Public lecture PhD Thesis
An insight into the expansion of laser induced plasmas

Xiang Yao

The Thin Films and Interfaces Group
https://www.psi.ch/lmx-interfaces/about-the-tfi-group
Paul Scherrer Institut
E-Mail: xiang.yao@psi.ch

Abstract:

Pulsed laser deposition (PLD) is a thin film deposition technique that uses a high energy nanosecond UV laser pulse to evaporate material from a solid target. It stands out among the different thin film deposition techniques due to its capability to transfer the stoichiometry of the target to the film. Nevertheless, the congruent stoichiometry transfer occurs only in a narrow deposition window. The stoichiometry issues of PLD can be assessed from the three basic steps: the ablation, whether the ejection of materials from the ablation is stoichiometric; the plume expansion, how the ablated species are transferred to the substrate; and the deposition, how the species adsorb on the substrate. Among the three steps, the expansion of the plume is the bridge between the other two. The different expansion properties of the different elements in the plume are the origin for the non-congruent transfer. However, the transient and complex nature of the plasma plume makes it difficult to obtain a detailed picture of the expansion process. Until today, efforts are made to identify mechanisms involved during the expansion of the plasma plume.

In this presentation, I will present my work done to characterize multi-component plasmas with the focus on the discussion of the expansion dynamics. Two techniques are combined to cover the different aspects of the plasma expansion: energy-resolved mass spectrometry for the analysis of the energy distributions for the ions with a specific mass to charge ratio, and spectrally resolved plasma imaging to provide time- and spatially resolved images of the atomic emissions of different excited species. The results show that the expansion of ions and neutrals in the plasma is governed by different mechanisms. A dynamic double layer model is proposed to explain the expansion of ions, while the expansion of neutrals is driven by the gas dynamics with the Knudsen layer formation. These findings can be generalized for the ablation of metals or low bandgap insulators by nanosecond UV lasers.