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Optimizing the deposition rate and ionized flux fraction by tuning the pulse length in high power impulse magnetron sputtering

Martin Rudolph[1], Nils Brenning[2], Michael A. Raadu[2], Hamid Hajihoseini[3], Jón Tómas Guðmundsson[3], André Anders[4], Daniel Lundin[5]

[1]Leibniz Institute of Surface Engineering, Leipzig, Germany [2]KTH Royal Institute of Technology, Stockholm, Sweden [3]Science Institute, University of Iceland, Reykjavik, Iceland [4]Institute of Surface Engineering (IOM), Leipzig, Germany [5] Linköping University, Linköping, Sweden

martin.rudolph@iom-leipzig.de

High power impulse magnetron sputtering (HiPIMS) is an ionized physical vapor deposition technique. While HiPIMS provides a high flux of metal ions to the substrate, the disadvantage is a reduced deposition rate compared to direct current magnetron sputtering (dcMS) at equal average power. This is mainly due to the high target back-attraction probability of the metal ions with typical values in the range 70 - 90 % during the pulse. In this work, we investigate how to reduce this effect by quantifying the contribution of ion fluxes after each HiPIMS pulse, a time also known as afterglow. Without a negative potential on the target at this stage of the HiPIMS process, the back-attracting electric field disappears allowing remaining ions to escape the ionization region. In order to analyze the fate of the film-forming ions, we extend the time-dependent Ionization Region Model (IRM) by adding consideration of an afterglow. This approach allows us to distinguish between fluxes from the ionization region during the pulse and during the afterglow. We show that by shortening the pulse length of a titanium HiPIMS discharge, the contribution to the outward flux of film-forming species from the afterglow increases significantly. The IRM predicts a gain in deposition rate of 46 % and 47 % for two discharges with different peak currents, when using 40 µs compared to 100 µs-long pulses at a constant average power. This is without compromising the ionized flux fraction that remains constant for the range of pulse lengths investigated here.

Keywords
HiPIMS
pulse length
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