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Numerical Study of Particle Deposition in Magnetron Sputtering with Electromagnetic Coil

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Extended Abstract

Magnetron sputtering is a widely used physical vapour deposition (PVD) technique for producing thin films with precise control. It is employed in a variety of industries, ranging from semiconductor fabrication to optical coatings, due to its scalability, versatility, and ability to deposit materials with excellent adhesion and high-density films [1]–[3]. In this method, ions from a plasma are accelerated towards a target material, causing target atoms to be sputtered and then deposited onto a substrate, forming a thin film. Magnetron sputtering is particularly notable for the use of magnetic fields to confine plasma near the target surface. This confinement enhances deposition rates by reducing electron loss and increasing ionization efficiency. However, challenges remain, particularly in improving target utilization and film uniformity. To address these issues, various strategies have been developed to improve target utilization and film uniformity [4]–[6]. Current carrying coils can change magnetic field distribution and control plasma confinement precisely, offering the potential to improve target utilization and deposition uniformity. However, there is a lack of research on cathodes constructed from electromagnetic coils, let alone its effect on erosion profile or particle deposition.

In this paper, a novel magnetron assembly based on a combination of permanent magnet and adjustable electromagnetic coil is proposed for improved uniformity of the sputtering and deposition. Numerical simulations have played a key role in advancing the understanding of magnetron sputtering processes, offering valuable insights into plasma dynamics, target erosion, and film deposition behaviour. This paper employed the finite element method (FEM) to focus on magnetic field distributions. A fluid model was used to simulate overall plasma behaviour, and binary collision Monte Carlo (MC) method was employed to simulate the transport and collisions of sputtered atoms as they travel from the target to the substrate. The effect of coil current on the magnetic field, plasma distribution, target erosion profile, and deposition density was explored. The purpose of this article is to provide a strategy for optimizing target utilization and improving deposition uniformity by studying the mass transfer process in magnetron sputtering.

The study uncovers the impact of the magnetic field on target erosion and particle deposition, demonstrating that the plasma discharge center occurs where the magnetic field lines run parallel to the target surface. This point serves as the primary erosion zone for the target material, producing an annular sputtering pattern that correlates with the deposition density of particles, leading to non-uniform film thickness. The paper further explores the effect of coil current on both target erosion and film thickness distribution. Results show that increasing the coil current shifts the erosion center toward the edge of the target, expanding the sputtering range and improving target utilization. As the current increases, the area of high deposition density expands, leading to better film uniformity. Additionally, the increased magnetic field strength intensifies the glow discharge, boosting particle deposition rates. The approach offers a way to optimize sputtering processes for more uniform thin-film coatings.

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