Introduction

- The growth of ultra-thin lattice-matched Cr$_{0.7}$Mo$_{0.3}$ films on an MgO substrate, in a dc magnetron discharge, was investigated by in-situ resistivity measurements.
- We compare the resistivity of the films to a combination of the Fuchs-Sondheimer and the Maydas-Shatzkes model, assuming a thickness dependence of the grain size.
- Ultra-thin metallic conducting layers are used in nanoscale electronics as interconnects and diffusion barriers (Shinshhu et al., 2005).
- The resistance of the substrate determines the operating frequency and/or sensitivity of the devices.
- As the thickness of the conductor approaches the mean free path of the conduction electrons, specular reflection at the surface becomes dominant, limiting the conductivity.

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In-situ measurements make it practical to vary growth parameters and optimize processes based on the resulting resistivity curves. Furthermore, the study of transient behavior of films after growth is possible (Barnat et al., 2002).

Experimental procedure

- Films of Cr$_{0.7}$Mo$_{0.3}$ alloy were grown on an MgO (100) substrate, at temperatures of 24°C, 200°C, and 400°C, in a direct current (dc) magnetron sputtering discharge.
- Contact pads of thickness greater than 200 nm were grown from Cr$_{0.7}$Mo$_{0.3}$, leaving a square (5x5) mm uncoated MgO in the middle of the sample.
- The substrate was electrically insulated from the chamber.

Results and discussion

- The voltage, over the film, is measured directly and the current, passing through the film, indirectly, by monitoring the voltage over a 50 Ω resistor, in series with the film.
- The signal was transmitted with a Capon filtered output, except the last 10 cm, that were made from Macor insulated tungsten wire, which can withstand the 780°C outgassing temperature.
- The substrate holder is made from Macor to electrically insulate the four probe tips.
- The probes and connectors are shielded from the flux of sputtered particles with a thin made of Macor, confining the growth to the rectangular exposed area of the substrate.

- The alloy composition was controlled by regulating the current to the magnetron target.
- The composition was found with X-ray’s from the lattice constant of the O/Mg peak at 62.9° in the 2θ X-ray diffraction (XRD) scan of the films.
- Growth rate was found with low angle X-ray reflection measurements.

- The coalescence thickness varies from less than 0.3 nm at 24°C to 0.4 nm at 400°C. The coalescence thickness can be as low as the film thickness, for layers grown at 400°C.
- The combined F-S and Maydas-Shatzkes model.
- By assuming a thickness dependence of the grain size, a reasonable fit was obtained.
- The model suggests that the grain size of the films increases with growth temperature.
- The growth curves give a good indication of the lower limit that film resistivity would put on interconnect dimensions in devices made with similar processing.

Conclusions

- The resistivity of thin Cr$_{0.7}$Mo$_{0.3}$ films, deposited by magnetron sputtering on MgO, was examined in-situ at three different growth temperatures.
- A coalescence thickness of less than two monolayers suggests large layer growth of the films. The films grown at 24°C and 200°C coalesced at a lower thickness than that of the film grown at 400°C.
- The thickness dependence of the resistivity was compared to a combined Fuchs-Sondheimer and Maydas-Shatzkes model.

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References


