LBNL-62579 Abs.

Invited Presentation
at the

Fourth Sheffield HIPIMS Days.
Advances in Industrial PVD Technologies & High Power Impulse Magnetron Sputtering.
10th and 11th July 2007
Sheffield Hallam University, Sheffield, England.

HIPIMS with different target materials: Unexpected diversity requires rethinking of the process physics

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The goal of high power impulse magnetron sputtering (HIPIMS) is to provide a flux of sputtered material that is ionized, as oppose to a flux of neutrals, thereby enabling physical vapor deposition with an effective use of bias. HIPIMS may replace some of cathodic arc processing leading to improved coatings quality. For years it has been understood that self-sputtering is a key element in HIPIMS. Some materials including Cu and Ag have very high self-sputter yields, and therefore they should most readily reach the self-sputter sustaining condition $\alpha\beta\gamma > 1$, where α is the ionization probability, β is the ion return probability, and γ is the self-sputter yield. New experiments with different target materials and long pulse lengths show that certain materials not belonging to this group, like Ti and Nb, transition into the high current stage much faster than Cu, for example. This suggests to have a closer look at the other processes, namely those affecting α and β. In particular, the secondary electron yield is determined by "potential emission" by the primary impacting ion. Secondary electrons are trapped near the target surface due to the parallel component of the magnetic field over the race track. Their motion leads to a strong $\mathbf{E}\times\mathbf{B}$ drift current, which in turn generates a significant magnetic field when the discharge reaches a high current level. Trapped secondary electrons "dilute" the positive space charge, indicating that the sheath cannot be described by the usual Child-Langmuir law. These electrons cause collisions, leading to ionization and enabling them to leave the sheath. A better understanding of the sheath structure in the presence of magnetic fields and collisions is important to explain the unexpected diversity of current-voltage characteristics with different targets.

Contributions by A. Ehasarian and J. Andersson are gratefully acknowledged. This work was supported by the Assistant Secretary for Energy Efficiency and Renewable Energy, Office of Building Technology, of the U.S. Department of Energy under Contract No. DE-AC02-05CH11231.