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High density models of magnetron plasma. From short-pulse HIPIMS to spokes

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Enhanced ionization of magnetron by applying high power pulses (HiPIMS) has demonstrated its interest in terms of ionization degree (up to 10% of the gas), target sputtering, control of precursors flux, and improvement of the deposited thin film properties. Very impressive results have been obtained combining the film and plasma diagnostics of HiPIMS. However, the modeling of magnetized plasmas of very high density (> 10 m^{-3}) such as HiPIMS is still very challenging.
Recently, we developed at LPGP (Orsay) an improved approach PIC-MCC (Particle-in-Cell Monte Carlo Collision) approach, called OHiPIC (Orsay High Density Particle-In-Cell). It models the high density of the plasma magnetron, including the temporal evolution of HiPIMS (), two dimension (2D), assuming the azimuthal symmetry. OHiPIC has been first used to model the direct current (dc) test-case and further the HiPIMS, which was deeply studies, with respect with the cathode voltage and current assuming the pre-ionization and short-pulses.
Moreover, to describe the third (azimuthal) dimension, a novel algorithm, called pseudo-3D, has been implemented to describe self-organizing structures called “spokes” rotating around the magnetron axis and appearing with fast time acquisition camera (). The pseudo-3D algorithm could successfully describe the spokes extending thus OHiPIC capabilities. The numerical results clearly demonstrates the interdependency between the spokes and the cathode (secondary emission) current as well as between several drift instabilities.

Keywords
magnetron
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