Deposition of Thick Tantalum Coatings by Modulated Pulse Power Sputtering

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Abstract: High power pulse magnetron Sputtering (HPPMS) is a very important advancement in sputtering technology because it produces a high degree of ionization of the sputtered material by applying a very high power pulse of electrical energy to the sputtering target for a short period of time. A variation of the HPPMS process is modulated pulse power (MPP) sputtering, and it applies a multi-step high power pulse to the sputtering target for times longer than the single step HPPMS process. MPP also produces a high degree of ionization of the sputtered material, but it can do so without a reduction in the sputtering rate that is observed with the conventional HPPMS process. MPP can also lead to deposition rates higher than the DC sputtering rate for an equivalent amount of applied power for a variety of materials.

A highly ionized flux of sputtered material arriving at the substrate changes the way a sputtered film can be deposited compared to conventional sputtering. With a high ion to neutral ratio, lower bias voltages can be used, which will reduce the residual stress in the coating allowing fully dense thick films to be deposited. The materials scientist now has a new tool for depositing coatings with excellent properties.

In this presentation, we will report on the deposition of tantalum (Ta) coatings with thicknesses up to 100 μm without coating delamination. Substrates were pieces of AISI 304 stainless steel and A257 hardened steel,. The deposition took place within a dual cathode closed field unbalanced magnetron sputtering system, and the target to substrate distance was 100 mm. Deposition rates were as high as 14.3 μm/hr for an average target 4.5 kW delivered from a Zpulser SOLO^{TM} pulsed MPP power supply.

An electrostatic plasma mass spectrometer was used to determine the time averaged ion mass distributions (IMDs) and ion energy distributions (IEDs) during the deposition of the Ta coatings. The ionization of the sputtered Ta material exceeded that of the argon process gas. The average energy is about 3 eV for the Ar^+, Ta^+, and Ta^{2+} ions, and there was a small high energy tail for all species detected. Ta^+ ions were the dominant species present in all cases under the conditions that the Ta films were deposited.

Both the deposition pressure and the substrate bias voltage strongly affected the structure and properties of the coatings. When the substrate bias potential was floating and the working Ar gas pressure was between 0.27 and 0.67 Pa , the crystalline structure of the Ta coating was the α-Ta phase, whereas for pressures between than 0.67 and 1.33 Pa the β-Ta phase was present. The hardness of the α-Ta varied from about 9 GPa 9 to 11 GPa as the pressure was increased from 0.27 to 0.54 GPa, whereas for the β-Ta, which was considerably harder than the α-Ta, the hardness decreased from about 20 to 17 GPa as the pressure increased from 0.67 to 1.33 GPa.

For Ta coatings deposited at a pressure of 0.67 Pa, the Ta crystalline structure changed from an all β phase to a mixture of the β and α phases and finally to an all α phase as the bias voltage was changed from 0 to -70 V.

Additional information about the microstructure and hardness of the coatings will be given during the talk.