Egypt. J. Sol., Vol. 8, No. 2, (1986)

EFFECT OF TEMPERATURE ON THICKNESS-RESISTIVITY RELATIONSHIP OF AL-FILMS.

A. Ashour, N. El-Kadry and A.A. Ramadan

Faculty of Science, Minia Universitry,
El-Menia, Egypt.

Abstract:

The relationship between thickness and electrical resistivity of aluminium thin films was studied at different thermal conditions. The films were prepared by evaporation technique onto glass substrates kept at different temperatures. Measurements were performed at 300 K for the as deposited and annealed films. It was found that the resistivity decreases as the substrate or annealing temperature increases. The data for all thermal conditions were found to fit Mayadas-Shatzkes theory as the reflection coefficient R at the grain boundaries equals 0.05. This indicates that the scattering mechanism due to the grain boundary is week. The change of resistivity during thermal cycles was also studied. In the first cycle hysterisis was observed, while reversible paths were obtained in the subsequent cycles. This leads to the conclusion that the contribution of the lattice deffect to the total resistivity is quite significant.

Introduction:

It has been known that the transport properties of materials will change when the size of the sample decreases. The size effect dependence of the electrical, thermal and other transport properties of thin metal films have been studied for many years (1). The experimental results are analysed using Fuchs-Sondheimer theory (F-S)(2). Whereas the electric resistivity exhibited good agreement with F-S theory, other transport properties such as the temperature coefficient of resistivity (TCR) showed considerable departure from the predictions of the theory (3).

Mayadas and Shatzkes(4) have taken into account the scattering of conduction electrons by the grain boundary surfaces, and they have shown that it contribute significantly to the transport properties at a grain size smaller than the mean free path of the electrons. According to M-S formula for film resistivity, an expression for TCR has been obtained(5).

The excessive resistivity of thin films may be ascribed to structural defects and impurities. If the concentration of structural defects is large enough, their

curves was obtained using ρ_0 equal 4.06×10^{-8} and $3.13 \times 10^{-8} \Omega$m, and $l_0(1-P)$ equal 445 and 709 Å for annealing at 373 and 423 K, respectively. In both figures there is a decrease in the resistivity either by decreasing the measuring temperature or by annealing at high temperatures. In the first case, the phonon scattering is greatly reduced, which is the temperature dependent part. In the second one, the decrease in the total resistivity is due to the annihilation of structural defects. This contribution of the structural defects to the resistivity was also studied during thermal cycling. Figs. (3) and (4) give the heating and cooling curves for films with two different thicknesses, namely 750 and 2000 Å. In the first cycle during cooling the resistivity vs temperature plot does not coincide with that during heating. Hysterisis was observed in the first thermal cycle while reversible paths were obtained in the subsequent cycles. This is because, the majority of the forzen-in defects are annealed out during the first heating and there is no further removal of defects in the subsequent cooling and heating. The area of the hysterisis is larger in case of thiner films. These means that the contribution to the total resistivity due to lattice defects was quite significant and specially for thinner films.

Decrease in resistivity values of film of thickness 1000 Å as a function of annealing temperature is shown in Fig. (5). The same effect was observed when the substrate temperature was increased. This is represented in Fig. (6) which shows the resistivity of 1000 Å thick film as a function of substrate temperature. This can be considered as a "dynamic recrystallization" and the annihilation of defect due to annealing of the sample deposited at room temperature as "static recrystallization". This is in analogy with recrystallization during hot deformation and that during annealing after cold deformation of materials. These observations in agreement with those of Bandyopadhyay and Pal(9). Therefore as the substrate or annealing temperatures were raised, the resistivity was decreased due to annihilation of structural defects.

The continuous line in Fig. (7) were drawn according to Mayadas-Shatzkes theory(4). The reflection coefficient at the grain boundary, R, was found to be 0.05 for the best fitting. This indicates that also in case of annealed films the scattering mechanism due to the grain boundary is still weak as was shown before(8) for the as deposited films.

Another important and interested transport property is the temperature coefficient of resistivity α, (TCR). The theoretical variation of TCR is represented by the following approximate from of the F-S theory:

$$\alpha = \alpha_0 \left[1 + \frac{3\, l_0}{8\, t}(1-P)\right]^{-1}$$

where α_0 is the TCR of the bulk, l_0 is the mfp, t is the film thickness, and P is the specular parameter. Fig. (8) gives the variation of $1/\alpha$ with 1/t where α is

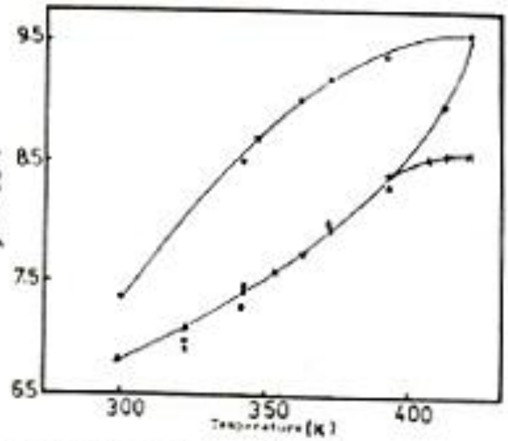

Fig.(3): The heating and cooling curves for Al-film of thickness 750 Å

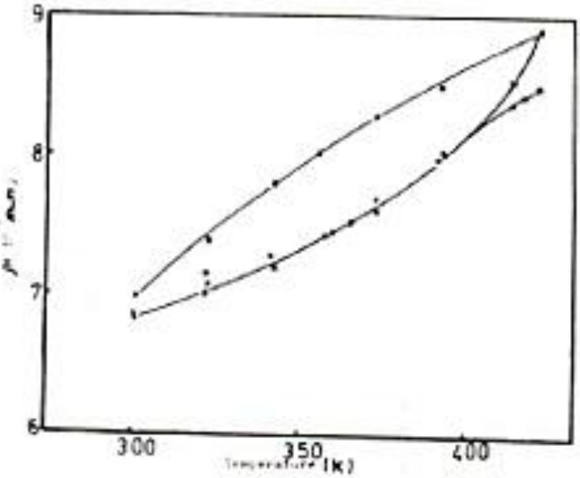

Fig.(4): The heating and cooling curves for Al-film of thickness 2000 Å

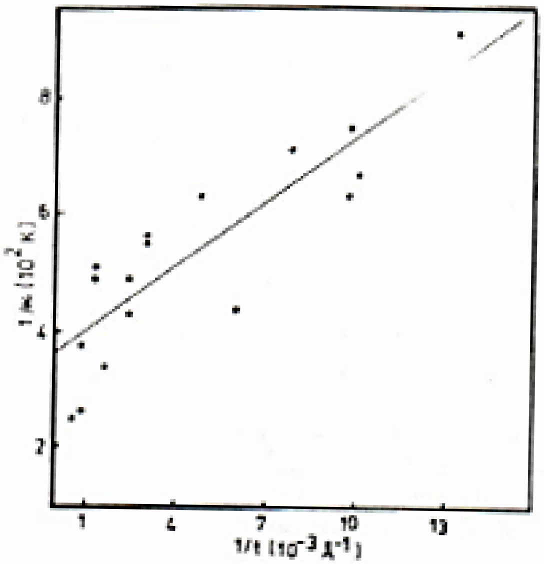

Fig.(8): Plot of $1/\alpha_f$ VS 1/t

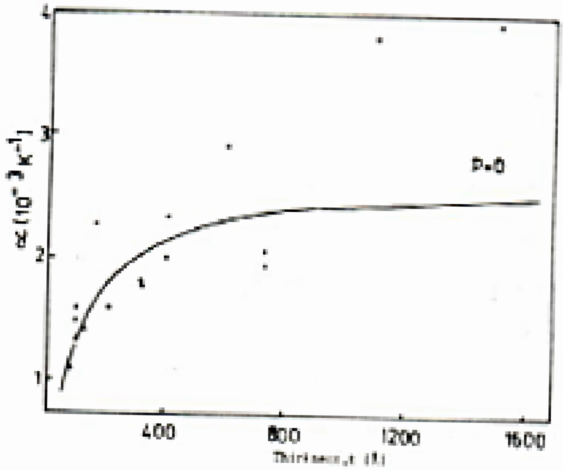

Fig.(9): Thickness dependence of TCR at room temperature (the solid curve is calculated theoretically from Fuchs theory)