Kinetic Approach to Neutral Particle Transport in High Power Impulse Magnetron Sputtering

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In the High Power Impulse Magnetron Sputtering (HiPIMS) regime the spatial and temporal evolution of the plasma as well as the neutral gas species is of great importance. The plasma is highly ionized and the neutral gas no longer behaves as a constant background for the plasma. Due to the low operating pressures, modeling of the involved gas dynamic and plasma processes is however challenging. Only a kinetic description of the plasma and the neutral gas is appropriate. We approach this scenario by simulating the transport of sputtered aluminum particles through a neutral gas atmosphere of argon. We use a modified version of the 3D Direct Simulation Monte Carlo (DSMC) code dsmcFoam [1], which is part of the open source CFD toolbox OpenFOAM [2]. By imposing a time-varying flux of sputtered particles, the sputtering wind in a generic geometry of a parallel plate reactor is mimicked. First we investigate the particle densities and fluxes in a low plasma density sputtering regime representative of a capacitive sputtering discharge. We then investigate the influence of different pulse parameters e.g., the pulse duration, the repetition rate, or the sputtered particle flux of a HiPIMS pulse on the individual particle densities and fluxes. As expected, only above a certain threshold of the sputtered particle flux we observe the predominance of the sputtering wind. We further find its influence to be largest in a well-defined region below the race-track. In this region strong rarefaction and subsequent recovery of the argon gas is observed, depending on the discharge parameters used. Finally, their significance is discussed with respect to the inherent time scales and time delays.

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