

Manufacturing of Nichrome Thin Film Potentiometer

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Abstract – Potentiometers are main part in electronic equipment. Thin solid films and especially NiCr are used in some kind of them as resistive layers on an isolated substrate. The challenge here is to produce a temperature stable, wear- and environmental resistant films. This was our aim choosing NiCr for this application.

Keywords – potentiometers, thin film resistors, flash evaporation, magnetron sputtering, nichrom

I. INTRODUCTION

Topological special features of the variable thin film nichrome resistors

Potentiometers are electronic elements which play an important role in the electronic equipment. Their main characteristics correspond to these of the fixed resistors [1, 2], but with lower criteria in respect to the resistor tolerances [3]. At present leading electronic companies produce thin film potentiometers using NiCr as resistive material [4, 5].

While in general the technologies for producing variable resistors are similar and include depositing of the layer, configuring the images and assembling, there are a vast number of possibilities for the potentiometer geometry. As construction the variable resistors consist of resistor element and a slider. The slider position defines the resistance value or with other words there exists a possibility for getting a row of values, which are subordinated to a specific low. This low for arranging the values is determined by two factors – the geometry of the resistive layers and the kind of the slider movement – in a straight line or circular.

Having ideal contacts situated on both sides of a resistive surface – Fig. 1, the resistance should be calculated by integrating the equation:

$$R = R_s \int_{r_1}^{r_2} \frac{I(l)dl}{I} \quad (1)$$

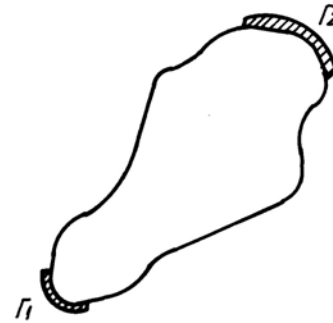


Fig. 1: A general case of a resistive layer, supplied with contacts

Besides the case of ideal contacts we can integrate (1) if R_s is constant for the whole surface and the contour can be integrated.

The first main type of variable resistors are these with a circular movement of the slider and a constant bright of the resistive layer – Fig. 2:

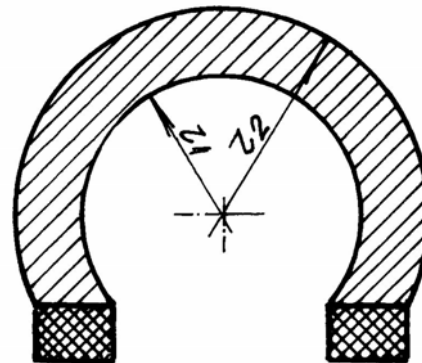


Fig. 2: Ω shaped potentiometer (K_1, K_2 - contacts, r_1 и r_2 – inner and outer radius)

The resistance value of the potentiometer in Fig.2 is:

$$R_\alpha = R_s \frac{\alpha}{\ln \frac{r_2}{r_1}} \quad (2)$$

where α [rad] is the turn angle.

Because r_1 and r_2 are constant, the ratio R_s to $\ln(r_2/r_1)$ is a constant too, and this means that the resistance will change linear with the angle, that is:

$$R = R'_s \cdot \alpha \quad (3)$$

R'_s stands for the normalized surface resistance to respect to the geometric dimensions r_1 and r_2 .

There is a practical interest for circular potentiometers with a nonlinear change of the resistance:

$$R = R_s \cdot f(\alpha) \quad (4)$$

Where $f(\alpha)$ is a nonlinear function of the angle - Fig. 3:

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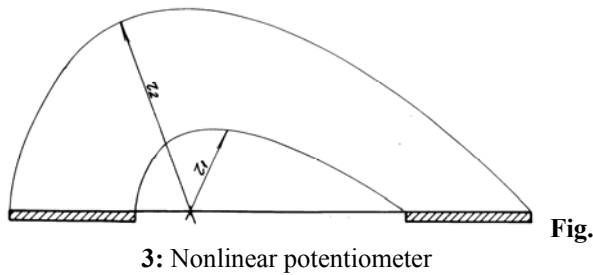


Fig.

On Figure 3 r_1 and r_2 constants but they depend on the rotation angle:

$$r_1 = r_{01} \cdot f_1(\alpha) \quad r_2 = r_{02} \cdot f_2(\alpha), \quad (5)$$

where $f_1(\alpha)$ and $f_2(\alpha)$ are different.

The most frequently used in the practice trimmer potentiometers do have a low for changing the resistive value with the turn angle linear, exponential and logarithmic respectively [2]: $R = R_s \cdot k$, $R = R_s \cdot \exp(\alpha)$, $R = R_s \cdot \ln(\alpha)$ (6)

It has to be mentioned that in constructions where the slider moves linear, but not circular and in the above showed cases it is possible to realize a great variety of lows $R(\alpha)$ in according to the geometry of the resistive element.

II. EXPERIMENT

Because of the great mechanical load which the conducting parts of the potentiometer experience during their assembling and exploitation there are additional requirements to the parameters of the substrate like: enhanced mechanical strength, possibility for making holes in it and a kind of substrate surface which enables the slider movement. The glazed ceramics 96% Al_2O_3 and the 99% Al_2O_3 (Polycor) are best satisfying this complex of requirements. All other materials have worse mechanical characteristics (Corning 7059, Sital ST 50-1, Si/SiO₂) or roughness (Alumina).

The technological process sequence for preparing potentiometers and trimmers with a resistive layer of nichrome is shown in Table 1. One of the most labour-consuming and capricious operations is the forming of the isolative body. This often need making of contact holes and technological cuttings.

By the ultrasonic cutting a comparative clean surface is achieved, but the cutting instrument wears out rapidly. Low productivity and limited exactness characterize this method. The most universal method for the first operation is the laser cutting followed by cleaning the substrate surface from the oddments of the melted material (the so called "craters") – operation 2. This operation is made by grinding and polishing for the second time but it is obvious, that all this is a question of compromise between technological requirements and quality.

TABLE 1. TECHNOLOGICAL SEQUENCE BY PRODUCING NICHROME POTENTIOMETERS

1	2	3	4	5	6
Laser or ultrasonic formation of the substrate	Preparing the substrates for metallization	Metallization NiCr + contacts	Photolithography	Assembling, trimming	Training trade control

The third and most important operation is the metallization of the substrates with nichrome. Because of the different vapor pressure of the elements (Ni and Cr) in the alloy the thermal evaporation is not suitable. The only specialty here is that the metallization can be done either through mask (that is in different vacuum cycles) or in one technological cycle depositing one after the other nichrome–nickel–silver followed by photolithography – operation 4.

III. RESULTS AND DISCUSSION

The experiments are carried out in a high vacuum apparatus B 55, where flash evaporation from NiCr wire is used what is described in an other work [6]. An other B 55, which is modernized to a magnetron sputtering machine is used to obtain NiCr layers sputtering nichrome targets [7]. Using both methods trimmer potentiometers with nominal values from 50 Ohm to 5 kohm and $TCR < + 200 \text{ ppmK}^{-1}$ are produced.

A comparison between the carbon and nichrome potentiometers show besides the higher prize of the latter in this value range a much better quality (tolerance, temperature and time stability, power) of the nichrome potentiometers. So, when quality is determinant for an electronic scheme the nichrome trimmer potentiometers are an alternative to the carbon potentiometers.

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