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SHORT COMMUNICATION
Variations of Thin Metallic Zinc Film Resistances with Sputtering Rate

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Variations of resistance of evaporated[1] or sputtered[2] films during deposition have been studied for deposition times lower than five minutes and for resistances higher than 100 Ω sq^{-1}. As our main objective is to study the conduction mechanisms[3] in sputtered films over the thickness range from 200 to 1500 Å (i.e. in the 10 to 100 Ω sq^{-1} sheet resistance range), we report in this note our investigations about the electrical resistance $R(T)$ of zinc films for deposition time, T greater than two minutes and for four average deposition rates.

Preparation of films has been described in a previous paper;[4] they are deposited by d.c. diode sputtering of a zinc target (99.9% purity) in an atmosphere of U grade argon. As broken sputtering is equivalent to continuous deposition[4], sputtering was stopped every minute to measure the resistance R with a multimeter. The average sputtering rate was determined from the deposition time and the film thickness measured by an optical method;[5] this method is adequate for we have observed very slight anisotropic effects,[6] which seem more important for higher sputtering rates;[7] it varied with the intensity I_e of the glow discharge current, the voltage U_e remaining constant (curves 1, 2, 3 on Figure 2). Variations of the deposition rate as a function of the intensity I_e of glow discharge current for a voltage equal to 1500 V are shown in Figure 1. This curve is in good agreement with the results of Laville Saint-Martin[8] who established that sputtering rate ν is given by

$$\nu = I_e U_e \exp\{-A U_e^{-1} - B U_e\} \tag{1}$$

where A, B are constants.

For high voltage values in the range 1000 to 1750 V, eq. (1) may be expressed as

$$\nu \propto I_e \tag{2}$$

Variations of zinc film resistance $R(T)$ versus deposition time T are plotted in Figure 2. Attempts have been made[1,2] to fit these experimental variations to an empirical equation in the form

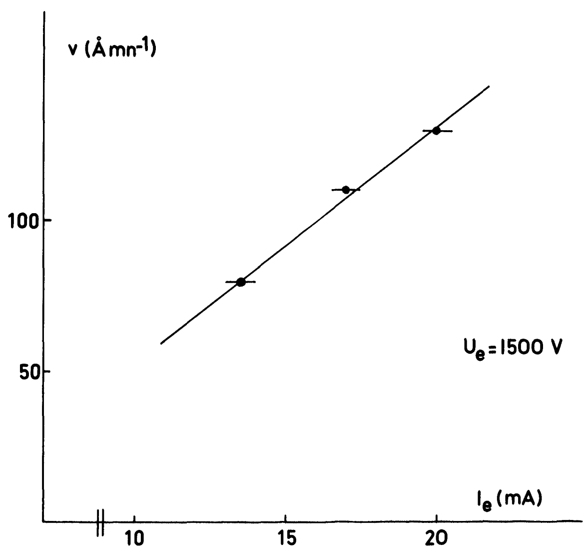

FIGURE 1 Variations of the average sputtering rate ν with the intensity I_e of the glow discharge.

$$R(T) = R_\infty \exp \frac{1}{K_1 + K_2 T} \tag{3}$$

where R_∞ is the limiting value of $R(T)$ when T is large and K_1 and K_2 are constants.

As we have established that films thicker than 5000 Å exhibit bulk properties,[4] their resistance $R_b \approx 2.5$ Ω sq^{-1} is assumed equal to R_∞. Substituting for R_∞ in Eq. 3, this yields

$$R(T) = R_b \exp \frac{1}{K_1 + K_2 T} \tag{4}$$

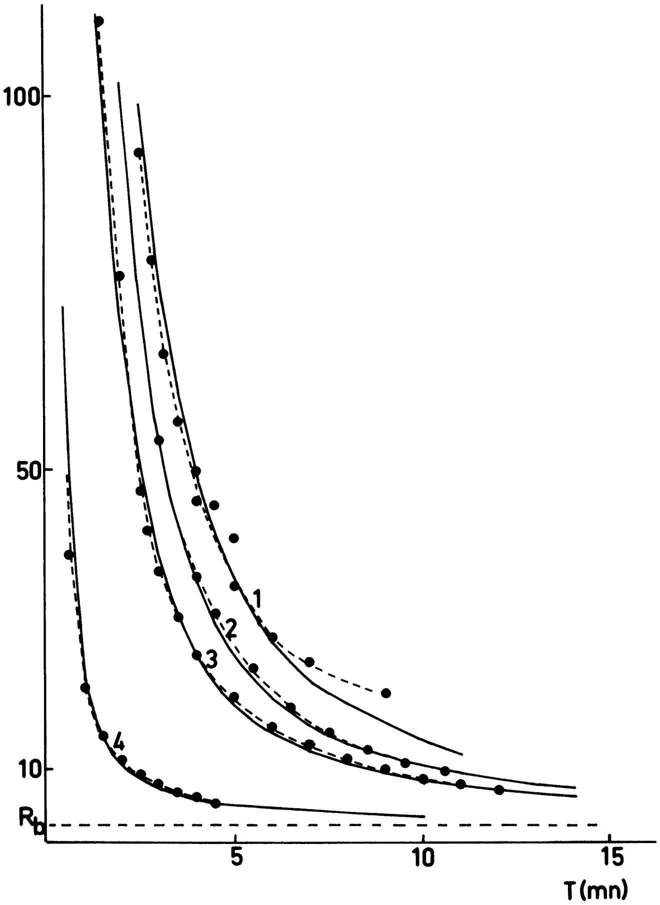

FIGURE 2 Experimental (dotted lines) and theoretical (full lines) variations of zinc film resistance R, with sputtering rate ν, equal to: (1) 80 Å mn^{-1}, (2) 110 Å mn^{-1}, (3) 130 Å mn^{-1}, (4) 550 Å mn^{-1}.

K_1 and K_2 are determined by plotting $1/Ln[R(T)/R_b]$ versus deposition time T (Figure 3). The slopes of the best fit straight lines determine the values of K_2, while K_1 is calculated from the intercept with the vertical axis.

From Figure 3 it can be seen that K_1 is independent of the deposition rate as indicated by Eq. 4. Thus,

$$K_1 \approx 1/Ln[Ro/R] \qquad (5)$$

where Ro is the substrate resistance.

However the value of Ro calculated from the experimental value of K_1 is low (about 6 kΩ). As quasi-linear growth occurs only above the first critical thickness[9] we assume that this value corresponds to a smaller thickness for which the granular structure consists of a large number of empty channels distributed throughout the film. It has been shown that the value of the resistance of such a film depends essentially on the geometrical arrangement of the sputtering chamber which remained unchanged in our experiments.

Calculations allow one to determine suitable values of K_2, leading to a good agreement between the experimental and theoretical curves (Figure 2) in the resistance range 10 to 100 Ω sq^{-1}. A discrepancy of less than 10% is observed except for the lower sputtering rate but experimental accuracy is low in this case (15%).

The observed slight departures from the theoretical resistance at low R values occur at low sputtering rates,[3] whereas considerable departures have previously been observed by Laville Saint-Martin[7] for higher sputtering rate.

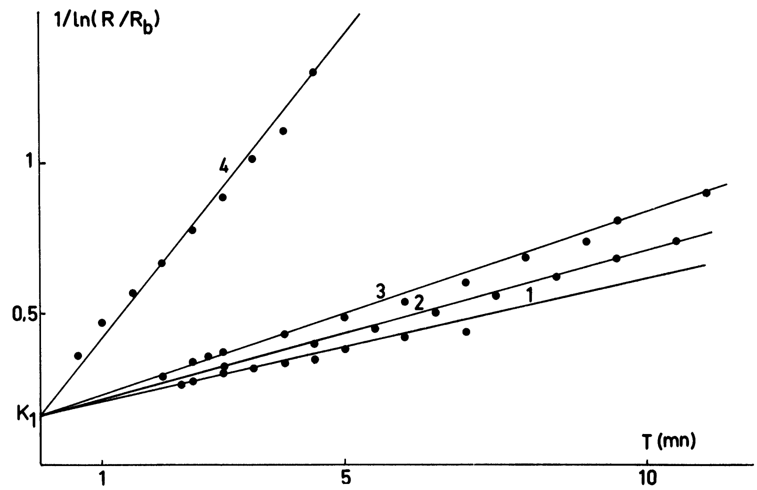

FIGURE 3 $1/Ln[R(T)/Rb]$ versus T (deposition time) with sputtering rate, ν, equal to (1) 80 Å mn^{-1}, (2) 110 Å mn^{-1}, (3) 130 Å mn^{-1}, (4) 550 Å mn^{-1}.

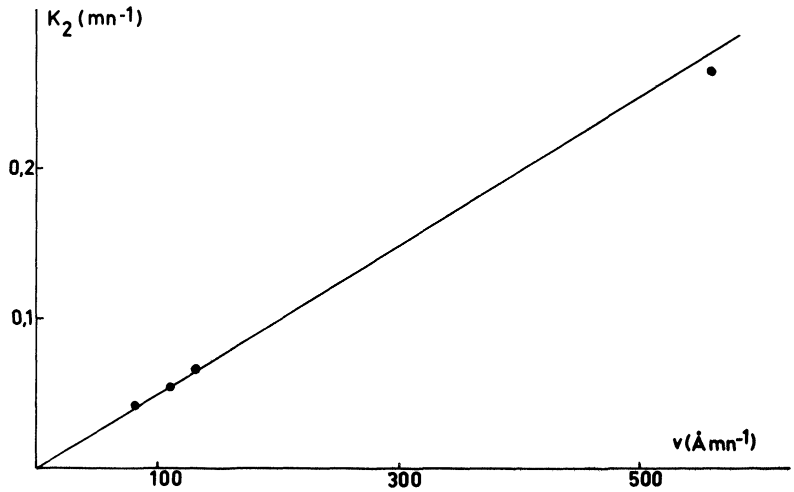

FIGURE 4 K_2 versus deposition rate, ν.

We observe (Figure 4) that the magnitude of constant K_2 differs markedly for different deposition rates. Constant K_2 has been defined as a velocity constant related to the sputtering rate ν and may be given approximately by

$$K_2 \approx \alpha\nu \quad \text{with} \quad \alpha = 5.10^{-4}\ \text{Å}^{-1}$$

It may be concluded that in these experimental conditions the measured resistance fits the theoretical formulae obtained with the deposition rate as a parameter in the range 80 Å mn^{-1} to 600 Å mn^{-1}; a simple way to predetermine thin film resistances is thus available.

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