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Investigating Transient Effects To Improve The Footprint In Magnetron Sputtering

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Precision in nanoscale material deposition is critical for advanced optical and semiconductor applications, where even slight thickness variations can degrade performance. Magnetron sputtering, a widely used plasma-based thin-film deposition technique, plays a central role in fabricating multilayer coatings for such applications. This work investigates position dependent thickness variations in Mo/Si multilayers critical components in extreme ultraviolet lithography (EUVL) to improve deposition uniformity and interface quality. In magnetron sputtering, deposition can occur under static or dynamic conditions. In the static mode, the substrate remains fixed beneath the target, allowing detailed analysis of localized deposition characteristics. In contrast, the dynamic mode involves substrate motion, which averages out spatial variations and enhances overall uniformity. Initial static deposition experiments on individual Mo and Si layers revealed a consistent increase in thickness with repeated runs. This was primarily attributed to oxidation during idle times and variability from repeated target ignition common issues in non continuous sputtering. To mitigate these effects, dynamic deposition with continuous target ignition and substrate rotation was introduced. The study was extended to full Mo/Si multilayer stacks under both static and dynamic conditions. Results showed significant interdiffusion between Mo and Si, leading to layer shrinkage with increasing periods, especially under static conditions. To address this, thin barrier layers were introduced at interfaces, effectively suppressing intermixing and enhancing structural stability and predictability in f ilm growth. Dynamic multilayer deposition with barrier layers demonstrated superior performance by minimizing oxidation, reducing ignition induced variability, and limiting interdiffusion, leading to significantly improved footprint uniformity. However, some degree of interdiffusion remained, indicating that barrier layers provide partial but not complete suppression. Despite the advantages of dynamic deposition in achieving uniform coatings, static sputtering remains crucial for studying intrinsic deposition characteristics. Because it directly reflects the target's emission profile, it allows for precise evaluation of thickness and local footprint errors. Comparative studies using Mo/Si bilayers with 10 and 20 periods further confirmed that oxidation and ignition effects lead to apparent thickness increases, while interfacial interdiffusion contributes to reductions. By decoupling these effects, the study provides a clearer understanding of how each mechanism impacts overall film quality. This work presents a comprehensive approach from identifying deposition errors to implementing material and process level improvements that enhances thin film growth dynamics and interface integrity. These f indings are particularly relevant to high precision multilayer applications such as EUV lithography mirrors, multilayer Bragg reflectors, and X-ray optics, where tight control of layer thickness and interface sharpness is critical. The strategies demonstrated here offer valuable guidance for optimizing magnetron sputtering processes to achieve reliable, scalable, and high-performance multilayer thin-film systems.

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