ION PLATED THIN FILM THERMORESISTORS

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ABSTRACT

Nickel thin film thermoresistors offer a sensitive way of making accurate surface temperature measurements. When a meandering path is used to achieve large values for film resistance, the path need to be patterned by photolotographic technique and strong film adhesion must be assured.

In this work the presence of a thin underlayer adhesive film was avoided by the use of the ion-plating deposition technique which provides an excellent adhesion. The fabrication and electrical properties of ion-plated nickel thin film sensors with thicknesses above 1000 A are described. The adhesion of the films was examined by means of the scratch test. After a post-deposition annealing the films were stable and the TCR was reproducible.
For comparison, results for vacuum evaporated films of the same thickness are presented.

1. INTRODUCTION

For a thin metal film resistor of constant resistivity ρ, thickness t, width w and length l, the change ΔR in resistance due to a change in temperature ΔT is given by:

$$\Delta R/R = \alpha\, \Delta T \qquad (1)$$

where α is the temperature coefficient of resistivity (TCR).

It is preferable to achieve large values for ΔR and this implies a high value for R. Since $R = (\rho.l)/(w.t)$ the use of the photolitographic technique offers the possibility of making l large and w small. In order to pattern by photolitographic technique strong nickel adhesion is usually provided by a very thin adhesive nickel-chromiun film [3].

In this work the intermediate thin NiCr layer was avoided by the use of the ion-plating deposition technique. The preparation and electrical properties of ion-plated nickel thin film resistors are described. For comparison, results for vacuum evaporated films are presented.

2. EXPERIMENTAL

The films were deposited onto Alsimag 838 substrates patterned by reverse photolitography. A photoresist negative relief mask was applied before Ni deposition. The film contacted the substrate directly only in the areas left open by the mask.

Ni film was evaporated from resistively heated boat sources by using the ion-plating technique which essentially consists on the deposition of an evaporant onto a substrate which is the cathode of a glow discharge. The basic apparatus (Figure 1) has been described by Mattox [4,5]. The plating conditions

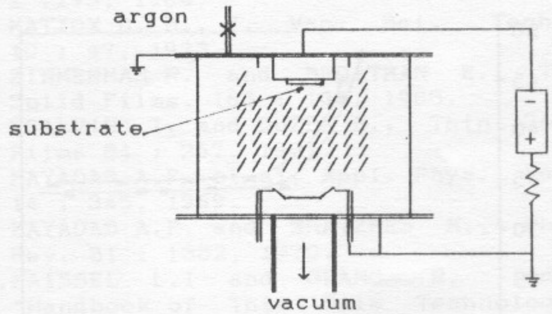

Fig 1: The ion-plating technique

were a negative potencial of 3 kV and a substrate current density of 0.7 mA/cm^2 in an argon plasma at a pressure of 20 mTorr.

The configuration of the meandering path obtained by means of the photolitigraphic technique is shown in fig.2. It is 0.3 mm wide by 36 mm long. Thick Ni electrodes for end contacts (0.5 μm) were deposited by vacuum evaporation using a contact mask.

The resistivity of the films has been measured at room temperature by a four-point probe technique.

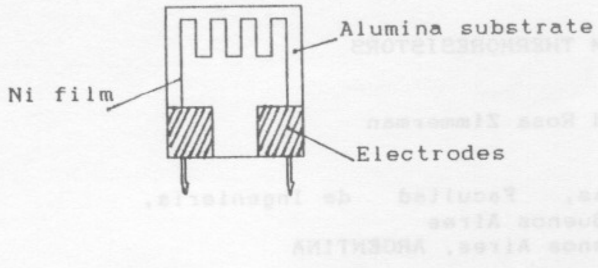

Fig.2: Schematic diagram of the thermoresistors

The thicknesses were measured by multiple beam interferometry.

Film annealing was performed under vacuum at temperature of 270°C for 1 h.

For comparison, thin film resistors of the same thicknes were obtained by vacuum evaporation.

3. RESULTS AND DISCUSSION

3.1 Resistivity

Plots of the resistivity versus thickness for both ion-plated (i-p) and vacuum evaporated (v-e) films are shown in figure 3.

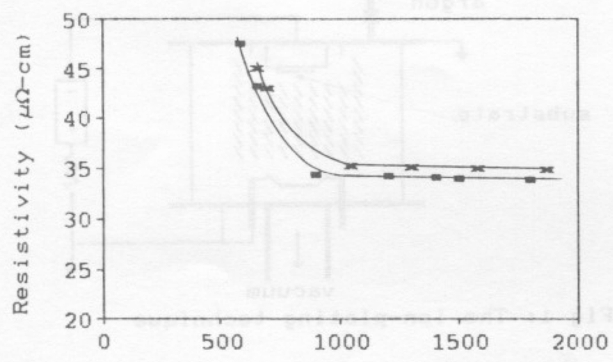

Fig. 3: Resistivity vs. thickness for as-deposited v-e (■) and i-p (x) films.

The i-p films all have a higher resistivity. In the range from 1000 Å to 2000 Å the film resistivity shows a small decrease.

Figure 4 shows the ρ vs. thickness after annealing. While i-p film resistivity decreases in a range of 10%, in v-e films the decrease is more pronounced, about 30%

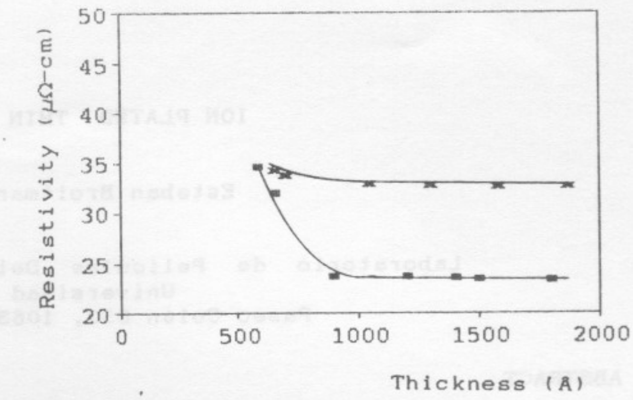

Fig. 4: Resistivity vs. thickness for heat-treated v-e (■) and i-p (x) films.

After a second annealing treatment at the same temperature the irreversible resistance changes were less than 1 %. Thus for practical purposes one stabilizing treatment is sufficient.

TEM micrographs have confirmed [6,7] the singular characteristics of nucleation and growth of ion-plating. Ion- plated films were produced with a final grain size considerable smaller than vacuum evaporated films and whereas the i-p films had a uniform structure in size and shape, v-e films showed a high degree of non-uniformity.

TEM micrographs after annealing have shown that grain size in v-e films increased twice as much as in i-p films.

On the basis that in thin polycristalline films grain boundary scattering is the dominating mechanism in film resistivity [8,9] a higher ρ value is to be expected in the case of i-p films.
On the same basis, having micrographs shown a smaller grain growth in the case of heat-treated i-p films, the ρ decrease is expected to be smaller.

3.2 Temperature coefficient of resistivity

The table shows the average values of TCR measured in the range of 273 to 403 °K for as-deposited and heat treated films.

	TCR (ppm/°C)		ΔTCR %
	as-dep.	heat-treat.	
v-e	2470	3450	40
i-p	2320	2870	24

Because electron-defect collisions are

temperature insensitive [10], grain boundary scattering decreases TCR. Vacuum evaporated films will have a higher TCR than i-p films due to their lower grain boundary area and after annealing will have a higher TCR increase due to the higher increase in grain diameter.

3.3 Adherence

Ion plating provides an exceptionally strong adherence because of the high energy of vapor ions and neutrals and the permanent bombardment of the substrate and the depositing film, throughout the

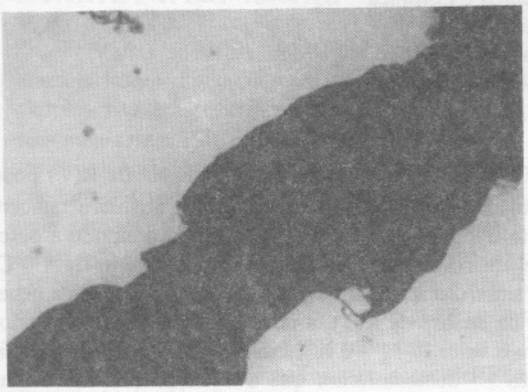

Fig.5: Scratch test for v-e film (320X).

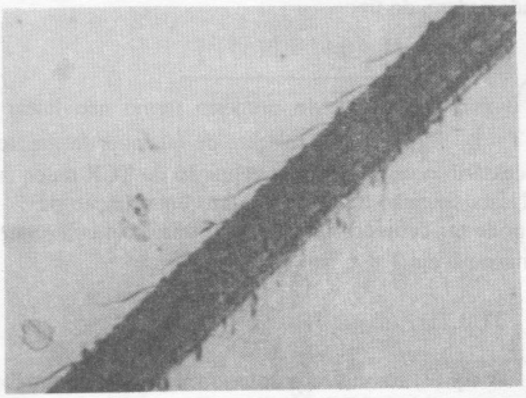

Fig.6: Scratch test for i-p film (250X).

evaporation [11].

Nickel films prepared for adhesion tests [12] have been deposited on Corning 7059 glass substrates in order to be examined by means of a scratch test (Fig. 5 and 6) The critical loads obtained were:

v-e films: 25 gr.
i-p films: 500 gr.

4. CONCLUSIONS

Strong adherent Ni thin film can be obtained by ion-plating.

In contrast with the volumetric value (6750 ppm/°C), the average TCR of our Ni ion-plated films was 2870 ppm/°C and one thermal treatment was sufficient to stabilize the sensor.

5. REFERENCES

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