Metal – Polymer Based Power Bulk Resistors

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Abstract – **The goal of this work is the process for producing single end small series power resistors for laboratory application. The production steps include mixing conductive powder with polymere pressing and thermal treatment of the composition. The attention is paid for resistors shape and the possibility of trimming.**

Key words – **power resistors, bulk resistors, polymer resistors.**

I. INTRODUCTION.

Power resistors are commonly used in electrical circuit such as electrical motor control, power supply, grounding etc.

The rang of electrical parameters and sizes is very wide [1÷5].

For example power dissipation (Pmax) varies from 1 W to 1200 W; length (L) from 53 mm to 615 mm; accuracy (ΔR) - 5 to 20%.

There are several types of power resistors:

- ❖ Wire wounded;
- ❖ Film (thin or thick);
- ❖ Bulk (cermets, conductive polymers).

The disadvantage of some of them are: high parasitic inductance (wire – wounded), high capacitance (film resistors).

The best solution for power resistors working at high frequencies are bulk components with their representees:

- ❖ Sintered materials (high temperature, high pressure process);
- ❖ Composition based on polymers.

The first ones have very good stability but heavy technology.

For example, the resistors from boron carbide are sintered at the temperature between 1800 ÷2200 ^{0}C and they are very hard (black diamond).

For experimental uses the polymers based resistors are easy to be produced, trimmed and tested.

The aim of this paper are the results using compositions polymer (epoxy or silicon) and conductive phase (metals, alloys, semiconductors).

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II. PREPARATION OF THE EXPERIMENTAL SAMPLES

2.1 Technology and the choice of materials.

There are lots of combinations between organic materials (high temperature silicon and epoxy), conductive powder (Ag, Cu, Ni, est.), the ratio between them and technology parameters. For this reason the experiments are provided using only several combinations:

- ❖ Epoxy (two components 1:1). Hisol; high temperature silicon [7] with the parameters;
  - Adhesion - 35÷45 kg/cm^2;
  - Working temperature – (-60^0 C÷+600^0 C);
  - Specific resistivity – 10^{12} g.cm;
  - Dielectric strength – 5 kV/mm.
- ❖ Conductor – mainly carbon (C) with small additions of Ag, Cu, Ni;
- ❖ The ratio between organic and conductive phases is 5÷10% to 95÷90%.

In Table 1 the electrical properties of the used materials are given. It is clear that carbon has very wide range of resistance and strongly negative TCR.

To correct this, small additives (metal powder) will drift the specific resistance and TCR to desirable values.

TABLE I
DEPENDENCE BETWEEN CONDUCTIVE PHASE AND ELECTRICAL PROPERTIES

Conductive phase	Ag	Cu	Al	Ni	C
ρ (μΩ.cm)	0.66	1.78	2.9	8.2	708
TCρ (×10^4 K^{-1})	+0.40	+0.35	+0.41	+0.42	-70÷ -10

The technology includes next important steps:

- ❖ Mixing the components with laboratory mixer for 30 min and frequency about 100 t/min;
- ❖ Forming and hardening the compound at 120 ^{0}C for 2-3 hours;
- ❖ Measuring, trimming and making protective film.

2.2. Construction and particularities of the samples.

For the experiments the simple rectangular shape is used (Fig. 1).

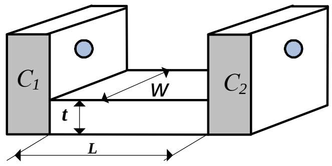


Fig. 1. Rectangular resistor shape.

C_1, C_2 - external copper metal contacts with Ni-Ag protection.

The sizes of the test resistor are chosen for easy preparation, testing and trimming: L=10 cm, W=1 cm; d=1 cm. It means if the nominal values must be about 100 Ω with these dimensions the specific resistance would be approximately 1 Ω.cm. The special attention is paid to the external contacts (Fig. 2).

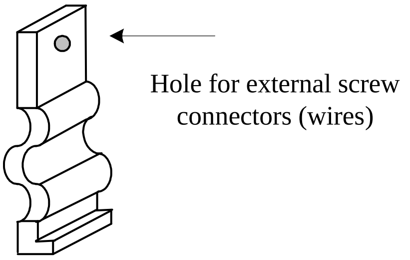
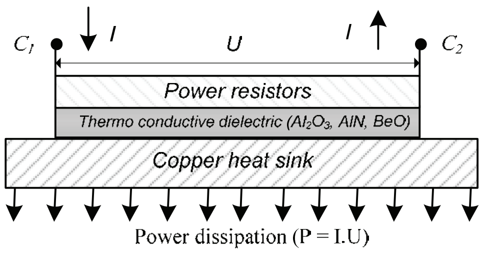
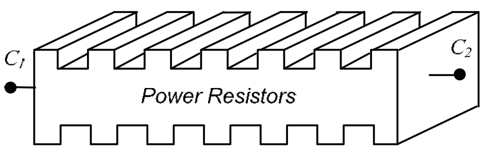


Fig. 2. Shape of the contacts.

The power resistors are usually low ohm that is why the contact resistance is very important. For the experiments the contacts are made using bended *Cu* (covered with parasitic resistance and to increase mechanical strength.



a.



b.

Fig. 3. Resistors for high power application.

The resistors for high and very high power dissipation are designed – Fig. 3,a, b.

III. RESULT AND TRIMMING

The results after the preparation of samples show that best results are obtained with the composition “epoxy - carbon - silver - nickel “(Table 2). This mixture has sufficient parameters with low price.

TABLE II
DEPENDENCE ρ, S AND TCR - CONDUCTIVE PHASE PHASE

Composition	C+Ag	C+Cu	C+Ni	C+Ag+Ni
ρ (Ω.cm)	0.35	2÷3	1.2÷2	1.2÷1.8
TCR (ppm.K^{-1})	$\geq 10^3$	$>10^2 \div 10^3$	$>10^2 \div 10^4$	$>10^2 \div 10^3$

It is interesting to trim the resistors to nominal value. It is easy done removing part of the resistors surface layer. That means decreasing the cross section S and increasing the value of the resistors to the desirable ones (Fig. 4).

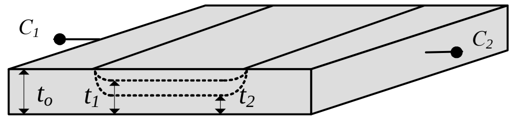


Fig. 4. $t_0>t_1>t_2$; $S_0>S_1>S_2$; $R_0>R_1>R_2$.

The best way to adjust the resistors is shown on Fig.5. Making channels with regulated parameters such as “t”, “x” and “a” it is not only possible to trim the resistors and to increase the surface for power dissipation.

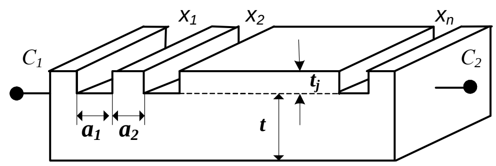


Fig. 5. x_n- number of the channels; d - depth of channels, t - width of channels; a- step between channels.

CONCLUSION

As a final conclusion this paper shortly describes simple, easy and cheep power resistors production, laboratory made for own use. This gives flexibility in experimental work with high power devices.

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