Influence of target heating on the growth of Nb coatings during hot magnetron sputtering

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In this work, we highlight the important features of a hot magnetron sputtering (HMS) discharge with a Nb target and study their impact on the growth of Nb coatings. Particularly, it is shown that once the target temperature reaches 1900 K, a thermionic emission from the target is stimulated. This phenomenon contributes to increased ionization of sputtered metal flux and is always accompanied by strong thermal radiation from the hot target. Ultimately, it is observed that Nb coatings obtained in the HMS configuration become less porous but have higher intrinsic stress as the target temperature increases up to 2100 K. On the other hand, we observe that if the substrate is exposed to the heated target for a longer time interval, thermal stress reduces and coating density increases. This, in turn, might be beneficial in the need of relatively thick (0.6-1 μm) but dense Nb coatings.

1 Introduction

Within the last decade, hot magnetron sputtering (HMS) has become more attractive to the coating community because of the deposition rate enhancement by an order of magnitude [1] as compared to classical cold magnetron sputtering (CMS). In HMS, the target is thermally insulated from the cathode to prevent magnets damage. The increase in the deposition rate can usually be understood by sublimation of the target. Although, it is negligible for refractory materials such as Nb (i.e. the materials with a melting point above 2500 K) even at high temperatures. Nevertheless, the use of HMS allows researchers to safely apply higher power loads to the magnetron source and thus to reach higher deposition rates.

During HMS with Nb, the target temperature can rise to 1900 K and promote a thermionic emission [2]. This, in turn, affects plasma properties, in particular the production of metal ions, and may change the coating characteristics. The aim of this work is to correlate the discharge parameters, the plasma properties, and the growth of Nb films by HMS.

2 Results

Our experimental data show that when the power density of 20 W/cm^2 is applied to the HMS source, the target temperature rises to 1900 K and the discharge current starts to increase dramatically due to amplification of a thermionic emission. Consequently, the release of additional number of electrons into the discharge contributes to higher ionization of the plasma bulk species, including the sputtered metal atoms. This effect was verified by laser-induced fluorescence, where both ground state Nb neutrals and ions were monitored.

In order to investigate the influence of the observed plasma features onto the film growth, Nb coatings were deposited at different target temperatures and during different deposition times, and then characterized by scanning electron microscopy, X-ray diffractometry (XRD) and ellipsometry. Coatings deposited with a conventional CMS configuration demonstrate a columnar structure with a porosity of 40% and a negligible stress. In contrast, the shift of the XRD peaks illustrates that an internal thermal stress is always noticed for coatings deposited by HMS. This stress can lead to delamination of the coating. It is also observed that the film porosity in this case is only 26%, i.e., lower as compared to the CMS coatings. In addition, it is shown that the longer the substrate is exposed to the heat radiation emanating from the hot target during HMS deposition, the less intrinsic stress is observed and the denser the coating becomes.

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References

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