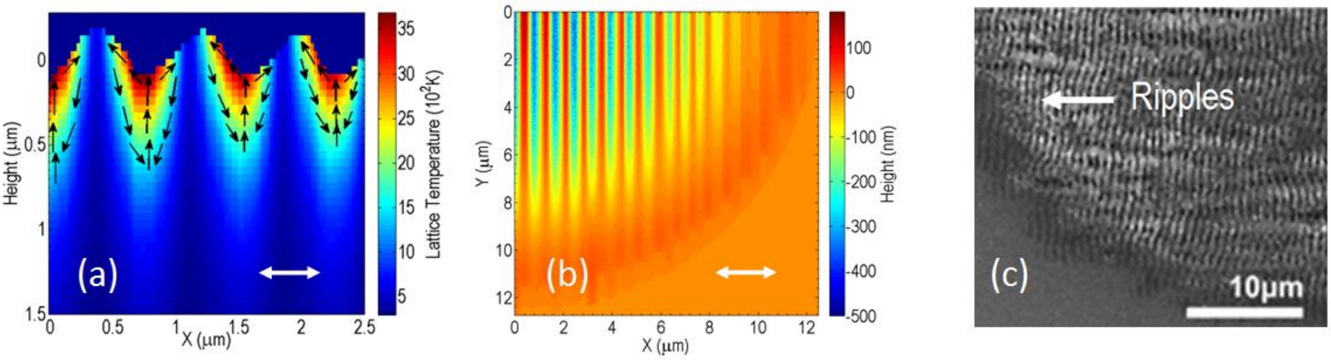

Figure 1. (a) Spatial distribution of lattice temperature at *t*=1ns for ten pulses. (Arrows indicate flow movement), (b) Ripple pattern for ten pulses, (c) SEM image of surface modification (fluence=0.6J/cm^2,pulse duration=430fs). (Double-ended arrow indicates the laser beam polarisation).

[1] M. Barberoglou *et al.*, Applied Physics A: Materials Science and Processing **113**, 273 (2013).
[2] G. D. Tsibidis *et al.*, Applied Physics A **114**, 57 (2014).
[3] G. D. Tsibidis *et al.*, Physical Review B **86**, 115316 (2012).