Transport of non-thermal deposition particles in an argon plasma at low pressures, in connection with the thin film nanostructure

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Plasma-assisted thin film deposition techniques are widely spread in the technological industry and their study represents one of the most important research areas within the field of plasma physics. The scientific challenge here resides in relating experimental controllable quantities to fundamental physical and chemical processes [1] in the deposition in order to control the development of the film nanostructure. This research is not straightforward due to the strong non-lineal behaviour of plasmas [2] under external perturbations and the existence of a far from equilibrium situation [3,4] on the growth surface of the film. A complete description of the deposition process requires the understanding of i) the plasma chemistry, in order to determine the species arriving at the growth surface, ii) the transport of energy towards the film, to understand the physical/chemical processes activated on the surface, and iii) the relaxation of the species and the development of a final nanostructure of the film.

In this talk we present results concerning the evolution of the surface morphology of plasma-assisted magnetron sputtering deposited thin films. In sputtering deposition, the so-called Keller Simmons formula [5] describes the deposition rate of the growing film, r, as a function of the number of sputtered particles per unit of time and per unit of area, Φ_0, the pressure of the, predominantly neutral, particles in the plasma, p, and the distance between the film and the cathode, L, as $r = \Phi_0 \left(p_0 L_0 / pL \right) \left[1 - \exp\left(-pL / p_0 L_0 \right) \right]$, where the quantity $p_0 L_0$ is known as the characteristic pressure-distance product. In a recent publication it was shown the intrinsic link between the thermal transport in the plasma and the transport of sputtered particles from the cathode towards the deposition surface through the relation $p_0 L_0 = k_B \left(T_s + 2T_c \right) / 3\sigma$, where T_s and T_c are the film and cathode temperature, respectively, k_B the Boltzmann constant, and σ is the so-called thermallization cross-section. This latter quantity determines the *thermallization mean-free path* of the deposition particles in the plasma, i.e. the typical distance covered by a sputtered particle in order to reduce its original kinetic energy to the thermal energy of the background gas particles due to collisions [6]. The value of σ defines the proportion of non-thermal particles that reach the growth surface and is related to the amount of thermal particles that remain in the gas phase and that eventually are deposited due to diffusion.

The deposition of the species on the growth surface has been simulated through a Monte Carlo model. Although this approach represents a rough approximation to atomic scale models, it allows studying the film growth over relatively large lengths and time scales, which could hardly be simulated otherwise. In this way, we show that the proportion of thermal and non-thermal deposition particles are relevant to determine the thin film morphology, as they follow different velocity distribution functions in the gas phase and generate different shadowing effects when they are deposited. We also present results about the influence of the film temperature on the development of the film morphology. Trends predicted by the model match well with experimental results appearing in the literature, relating experimentally controllable quantities to the film nanostructure.

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