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STUDIES ON THE PERCENTAGE VARIATION OF RESISTANCE OF PVC-GRAPHITE THICK FILM RESISTORS

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Abstract: The percentage variation of resistance of PVC-graphite thick film resistors has been studied. Two different grain sizes of graphite, as well as four different compositions of PVC- graphite are adopted in the preparation of thick film resistors. Among the four different compositions of PVC-graphite i.e. 90%:10% to 60%:40%, 90%:10% PVC-graphite composite thick film resistor shows the least variation with temperature changes. This can be attributed to high composition of graphite. The variation will be lowered down with a decrease in the loading fraction of PVC in thick film resistors. The percentage variations of resistance of PVC-graphite thick film resistors, after 700C for 1000 hours, or after 30 cycles thermal shock tests as well as the variations after the short term overload tests, have been measured and studied. A possible explanation on these experiments is also presented.

Keywords: *Polymer resistors, thick films, reliability, composition.*

1. INTRODUCTION

From the previous studies of the authors [1-4], it is known that the mixtures of graphite and PVC can be utilized as thick film resistors. Their electrical properties such as sheet resistivity, current noise and TCR have been obtained and studied. However, TCR is only measure of resistance change between two specific temperatures ie. 25^0C and 50^0C for hot TCR. No information of resistance variations, for the temperatures in between, can be known. So, the percentage variations of resistance of PVC-graphite thick film resistors prepared by different ingredients are measured and studied to try to get a better understanding about the thermal effects on PVC-graphite thick film resistors.

In order to find out the effects of different grain sizes and different volume fractions of graphite on the stability of resistance values of PVC-graphite thick film resistors, several experiments have been conducted. Besides the measurements of resistance variations with respect to temperature changes, the percentage variations of resistance after being stored at 70^0C for 1000 hours, or after thermal shock tests are also measured and studied. A possible explanation on the experimental results will also be given.

2. EXPERIMENTAL WORK

Resistor Fabrication

Polymer paste containing PVC and graphite has been prepared by first dissolving PVC granules in cyclohexanone and then by blending graphite in to it. The graphite powder (average grain size 45 to 100 microns) is prepared from a graphite block, supplied by Graphite India Limited, with electrical conductivity of 0.33*105 mho/cm. The PVC powder is supplied by Calico Chemicals Limited and has a density of 1.37Mg/m^3. This past has been used for printing resistors on PVC substrate with a screen printer. These printed resistors are processed by using the usual thick film processing of polymer based films [4]. The heat treatment involves drying at room temperature for 15 minutes, followed by curing at 100^0C for four hours. The thickness of the cured sample is found to be in the range of 40 to 150 microns. Various PVC-graphite compositions used in making the paste are given in Table.1.

Table 1 Various compositions of PVC-graphite Thick Film Resistors.

PVC(% by weight)	Graphite (%by weight)
40	**60**
30	**70**
20	**80**
10	**90**

Electrical Measurements

The percentage variations of resistance are measured on the cured polymer thick film resistors in a thermostat chamber. The variations are measured for every 5^0Ctemperature change. Starting from room temperature to 50^0C and there are 5 pieces of each sample point.

Long term resistance drifts are measured and expressed as percentage variations of resistance. The drift tests are carried out in the thermostat chamber by setting the temperature at 70^0C. The resistance values are measured after 1000 hours.

Thermal shock tests are practices by placing the samples at 25^0C and 80^0C for 20 minutes each time and the process is repeated 30 times. The resistance variations are measured.

The short term overload (STOL) test is carried out by applying voltage to the resistor samples, which are

rectangle in shape and the length is 8 mm and width is 2 mm, till the power reaches a value of 250 mw. After 20 seconds, remove the voltage source and record the resistance variation after it has been in room temperature for 30 minutes. The rating of the resistors is approximately 100 mw / 16 mm^2.

3. EXPERIMENTAL RESULTS

Figure.1 and 2.are the relationship between ΔR/R × 100% and the temperature of PVC-graphite thick film resistors. In Figure.1, the content of graphite is varied from 10% to 90%. In Figure.2, the 90%:10% PVC-graphite thick film resistors shows the smallest variation. The reason might be attributed to the high composition of graphite.

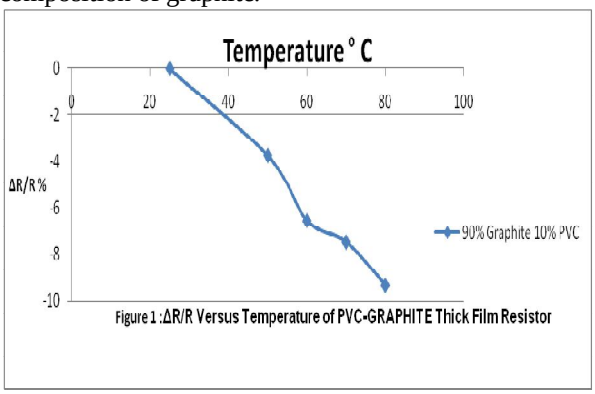

Figure 1 :ΔR/R Versus Temperature of PVC-GRAPHITE Thick Film Resistor

No unique relationship can be obtained between graphite and the percentage of variations. However, a resistor with higher sheet resistivity will show a higher variation from 25^{0}C to 50^{0}C.

The result is coincident with the work done by other author[7] and all variations are negative direction when temperature goes higher. A decrease in the percentage variation of resistance has also been observed when the content of graphite is increased.

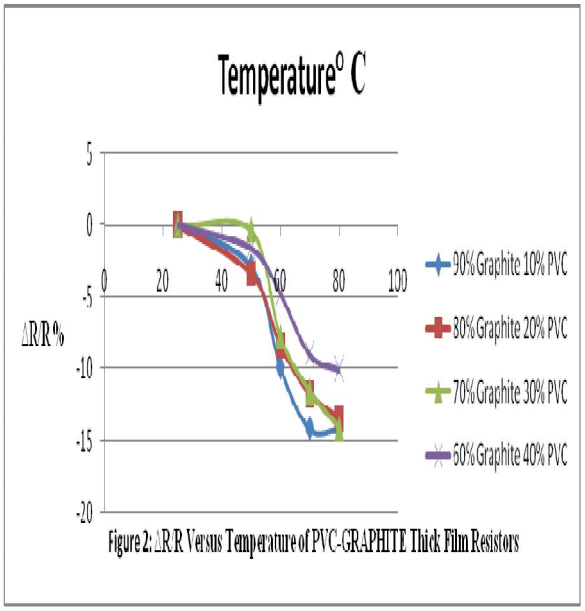

Figure 2: ΔR/R Versus Temperature of PVC-GRAPHITE Thick Film Resistors

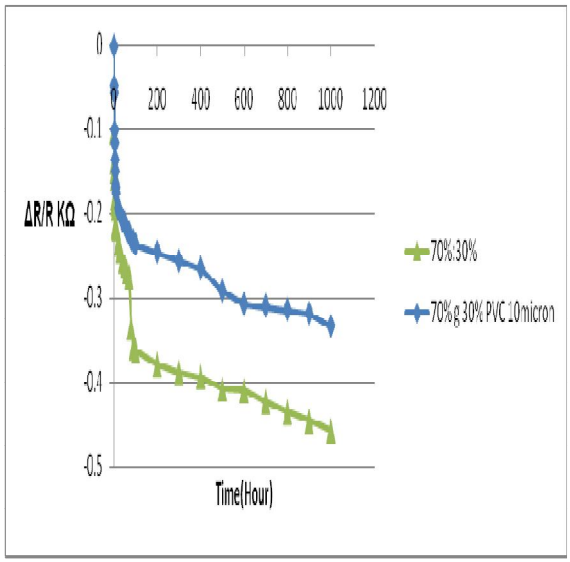

Figure3: ΔR/R Versus Time (hrs) of PVC-Graphite Thick film Resistors at 45 Microns and 10 Micron

Figure.3 and 4.shows the long term resistance drift characteristics. After storing at 70^{0}C for 1000hours, the drift of PVC-graphite thick film resistors is with in 10%.

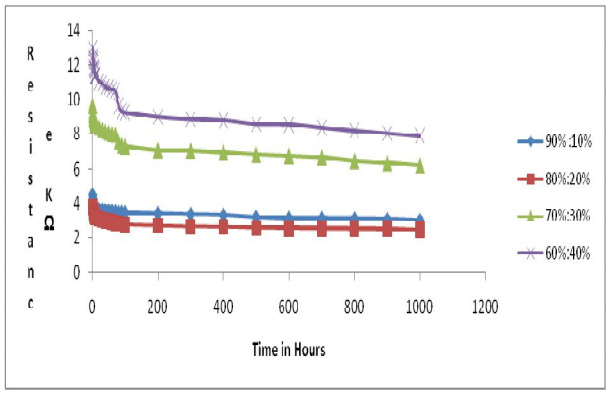

Figure 4: Long term drift characteristics of PVC-Graphite Thick film resistor at 70°c

Figure.5 shows the measured variations of PVC-graphite thick film resistors after thermal shock tests, i.e. placed at 25^0 and 80^{0}C for 20 minutes each time, and measured after 30 times test. The percentage variations are smaller than 39 %.

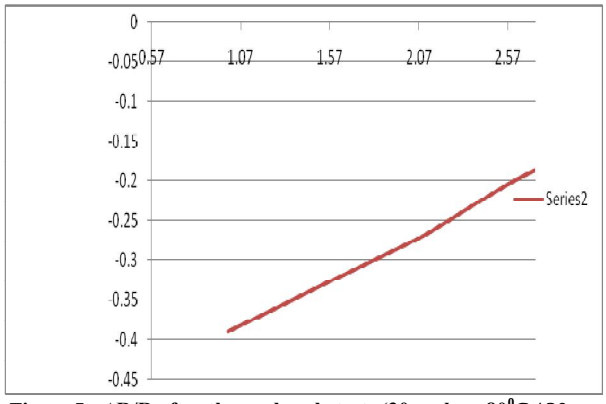

Figure.5: ΔR/R after thermal cycle tests (30 cycles : 80^{0}C / 30 sec to 25^{0}C / 30 sec)

The STOL tests carried out on the 8mm ×2mm resistors (rating 100 mw), by applying 250 mw on it for 20 seconds. The variations measured after 30 minutes power off are shown in Figure.4. The variations are with in 10 % and it's still larger in 10%:90% PVC-graphite thick film resistors.

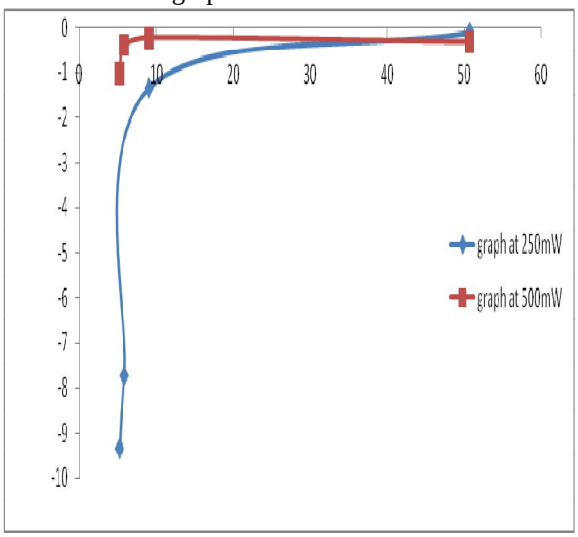

Figure 6: ΔR/R Versus Resitivity at 250mW and 500mW

4. DISCUSSION

From the experimental results obtained in the study of percentage variations of PVC-graphite thick film resistor with temperature change, it can be seen that 40%:60% PVC-graphite thick film resistor has shown more negative effects.

The percentage variation of resistance of PVC-graphite thick film resistors all are in negative in value.

This can be taken as the evidence that the thermal motion of graphite might be the dominant factor in the resistance variations of PVC-graphite thick film resistors, when subjected to temperature changes.

The resistance variations of PVC-graphite thick film resistors, after undergoing different tests, are expressed as percentage variation as shown above. The variations are larger than those of the commercial cermet resistors. However, one can see that the 10%:90% PVC-graphite thick film resistors will have smaller variation than those of 40%:60% PVC-graphite thick film resistors due to the variation of percentage of graphite in PVC-graphite thick film resistors.

5. CONCLUSIONS

Among different compositions of PVC-graphite used in the preparations of polymer thick film resistors in this study, 10%:90% PVC-graphite thick film resistors shows the smallest variations. This can be attributed to the high concentration of graphite.

Almost all variations show negative values, implying that the Brownian motion of graphite are more effective that of the thermal expansion of the matrix resin.

The percentage variations of resistance after long term drift, thermal shock and short term overload tests are, in general, larger than those of cermet type thick film resistors, and implies that the stability of PVC-graphite thick film resistors is worse than that of cermet resistors.

The reason that larger variations in resistances are observed in 40%:60% PVC-graphite thick film resistors can be attributed to the higher compositions of PVC.

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