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Resistive Ni-W-P layers obtained by chemical metallization method

Abstract. *The paper describes a new method of obtaining of Ni-W-P resistor layers, featuring elevated electrical stability. Such layers may be introduced into the manufacturing process of precise metal film resistor.*

Streszczenie*. Artykuł opisuje nową metodę uzyskiwania warstw rezystywnych Ni-W-P, charakteryzujących się podwyższoną stabilnością elektryczną. Warstwy te mogą być wykorzystane do procesu wytwarzania precyzyjnych rezystorów warstwowych. (****Rezystywne warstwy Ni-W-P wytwarzane metodą chemicznej metalizacji****).*

Keywords: resistive layers, Ni-P, Ni-W-P, precision resistors, chemical metallization.
Słowa kluczowe: warstwy rezystywne, Ni-P, Ni-W-P, rezystory precyzyjne, chemiczna metalizacja.

Introduction

The fixed metal resistors with the temperature coefficient of resistance (TCR) lower than 50 ppm/K are actually manufactured in two competitive ways i.e. vacuum magnetron sputtering and chemical metallization. Both method have their specific features. The advantages of the chemical method are low production cost and inexpensive equipment, but the metal film quality is not constant within the whole manufactured resistance range.[1-3] Moreover – the chemical method permits to form only such kinds of films, in which exist metals reducible in a water solution by means of reducers easy of access, so that is the reason, why the variety of layers compositions so obtained can not be competitive with numbers of combinations reached in the magnetron sputtering method. These are the reasons why up to now during the metal film resistors manufacturing the process was limited to forming of Ni-P layers, while divalent nickel salts ina water solution and sodium hypophosphite as reductor were used. The alloys Ni-P obtained in acid technological baths and characterized by relatively high content of phosphor amounting to 15 atomic percent, are stable in a wide range of temperatures, up to 380°C, and therefore they can be applied in any types of fixed film resistors having the sheet resistance from 0.5 to 10.0 Ω/□ [4].

For the resistors having the surface resistance within the range 10÷100 Ω/□ it is necessary to introduce an additional metal to the alloy, and therefore the application of the film type Ni-W-P is suggested. The introduction of an additional high-melting element to the alloy Ni-P as for example tungsten (W)[5] or rhenium (Re)[6] effects the rise of crystallization temperature of resistive alloy, especially the one in which the content of phosphor is high. Since together with the rise of resistance the concentration of phosphor in the alloy should be increased so the additional element plays the role of stabilizer which prevents the crystallization of saturated solid solution Ni-P, which in turn prevents the uncontrolled rise of TCR of the film due to the occurrence of structural disturbances.

The literature data [7] indicate the lack of changes of composition in case of compound layer crystallites Ni-Mo-P and Ni-W-P, while Mo as well as W are exhaled from the anion form. Considering the difficulties in molybdates reduction the present study is limited to the performing of Ni-W-P layer properties, which are characterised by tungsten content not exceeding 2,4% and phosphorous content of the order of 10-20%.

The purpose of this study is demonstrating the improved quality of the Ni-W-P layer in comparision with up to now employed Ni-P layers, while only such parameters as temperature coefficient of resistance and electrical durability at temperature 343K under nominal load has been taken under consideration.

Experiment

The Ni-W-P metal film resistors with the layer composed of mass 15wt.%P and about 1-3wt.%W are manufactured by means of the following technological stages:

- cleanic and degreasing in acetone in order to obtain hydrophilic properties,
- activation and sensitizing in order to produce the initiators of process (atoms of palladium),
- chemical metallization while basic substances like nickel chloride ammonium, tungsten and sodium hydrophosphite as reductors are used, what permits under circumstances of proper process parameters choice to optimize the composition of the layer from the point of view of applications in electronics,
- thermal stabilization of so manufactured resistive layer (artificial ageing) in order to optimise the electrophysical parameters of the final product,
- resistor spiral cutting,
- hermetic sealing of the resistive layer by means of electroisolating enamels.

The chemical metallization has been accompliched at Institute of Electronics Silesian University of Technology, while the rest technological process stages and the measuremants of TCR and electrical durability – in Institute of Electron Technology in Kraków.

Results

As result of preliminary studies a successful deposition method of reproducible Ni-W-P resistive layer containing 10-15%P and 1-3%W was elaborated. After determining the most favourable parameters of the process and making it most efficient – a series of resistive layers of 0,5-10Ω/□ surface resistance was obtained, characterized by TCR lower than 15ppm/K, what became an experimental confirmation of the speculative assumptions.

At the first stage of the investigations, the influence of tungsten content on the TCR of resistors was analysed. The results were performed on resistors with a resistance of 1Ω/□, precut on the final resistance of 100Ω. The obtained results are presented in Figure 1.

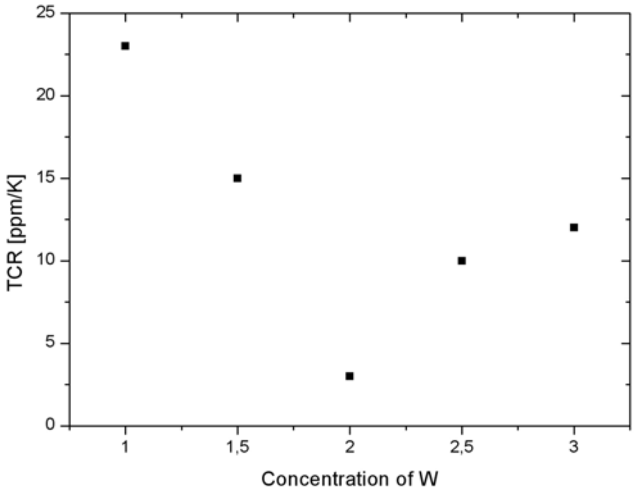

Fig. 1. Relationship between TCR of Ni-W-P layers and concentration of tungsten

At further stages of the investigations, the ifluence of stabilization temperature on TCR of resistor was analysed. Tests were carried out for Ni-W-P layer of tungsten content of 2%. The results were performed on resistors with a resistance of 1Ω/□, precut on the final resistance of 100Ω. The results were compared with Ni-P metallization of similar resistances. The obtained results are presented in Figure 2.

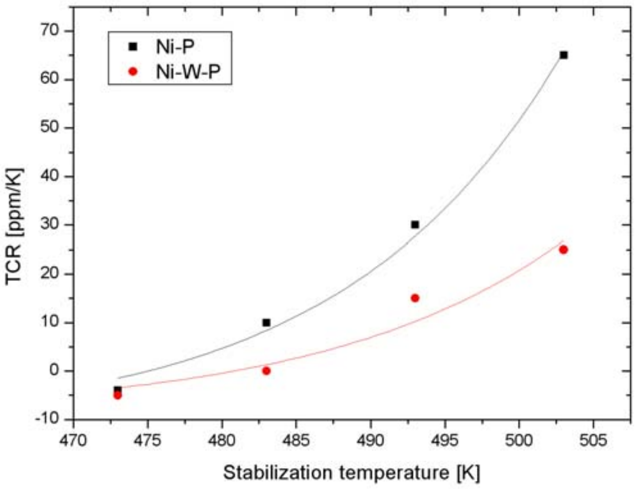

Fig. 2. Relationship between TCR of layers and stabilization temperature

Conclusions

The paper presents preliminary results of work on resistive alloy Ni-W-P. The work allowed us to define the following conclusions:

1. Optimal content of tungsten in the resistive layer should be 2%.
2. The use of tungsten increases isensitivity to increased stabilization temperature of resistive layer.
3. Research should be continued to optimize metallization bath and Long-term stability of the layer.

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