Oxidation of metals during topographic functionalization upon ultrafast laser irradiation

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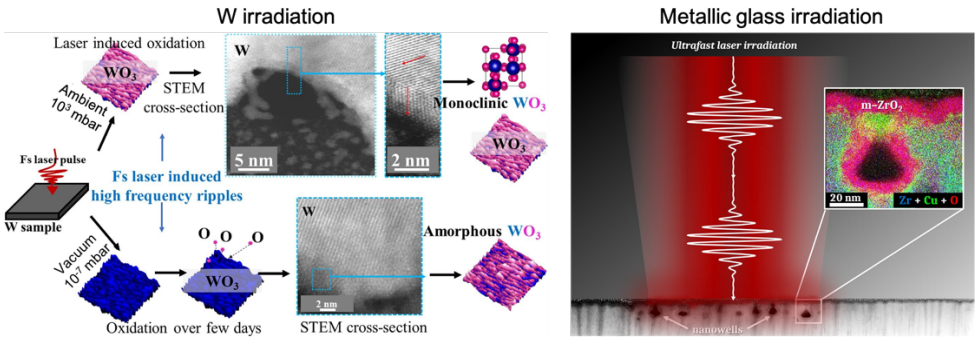
Ultrafast laser-induced surface texturing became a well-recognized technique of surface functionalization, with comparatively little work focused on the accompanying chemical changes. This paper reports a detailed investigation of the oxidation mechanisms induced on metals in the form of pure metal and metallic glass.
Ultrafast laser irradiation was performed in ambient and high vacuum conditions on tungsten to generate so-called High Spatial Frequency Laser Induced Periodic Surface Structures (HSFL) with a sub- 100 nm period and sub-20 nm amplitude, as they are supposed to arise in a non-ablative regime. Scanning Transmission electron microscopy cross-sectional images, and x-ray photoelectron spectroscopy analyses reveal significant structural differences between the laser-generated oxides and the oxides accumulated over time from ambient exposure [1]. The oxidation mechanism during ultrafast laser interaction was examined with the help of Two Temperature Model and Molecular Dynamics simulations (TTM-MD) complemented by oxygen diffusion data, providing a predictive insight into the development of a thin oxide layer induced by the laser, a conclusion substantiated by the STEM images.
This study is complemented by a detailed analysis of ultrafast laser irradiation of metallic glasses under conditions of generation in a one-step laser process of dense nanowell arrays with dimensions down to 20 nm spontaneously formed in the ultrafast laser irradiation spot [2]. In addition to the topographic functionalization, the laser-irradiated amorphous material exhibits structural changes analyzed by spectroscopic techniques at the nanoscale such as energy-dispersive X-ray spectroscopy and electron energy loss spectroscopy. Results reveal structural changes consisting of nanocrystals of monoclinic zirconia that grow within the amorphous ZrCu matrix. The mechanism is highlighted by an atomistic simulation of the laser-induced nanowell formation.



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