Studying Target Erosion in Planar Sputtering Magnetrons Using a Discrete Model for Energetic Electrons

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Abstract

Within planar sputtering magnetrons magnetically enhanced direct current gas discharges are employed to form thin film depositions on various types of substrates. Deposition material is eroded from a target through continuous bombardment by background gas ions. The static magnetic field established by permanent magnets arranged below the target provides confinement of the energetic electrons required for ionization to the vicinity of the target. This way, ionization and erosion rates are increased allowing the process being operated at low pressure which in turn increases deposition quality. As a drawback, however, varying magnetic field intensity in general leads to non-uniform erosion and low overall utilization of the target. This is seen by the characteristic erosion profiles and, furthermore, for rectangular planar targets by the so-called cross corner effect. Thus, making target erosion more uniform together with increasing its utilization becomes an objectives for process optimization.

In view of this a numerical model for relative prediction of target erosion rate by means of resolving the spatial distribution of ionization collisions and ion bombardment flux is presented. The model is formulated in spirit of discrete models and portrays trajectories of energetic electrons in the discharge using a Monte Carlo approach. Trajectories are integrated using electric and magnetic fields a priori computed using standard finite element schemes. Collisions with the background gas together with electron scattering are accounted for in discrete fashion at random time-instants based on total and differential cross-sections, respectively. An iterative scheme is adopted in order to obtain convergence of the normalized ion bombardment and secondary electron emission flux, respectively. The entire model is implemented within COMSOL Multiphysics® allowing for a fully integrated workflow in a single computational environment.

Verification of the model is shown by means of industry-scale examples taken from literature for both axisymmetric and rectangular magnetrons. Relative erosion profiles as well as the appearance of the cross-corner effect in case of a rectangular magnetron are accurately resolved. For future work the model will be employed to study design modifications on targets in order to fulfill the optimization objectives.