

Time- and Energy-resolved Mass Spectrometry Study of a Reactive High-Power Impulse Magnetron Sputtering Discharge.

M. Palmucci^{(*)1}, R. Snyders^{1,2}, S. Konstantinidis¹

¹ *Chimie des Interactions Plasma Surface, CIRMAP, Université de Mons, Place du Parc 23, 7000 Mons, Belgium*

² *Materia Nova Research Center, Av. N. Copernic, 1, 7000 Mons, Belgium.*

^(*)maria.palmucci@umons.ac.be

The aim of this work is to contribute to the understanding of the physico-chemistry of High Power Impulse Magnetron Sputtering discharges in reactive mode. Ti/Ar-O₂ HiPIMS discharges were studied by energy- and time-resolved mass spectrometry as a function of the oxygen content in the gas mixture. The results show that the peak current (I_p) is a key parameter to determine the transition between the metallic and the poisoned mode. The implantation of oxidized species in the target, responsible of the poisoning, is increased as a function of I_p .

High Power Impulse Magnetron Sputtering (HiPIMS) is a PVD technique allowing a high ionization rate of the sputtered particles compared to conventional DC Magnetron Sputtering processes [1]. The high ionization rate achieved allows tailoring the film properties such as density, microstructure, etc. due to the energetic bombardment during the film growth [2-4]. In this work, the plasma chemical composition and the time evolution of the ion energy distributions were studied during reactive HiPIMS discharges for titanium oxide deposition.

The discharges were operated with a titanium target (100 mm \varnothing) in argon-oxygen mixtures using a 5 mTorr working pressure. The orifice of the mass spectrometer is located 80 mm in front of the target, *i.e.* at the substrate position. The oxygen flow rate ratio was varied between 0 and 40 %. For these conditions, the discharge evolved from the metallic to the poisoned regime. Three target voltages (V_t) were also considered namely 700, 800 and 900 V; the average power was kept constant by modifying the pulse repetition frequency. For $V_t = 700$ V, two pulse widths (5 and 20 μ s) were used in order to vary the amplitude of the target peak current (I_p).

As I_p increases by increasing V_t , the amount of oxygen needed to reach the transition is reduced. Mass spectrometry scans performed on Ar⁺, Ti⁺, O⁺, O₂⁺ and TiO⁺ ion populations reveal an increase of the oxygen-based species (O⁺, O₂⁺ and TiO⁺) before the transition while signals related to Ti⁺ and Ti²⁺ slowly decrease. As V_t increases, the signal related to the TiO⁺ molecules, which are sputtered from the oxidized target, completely disappears. This might be attributed to a combination of i) the reduction of the erosion rate of the oxidized target surface when V_t is increased and ii) to the increased thickness of the oxide layer covering the target surface. Indeed, SRIM [4] simulations show that O⁺ ions can penetrate deeper in the Ti target as V_t increases. As O⁺ ions are thought to be produced to a large extent in the HiPIMS plasma, this would lead to a more efficient oxidation mechanism of the target. Moreover, the few TiO⁺ molecules sputtered might be dissociated inside the dense HiPIMS plasma as V_t is increased. These considerations are supported by time-resolved mass spectrometry measurements.

References

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