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A simple measuring method for the characteristic curve of $S(\theta)\cos\theta/S(0)$

In the last two decades there has been a growing interest in the study of ion-etching of solid surfaces. Many experiments have been carried out to investigate the development of surface topographies [1–6]. In many cases, since we are interested in the thickness of the material removed by the ion-etching process and in particular when we want to predict the evolution of a surface contour by ion-erosion, it is worth plotting $S(\theta)\cos\theta/S(0)$. Barber *et al.* [7] have produced such a graph, taking data from Bach [8], who used the interference–microscopic method to determine the sputtering yield.

It appears that it is convenient to utilize the expression

$$d(\theta) = \frac{\Phi t}{n} S(\theta)\cos\theta \qquad (1)$$

which expresses the depth d sputtered from a plane surface [9, 10]. Φ is the number of ions per second striking the unit area of surface normal to their direction, t is the time of bombardment, n is the number of atoms per unit volume of target material, $S(\theta)$ is the sputtering yield (sputtering ratio) and θ is the angle between the incident beam and the surface normal. For given values of t and Φ, and n being constant we can write

$$d(\theta) \sim S(\theta)\cos\theta \qquad (2)$$

or

$$d(\theta)/d(0) \sim S(\theta)\cos\theta/S(0). \qquad (3)$$

Hence, if we want to know the plot $S(\theta)\cos\theta/S(0)$ it becomes necessary to define $d(\theta)/d(0)$. A simple glow discharge ion gun for etching [11, 12] and a glass surface as a target were used for this purpose.

This kind of ion source can be used with electrically insulating materials due to the presence of energetic neutrons and electrons in the ion beam. Glass was chosen as a subject for study since it is single-phase and non-crystalline, and because the assumption can be made that the amount of surface etched is entirely dependent on the inclination of the ion beam to the surface. After 1 h of ion-etching under the conditions described earlier [13] a funnel-shaped pit could be observed on the glass surface. A profile of the funnel was recorded on a profilograph. Etchings of identical duration were made at various angles of beam incidence, θ, and for each angle the maximum depth, d, of the funnel was measured. In this way we obtained [13] a plot for $d(\theta)$, which after normalization, $d(\theta)/d(0)$, is proportional to $S(\theta)\cos\theta/S(0)$ according to Equation 3. The method described above is only an approximation but is very simple and useful, especially in the case of insulating materials.

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Effect of d.c. and a.c. electric fields on the electrical resistance of thin samarium films

Recently, the effect of a.c. and d.c. electric fields on the electrical properties of thin metallic films has been reported by many authors [1–7]. Although the effect of deposition parameters on the electrical and structural properties has been the subject of many experimental investigations [8–11], the effect of d.c. and a.c. electric fields on the electrical properties has not been reported so far for any rare-earth metal films. In this letter we report the effect of a.c. and d.c. electric fields on the electrical resistance of samarium thin films in the thickness range 100 to 800 Å.

Samarium of purity 99.9% (Leico Industries, New York, USA) was evaporated at a pressure of 10^{-6} Torr onto a glass substrate held at room temperature (22° C) in the presence of a d.c. electric field of $150\,\mathrm{V\,cm^{-1}}$. Two separate films of the same dimensions were grown on a single glass substrate, with and without the d.c. electric field. The resistance measurements were carried out *in situ*. Other experimental details are given elsewhere [12].

Fig. 1 shows the thickness dependence of electrical resistivity for films grown with and without the d.c. field. It is seen that the resistivity increases with the application of the d.c. electric field during deposition of the film. This behaviour is quite contrary to the decrease in resistivity with the applied d.c. field reported for thin tin [7], gold [3] and manganese [6, 13] films. We have reported [14] that samarium films exhibit an increase in resistivity with an increase in the substrate temperature, which is attributed to the greater tendency in the case of samarium thin films to form an island structure. We expect a similar enhanced tendency for the formation of islands in the presence of a d.c. field which might result in the increase of resistivity. However, it is not clear why the electrical resistivity increases even at greater thicknesses with the application of a field.

Although it is well known that metallic films exhibit very interesting frequency response characteristics very little work has been reported so far. To the best of our knowledge we are reporting for the first time the high-frequency response characteristics of d.c. resistance of thin samarium films in the frequency range 100 Hz to 1 MHz, for different film thicknesses. The a.c. signal was applied to these films after the film resistance had reached a steady value.

Fig. 2 shows a plot of R_f as a function of $\log f$, where R_f is the d.c. resistance of the film at a particular frequency f. It is seen that the frequency

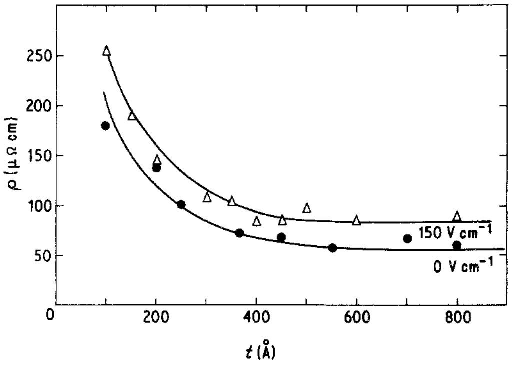

Figure 1 Thickness dependence of samarium film resistivity (ρ) with d.c. electric fields of 0 and $150\,\mathrm{V\,cm^{-1}}$.

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