FILM RESISTORS

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ABSTRACT

The choice of many metals for the fabrication of film resistors is caused by their good stability at high temperature. To these requirements are appreciably capable to satisfy of a thin film of finding materials. It's possible to make film resistors both vacuum evaporation and cathode dispersion. And it's usually accepted also to characterize of film resistors by normalized parameter, so-called surface resistivity of R_s. One of the main fabrication stages of film resistors is the operational development of resistance value up to nominal.

Keywords: metals, resistors, film, temperature, vacuum.

I. INTRODUCTION

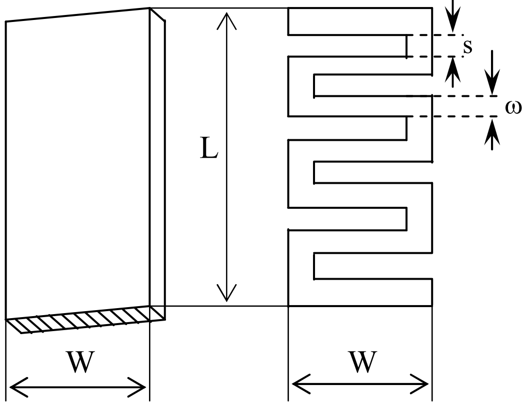
It's known that deposited thin films by thickness from hundreds angstreme up to several micron find greatly application in fabrication of electronic elements. It's caused by the special physical properties of solid states as thin layers (or multi-layer film structures). For example, fabrication even of such usual radio engineering elements, as resistors, condensers and smaller degree of inductance, in film performance opens rather tempting prospects, especially if the speech goes on creation of the circuit with large number of similar elements, vacuum evaporated on non conductive flat substrate.

The choice of many metals for the fabrication of film resistors is caused by their good stability at high temperature [1,2]. It's difficult to overestimate the role of substrate at fabrication of film passive elements. The surface of a substrate should be flat and smooth. The most important properties of substrate are surface character, chemical structure, and stability and thermal conductance. Dispersion of heat in any device plays a determining role in circuit stability. The resistance is in this respect especially critical, which is intended for high-power dispersion. Surface temperature is determined by radiation from a surface, convectional cooling and thermal conductance through a substrate to thermal drains.

II. EXPERIMENTAL PART

The needs of microtiny electronic device industry have given a push to investigations of the electrical characteristics low- and high-resistance film materials. Main requirements to such components are low dimension, low cost price of manufacture, high thermal and mechanical stability, large service life, good control of resistance value, low temperature coefficient of resistance, small high-frequency losses and compatibility with used substrates. To these requirements are appreciably capable to satisfy of a thin film of finding materials. It's possible to make film resistors both vacuum evaporation, and cathode dispersion.

It's usually accepted to characterize of film resistors by normalized parameter, so-called surface resistivity of R_s. Let's consider two basic configuration of film resistance showed in Figure 1 (a, b).



a) b)

Figure 1.

The resistance value can be expressed by equality for rectangular section of film resistor (Figure 1, a):

$$R = \rho L / dW$$

If L=W, then $R = \rho / d = R_s$, therefore resistance R_s of one square of a film depends not on square size, but only on resistivity and thickness. Where, R_s is resistance of film layer and is expressed in Ohms on square. This value is widely used for film comparison, in particular films of one material deposited under identical conditions. If the thickness is known, resistivity is easy to prepare from the equation of,

$$\rho = dR_s$$

The changes of thickness are provided variation of resistance value without change of the basic properties of a material. However, resistivity and temperature coefficient of resistance (TCR) depend on film thickness frequently, and freely to vary surface resistivity without change of the basic properties of a material it happens difficulty. Therefore, it's necessary to compare several films by resistivity value. As the stability of a film increases by increasing of thickness from 10 up to 3 10^3Å, for preservation of high surface resistivity of more thick films are very important for preparing of film with high resistivity.

The resistance value of R is product of surface resistance R_s to number of squares N

$$R = R_s \cdot N$$

The configuration is characteristic for many thin film resistors (Figure 1,b) and the resistance of such elements is determined by the equation,

$$R = R_s\left(\frac{LW}{n\omega^2} + \frac{1}{n\omega} - \frac{2(0.46)L}{n\omega}\right) \sim R_s\frac{LW}{n\omega^2},$$

$$n = \frac{s}{\omega} + 1$$

Where, ω - is width of lines, and S – is width of an interval between lines [2,3].

One of the main fabrication stages of film resistors is the operational development of resistance value up to nominal. Parameters of a film, which can be used for this operations is set by the equation,

$$R = \frac{\rho}{s}N \tag{1}$$

The number of squares can be adjusted by polishing [3]; the resistivity can be varied with the help of oxidation of a film grains borders, or annealing [4]. However at these methods changes TCR, too. There is not occurs changes, if the operational development of resistance is made by oxidation of film surface, which reduces it's thickness [5].

Temperature coefficient of resistance is described by the equations,

$$\alpha = \frac{1}{\rho}\frac{\partial\rho}{\partial T} \tag{2}$$

$$\alpha = \frac{R_1 - R_o}{R_o(T_1 - T_o)} \tag{3}$$

Thus resistivity and temperature coefficient of resistance are not independent [6] (Figure 2).

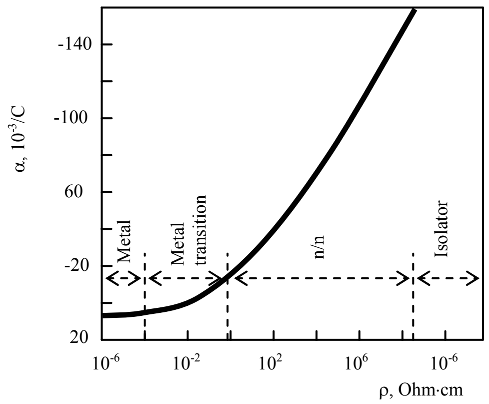


Figure 2.

III. RESULTS AND DISCUSSION

The metals with high volumetric resistivity have large positive temperature coefficient. However the small size of grains and ghettoriration of gases in thin films results to high concentration of defects and disseminating centers. The conductivity of such structure is described by the formula of Mettisons [7];

$$\rho = \rho_o(T) + \rho_r, \tag{4}$$

Were, $\rho_0(T)$ - is member appropriate electron-phonon dispersion, connected with temperature fluctuations of a lattice, and ρ_r - is residual resistance not dependent on temperature, which determined by dispersion on defects. Temperature coefficient is determined by expression

$$\alpha = \frac{1}{\rho}\frac{\partial\rho}{\partial T} = \frac{\partial\rho_o}{\partial T}\left(\frac{1}{\rho_o + \rho_r}\right) \tag{5}$$

The expression is a constant and represents derivative, which determine the temperature dependence of expression member for volumetric resistivity. For manufacturing of nickel-chromium films were used an alloy 80% Ni, and 20% Cr, which has higher resistivity, than chromium, and it's temperature coefficient close to zero. Glories sprayed from wolfram strings at temperature of ~1500^0S. There is a problem at alloying of evaporated material from wolfram. The change of structure is rather essential during evaporation owing to various pressure of components stream. This problem is aggravated also by that the resistivity is increased by change of nickel concentration from zero up to 20% [8]. The solid solution of chromium can be formed in system and the relation of evaporation speeds should follow the Raule law [9].

$$\frac{\text{Ж}_{\text{Cr}}}{\text{Ж}_{\text{Ni}}} = \frac{W_{Cr}}{W_{Ni}}\frac{P_{Cr}}{P_{Ni}}\left(\frac{M_{Cr}}{M_{Ni}}\right)^{1/2}$$

Where, j- is vacuum evaporation speed in terms of weight on area for a time unit; W– is weight contents of components in an alloy (%); P – is pressure of component stream at temperature of T (^{0}K); M – is atom weight of a component. It's results to expression for dependence on temperature, for an alloy 80% Ni -20% Cr;

$$\lg(\frac{\text{Ж}_{Cr}}{\text{Ж}_{Ni}}) = \frac{900}{T} - 0.58$$

The characteristic data about resistivity depending on film thickness are given in Figure 3.

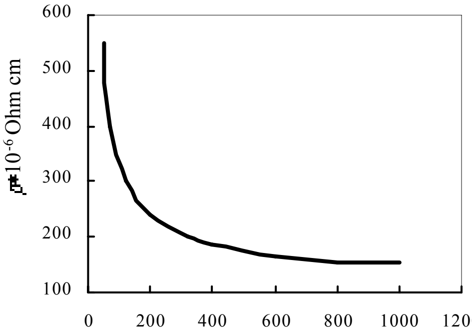


Figure 3

Vacuum evaporation of a film show in general smaller enrichment of chromium, and only in one case the increase of the chromium contents with temperature is observed. By this deviation many factors, for example alloying or primary oxidation of chromium can promote. Partial oxidation of chromium and capture of gas, obviously, play the large role, as density of films varies from 3,5 g/cm^3 at 8000 Å (density of nickel-chromium is 8,2 g/cm^3, and Cr_2O_3-5,2 g/cm^3).

IV. CONCLUSION

One of the main fabrication stages of film resistances is bringing resistance value to face value. Change of film thickness provides possibility of variation of resistance value without changing the basic properties of a material. However often resistivity and temperature coefficient of resistance depend on film thickness, thus making easy alteration of surface resistivity without changing basic properties of the material difficult. Therefore it's necessary to compare different films by their resistivity values.

To keep high surface resistivity of thicker films is important to get films with high resistivity. Resistivity can be changed by oxidation of boundaries of grains in the film or by annealing.

To make nickel-chromium films an alloy of 80% Ni and 20% Cr has been used as it has higher resistivity than chromium and its temperature coefficient is close to zero.

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