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Influence of Deposition Parameters on the Microstructure of Ion-Plated Films

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Abstract. Ion plating is essentially vapor deposition onto a substrate which is the cathode of a glow discharge. The most important characteristic of the technique is that the growing film is subjected to a flux of high energy particles (neutrals and ions). In this study we report information about the effect of ion plating parameters on grain diameter and crystallite size distribution. At a constant potential grain size remains constant with the increase of ion density. On the other hand, at a constant ion density the grain size decreases with the substrate potential increment. Ion bombardment also has an effect on the crystallite size distribution. The ion plated films show a higher degree of uniformity in grain size than vacuum evaporated films. In contrast with vacuum evaporated films, where the grain size is proportional to the thickness, no variation of grain size with film thickness has been observed for the ion-plated films. Electron diffraction patterns have shown that the orientation remains near random over the entire J and V range studied.

INTRODUCTION

Ion plating, generally defined as a plasma or ion activated deposition technique, is essentially vapor deposition onto a substrate which is the cathode of a glow discharge. The most important characteristic of the technique is that the growing film is subjected to a flux of high energy particles (neutrals and ions)(1). Despite the widespread attention paid to technological applications of ion plating since the introduction of the technique in 1963 (2), very little work has been done on the correlation between the deposition parameters and the microstructure of the resulting films (3-7).

In previous work (8) we have shown that nucleation and growth of thin films deposited by ion-plating technique are quite different from vacuum evaporated films; a continuous fine grained film is obtained at a lower thickness. The structural properties of the films have been explained on the basis of the special characteristics of the method: permanent bombardment of the growing film and a higher kinetic energy of the evaporant. Epitaxial growth at substrate room temperature was observed.

In this work we report the result of an analysis of grain diameter and crystallite size distribution, with changes in ion current density and ion energy.

EXPERIMENTAL

The samples have been prepared by vacuum evaporation and the ion-plating technique. The deposition system used in these experiments has been described in detail elsewhere (8). Ion bombardment of the growing film is supplied by the glow discharge plasma of argon. Control over ion energy is provided by the substrate potential, and ion current is controlled by substrate potential and pressure.

The gold films were deposited onto Corning 7059 glass substrates. For microstructural examination by transmission electron microscopy (TEM) and high energy electron diffraction (HEED), an aqueous HF solution (1:1) was used to separate the films from the glass. The average grain diameter and crystallite size distribution were determined directly from TEM micrographs.

For comparison, vacuum evaporated films of the same thicknesses were obtained. The thicknesses were measured by multiple beam interferometry.

RESULTS AND DISCUSSION

Figure 1 shows grain size versus current density (J) for films obtained at constant substrate potential (V). At the two observed potentials no decrease in grain size with increased current density is seen.

On the other hand, at a constant current density, a substantial grain size decrease with increased substrate potential has been observed. Figure 2 shows the

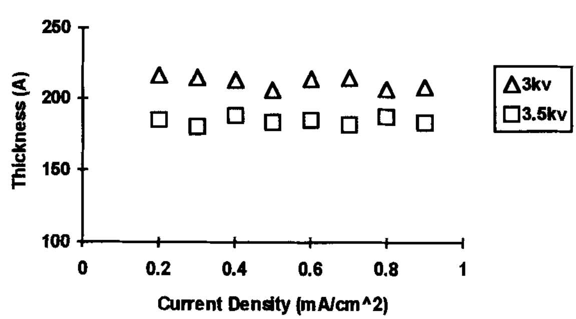

FIGURE 1. Grain size vs. current density

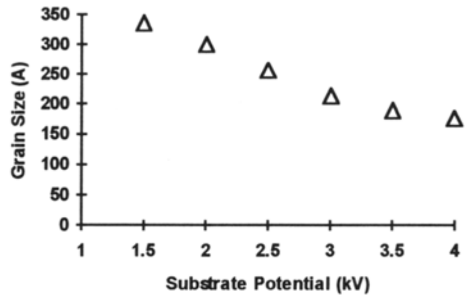

FIGURE 2. Grain size vs. substrate potential

grain size changes. These results show that argon bombardment (neutrals and ions) during deposition has a pronounced effect on the grain diameter. Bombardment causes point defects where continually new nuclei for growth can take place and prevents growth by recrystallization (9). The resulting structure is fine grained. Higher energy will stimulate these processes and therefore the grain size will become smaller.

Ion bombardment also has an effect on the crystallite size distribution. Histograms showing the number of crystallites in a given length range are shown in Fig. 3. The ion plated (i-p) films have a higher degree of uniformity in grain size than vacuum evaporated (v-e) films. This can be explained in the same terms. Continuous nucleation inhibits the coalescence behavior and the nuclei remain rounded during the entire time of growth without significant changes in diameter (8, 10, 11).

Plots of the grain size versus thickness for both ion-plating and vacuum evaporated films are shown in Fig.4. In contrast with v-e films, where the grain size is proportional to the thickness (12), no variation of grain size with film thickness has been observed on the i-p films. Unlike v-e films, where

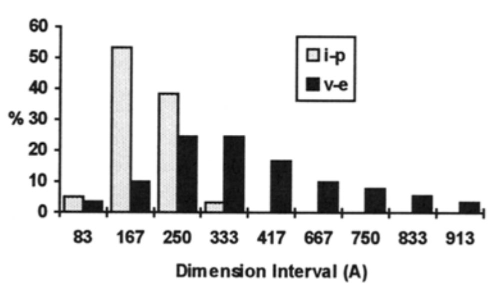

FIGURE 3. Variation of crystallite size distribution for typical ion-plated and vacuum evaporated films.

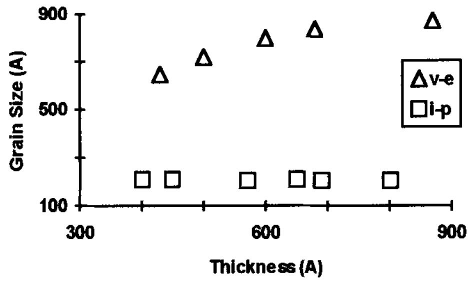

FIGURE 4. Grain size vs. thickness for v-e and i-p films

recrystallization grain growth takes place, in i-p films growth is caused by direct deposition onto previous nuclei producing an equiaxed columnar structure (13). Then, no dependence of grain size with film thickness is to be expected.

Electron diffraction patterns have shown that films remain polycrystalline with changes in current density and substrate potential.

CONCLUSIONS

The microstructure of thin gold films obtained by ion-plating technique has been analyzed and compared to that of an evaporated film. Variation of the substrate potential can be used for controlling film microstructure.

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