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Controlling the Stress in Titanium Nitride Thin Films by Reducing the Amount of Doubly-Ionized Metal Ion in HiPIMS discharges

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Controlling the properties, such as hardness and stress, is a crucial task for successful applications of transition metal nitride thin films on various substrates. High-flux low-energy ion bombardment in reactive discharges is commonly used as an approach for tailoring the film properties. In high-power impulse magnetron sputtering (HiPIMS), wherein the high plasma density results in a high degree of ionization of the sputtered material, the ion bombardment by the deposition species themselves plays an important role in the film growth. The energy of the bombarding ions, to which hardness (H) and stress (σ) values depend strongly, are determined mainly by a substrate potential (Ub), where singly ionized ions accelerate up to a maximum energy of q·Ub, where q is the elementary charge. Doubly ionized ions can accelerate to twice the energy (2q·Ub) and this need to be taken into account when using HiPIMS and sputtering situations where the first ionization potential of the sputtering gas (i.e. Ar) is higher compared to the second ionization potential of the target material (e.g. Ti, Hf, V, Zr and Nb). In the present work, TiN was deposited by reactive HiPIMS in Ar/N2 environment without substrate heating or bias, and the effects of Ti2+ ions on the resulting films properties was investigated.

In order to control the contribution of Ti2+ ions incident at the substrate plane, the power per pulse (Ppulse) was varied from 5 to 25 kW, while maintaining an average power of 1.5 kW. In situ energy-resolved mass spectrometry analyses of the ion flux reveal that by increasing the Ppulse, the doubly-to-singly charged metal ions ratio (Ti2+/Ti+) increases from 0.2 to 0.5. This effect was then correlated to the crystal orientation, film stress (σ), microstructure and hardness (H). It was found that increasing Ppulse strongly affect the microstructural development of the deposited films, resulting in a clear improvement of the H values, but with a steep price of a high-level of compressive stress. A good compromise of σ = -0.9 GPa and H = 22.7 GPa was achieved when using Ppulse = 8.3 kW corresponding to Ti2+ /Ti+ value of 0.3.

Keywords

Reactive HiPIMS

TiN

stress