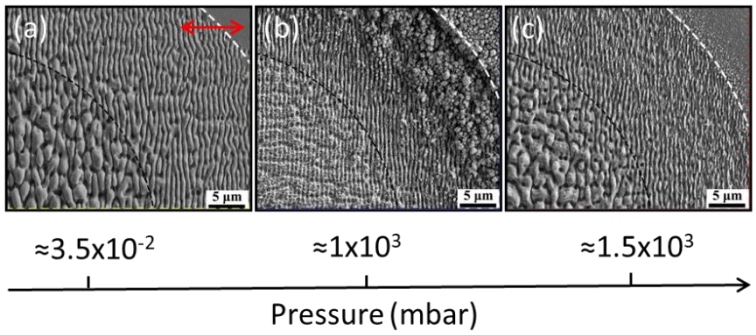
Influence of ambient pressure on LIPSS formation in silicon

Jijil JJ Nivas[1,2,*], Xiaona Zhao[2], Achu Purushothaman[1], Mohammadhassan Valadan[3], Carlo Altucci[3], Xuan Wang[2], and Salvatore Amouso[1,]

[1] Dipartimento di Fisica Ettore Pancini and CNR-SPIN, Università degli Studi di Napoli Federico II, Complesso Universitario di Monte S. Angelo, Via Cintia, Napoli I-80126, Italy
[2] School of Remote Sensing and Information Engineering, Wuhan University, Wuhan 430072, China
[3] Dipartimento di Scienze Biomediche Avanzate, Università degli Studi di Napoli Federico II, via Pansini 5, I-80131 Napoli, Italy
*Corresponding author email: jijil.jjnivas@unina.it

We report on the process of femtosecond (fs) laser irradiation and surface structuring of silicon at an ambient pressure ranging from dry vacuum (~10^{-2} mbar) to above atmospheric pressure, which is rarely investigated. For structuring in high pressure, nitrogen gas is pumped into the chamber maintaining the pressure level at ~1.5 bar. The change in the ambient pressure enables the surface structuring process in experimental conditions going from a freely expanding to a redeposited and highly confined nanoparticles cloud, which has a potential role in the formation and evolution of the various periodic surface structures [1]. The irradiation is carried out using a sequence of laser pulses with a duration of ~180 fs at a wavelength of 1030 nm. The surface morphology of the irradiated sample evidences the formation of a variety of subwavelength and supra-wavelength features, including ripples and grooves oriented in direction orthogonal and parallel to the laser polarization, respectively, as well as columnar structures. Our experimental findings allow shedding more light on the influence of the nanoparticle redeposition on the evolution of fine features and supra-wavelength structures, especially the hindering of grooves development below and above the atmospheric pressure, and provide valuable insights on potential formation mechanisms and for further applications. Finally, considerable change in the morphology of the ripples is also observed as a function of the ambient pressure.



SEM micrographs of surface spots generated in (a) dry vacuum (b) air and (c) high nitrogen pressure, for 240 number laser pulses at a pulse energy of ≈ 170 µJ. The red arrows indicate the polarization direction.

References: [1] J. JJ Nivas et al, Direct ultrashort laser surface structuring of silicon in air and vacuum at 1055nm, Appl. Surf. Sci. **417** (2017) 149-154, https://doi.org/10.1016/j.apsusc.2017.03.158.