Real-time plasma diagnostics: towards understanding gas phase chemistry during pulsed laser deposition

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One of the most important development directions within the thin film technology is the controlling and tailoring of the any plasma-based deposition techniques via simple and scalable parameters. In this context, the unfolding of 4th Industrial Revolution is targeting all industrial production technology and aims to control and take charge of the manufacturing process via Artificial Intelligence algorithms. Amongst all plasma-based deposition techniques, pulsed laser deposition (PLD) stands as one of the best available technologies to develop complex stoichiometric film. Controlling and tailoring PLD has been the main developmental pillar in its history with the focus on external factors (laser fluence, gas pressure, target bias, target-substrate distance, etc.). However, in the past 5 years a paradigm shift has occurred which is centred around considering the laser produced plasma as the active medium in the deposition. Therefore, understanding its kinetics and controlling the complex chemistry occurring during the deposition becomes the key steps in order to develop a complete picture of the deposition process and towards industrialization. In order to develop a complete picture of the deposition process we employed a dual approach based on in situ plasma analysis and thin film analysis to find common feature that would connect the properties of the plasma with the ones of the deposit.

In situ analysis of laser produced plasmas, generated in a wide range of conditions (laser fluences, background pressure, target nature) were performed by angular and time-resolved Langmuir probe (LP) technique and space- and time-resolved Optical Emission Spectroscopy (OES). The work was focused on understanding the complex oxidation chemistry occurring during transient plasma expansion in a PLD geometry in order to tailor the ionic energy distribution and control the oxidation phase in the film. A trademark feature of the study is the use of the angle and time resolved measurements during floating regime of the probe and show clear correspondences between the variation in plasma parameters and the generation of specific plasma phases. Plasma multi-structuring is observed for a wide range of pressures with each feature corresponding to an ionization state of the plasma ions, results confirmed by OES investigations. Complementary, OES allowed for angular, spatial and temporal monitoring of visible and UV emission of the plasma. Important results were found for the case of metallic deposition in O_2 where we observed oxide molecules formation and its impact onto the plasma energy and the oxidation state of the coating (Figure 1). A key aspect in this paper is to show proof of concept for oxide phase control via plasma diagnostic tools for a wide range of oxides (Ag_xO_y, Mn_xO_y, Cu_xO_y, NiO) with application in semiconductor industry. Confirmation of this control will be given by presenting the properties of the resulting thin films through a wide array of surface analysis techniques.

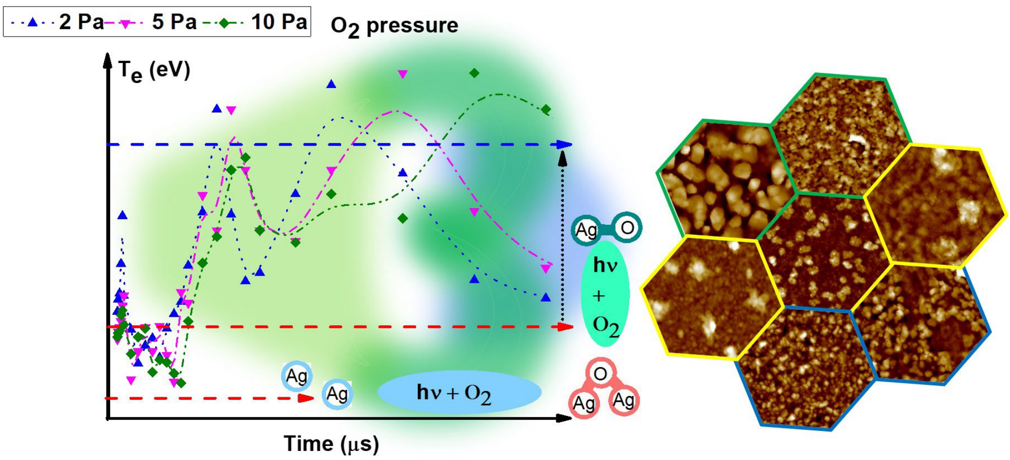

Figure 10. Representation of AgO reaction during the deposition its impact to the morphology of the coating

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