PhD Thesis Proposal

Thesis title: Comprehending the reactivity of metals during nanosecond laser treatment in liquid media

Department / Research team:
PMDM / LTm

Thesis Supervision and, if applicable, co-supervision:

Dr HDR Iryna TOMASHCHUK, Dr Rofka RAMDANI
E-mail : iryna.tomashchuk@u-bourgogne.fr ; rofka.ramdani@u-bourgogne.fr

Background – Description of the topic – Objectives

The treatment of metallic materials with short-pulse lasers (such as nanosecond lasers) is a flexible and versatile technology that allows for the production of various surface morphologies associated with the insertion of light elements such as oxygen and nitrogen. Modifying the roughness and chemical nature of the metallic surface opens vast possibilities for controlling its wettability, photoreactivity, and biocompatibility. At the same time, during the reaction of the metal plasma with ambient air, the laser treatment generates oxide nanoparticles, which is both a means of their production and a source of environmental pollution.

Performing laser treatments in liquid media solves the problem of nanoparticle propagation and facilitates their handling in view of future uses, thus making the process cleaner. However, the *understanding and mastering of the metal oxidation process under nanosecond laser radiation in liquid media* remain incomplete. As demonstrated by a preliminary study of laser oxidation of titanium in demineralized water [1], the liquid medium significantly influences the nature and morphology of the surface and particles generated in the confined plasma, compared to what is observed in ambient air [2].

To induce the formation of oxides in absence of air, two oxygen-rich media will be considered: demineralized water and hydrogen peroxide. Titanium and aluminum, which have been the subject of previous studies of nanosecond laser treatment in air [3,4], will be used as substrates. Finally, the effects of two nanosecond laser sources, with λ=532 nm and 1064 nm, will be compared. The laser-treated surfaces will be characterized by profilometry, XRD, SEM-EDS, Raman spectroscopy and XPS. The produced particles will be analyzed by SEM-EDS, Raman spectroscopy and TEM.

The oxidation conditions of metals during laser treatment in liquid media have not yet been fully elucidated. To determine the temperature and the nature of the species evolving in the interaction zone, emission spectra and plasma imaging will be studied in collaboration with Pr. Jean-Marie Jouvard. It is also planned to study the *in-situ* formation of nanoparticles using the SOLEIL synchrotron, as was previously done for laser treatment in air [3].

This experimental basis will provide a solid foundation for conducting a comparative study of oxidation processes in air and in liquid media at the atomistic scale. This will allow for a better understanding of nucleation, growth, and oxidation phenomena, with a view to optimizing nanosecond laser treatment process. The aim is to simulate the metallic vapor phase under extreme temperature and pressure conditions, characterize the nucleation and growth mechanisms of oxide nanoparticles, and analyze their interactions with various reactive environments, focusing on oxidation in air and in liquid phase, in order to identify conditions favorable to the stabilization of different metallic or oxide phases. Expected results include a better atomistic understanding of the condensation and oxidation processes, the differentiation of specific behaviors between gaseous atmospheres and liquid media, and the means for controlling the chemical composition and structure of the nanoparticles.

Keywords: nanosecond laser, metallic materials, oxidation, molecular dynamics.

Candidate profile:

Master's degree in physics, chemistry, materials science or nanoscience, capable of developing a multidisciplinary experimental approach and having a taste for numerical simulation and data analysis.

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[3] M. Girault. Etude d'un plasma généré lors d'un traitement de surface métallique par ablation laser dans l'air : caractérisations du rayonnement et des nanoparticules induits. PhD thesis, Université de Bourgogne (2015) https://theses.fr/2015DIJOS028

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