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Space-resolved evolution of sputtered species number densities in HiPIMS and DCMS discharge

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Magnetron sputtering is a physical vapor deposition technique used in the whole spectrum of industrial applications; thus, it is crucial to characterize the process behavior thoroughly. The analysis of non-reactive Direct Current Magnetron Sputtering (DCMS) and High Power Impulse Magnetron Sputtering (HiPIMS) in the presented study is performed using a Quartz Crystal Monitor (QCM) and Optical Emission Spectroscopy (OES). The QCM system can be equipped with biasable grids or a gridless sensor with magnetic electron filter, and it is used to measure separately the flux of atoms and of the ionized particles impinging the substrate. A spectroscopic method utilizing self-absorption of the plasma and Effective Branching Fractions (EBF) is employed to evaluate the absolute ground state titanium atom and ion number densities. A systematical study on three discharge parameters – working pressure, duty cycle and distance from the titanium target - is presented. The study is realized at three different distances from the target – in the magnetized plasma region, between the target and the substrate and at the substrate level. The investigation is performed at a constant mean power and pulse duration. Both the titanium atom and titanium ion number densities are correlated with the overall atom and ion deposition fluxes at the substrate level, respectively. For instance, at the substrate level, the maximal sputtered species ionization fraction of 70% is obtained for 1.6% duty cycle. Increasing a working pressure and a duty cycle, ionization fraction of the sputtered species at the substrate level decreases, for example in HiPIMS, the ionization fraction of the sputtered species of 30% is attained for 4% duty cycle and maximal studied working pressure. However, in the magnetized plasma region, the ionization fraction of the sputtered species is almost independent on the working pressure and is always higher than 70% through the studied duty cycle range of 1.6% - 4%. The ionization fraction of the sputtered species decreases with the increasing pressure, the duty cycle and the distance from the target.

Keywords
HiPIMS
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