Electrocomponent Science and Technology, 1983, Vol. 10, pp. 323-326
0305-3091/83/1004-0323 $18.50/0
Printed in Great Britain

TOWARDS A MORE THOROUGH PASTE SPECIFICATION

PETER BARNWELL

CorinTech Limited, Ashford Mill, Station Road, Fordingbridge, Hampshire, England

(In final form October 21, 1981)

A thorough specification of thick film resistor pastes is of vital importance to modern production methods. Proposals are, therefore, made to revise suitable specification with particular reference to resistance values.

1. INTRODUCTION

Over the years many technical papers have been presented by manufacturers of both thick film pastes and hybrid circuits on the characteristics of thick film resistors. Much has been made of problems relating to resistor stability, temperature coefficient, process variables etc. Since the mid-1960's dramatic strides have been made in resistor paste performances which allow the thick film manufacturer to produce precise high stability resistors with relative ease. For some time now the industry has been in a relatively stable technical situation with detail rather than radical advances being made in resistor material.

With the increased application of thick film technology, more effort is being applied to fulfilling economic requirements in all areas of manufacture. Once again, paste manufacturers have made significant efforts in cost reduction by producing low cost resistor families with tolerant printing parameters and fast firing cycles.

Equipment manufacturers are also closely involved with improvement of production economics and many automatic machines are now available for use in all stages of circuit manufacture. However, as with all automatic processes, it is imperative that expensive equipment should be in production for the majority of the time and set-up operations should be minimised. With a thoroughly developed thick film circuit and an established resistor material it should be possible to set up automatic printing rapidly. Unfortunately, it is the author's experience that frequently resistor materials have severe limitations in terms of process set up due to the sensitivity of the resistor material to termination effects.

2. DEFINING THE PROBLEM

Paste manufacturers normally publish curves of the form shown in Figure 1 specifying the termination effect of a resistor paste in conjunction with a specific conductor. Such a curve possesses limitations:-

a) It neither clearly indicates the actual slope resistance of the paste nor the termination effect. For example, in Figure 1 with a nominal 10K/sq paste we achieve the required resistivity on a 1 mm. sq. resistor, but for longer resistors, a considerably higher value results.

By plotting an alternative form of curve as shown in Figure 2 far more information becomes available. The slope resistance is clearly shown and can be measured at 17K/sq.

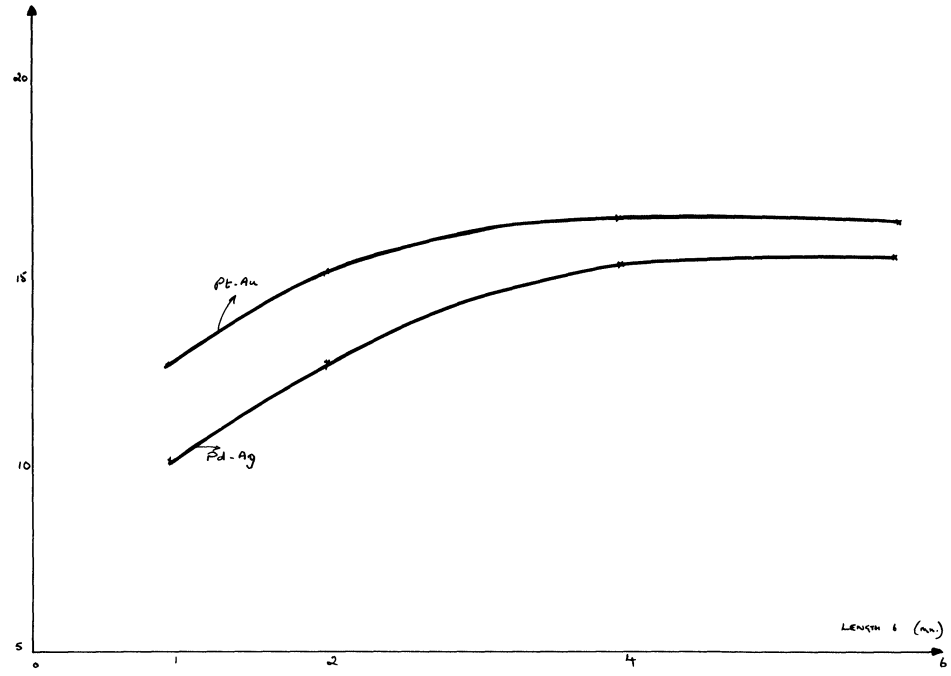

FIGURE 1 Resistivity/Length – 1 mm Wide Resistor Nominal 10KR sq.

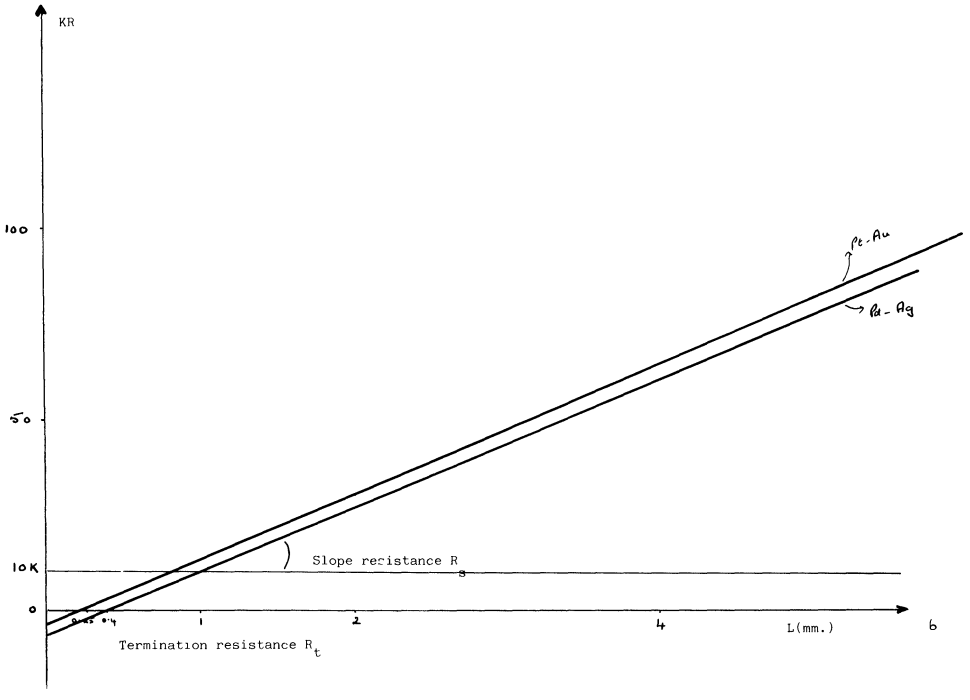

FIGURE 2 Resistance/Length – 1 mm Wide Resistor Nominal 10KR/sq.

Not surprisingly this approximates to the long resistor resistivity in Figure 1. Additionally, a termination resistance of minus 7K is indicated with Pd-Ag and minus 4K with Pt-Au. Similar curves can naturally be plotted for other termination materials such as Gold (Au). This discussion is however primarily concerned with solderable conductor terminations as these are the standard in economic hybrids designed for automatic production.

Using the characteristic of Figure 2 an expression for resistance value can readily be established as:-

$$R = \frac{(R_s \times L + R_t)}{W} \quad \ldots\ldots\ldots \quad (1)$$

Where R_s is the slope resistance
R_t is the termination resistance
L is the resistor length in mm.'s
W is the resistor width in mm.'s

This expression assumes that the resistance value is linearly related to width. It has been established that for all practical purposes this is the case, although for resistors of very small geometry a second order correction factor should be introduced.

(b) Even if the manufacturer provides slope and termination resistance information, as illustrated in Figure 2 problems still arise. It is the author's experience that such termination effects vary significantly from batch to batch of material.

Table I lists typical measured figures for a number of paste resistivities which clearly illustrates the problem. For example, if a circuit is designed for manufacture using Product A, then made using the same product but from another batch, an insurmountable problem arises. If the pastes are both blended to print to value with a 1 mm square resistor and the design is based on batch 1 paste the 4 mm long resistor will be almost 30% too high. Even if the circuit manufacturer controls all his processes perfectly, and

TABLE I
Batch variation of pastes

Resistivity	Product	Batch	R_s Measured	R_t Measured	Computed values for 1 mm. wide resistor			
					1 mm. long		4 mm. long	
					Value	Deviation from ideal	Value	Deviation from ideal
10K	A	1	12K8	−3K7	9K1	− 9%	47K5	+18%
	A	2	16K2	−6K8	9K4	− 6%	58K	+45%
	B	1	12K6	−0K7	11K9	+19%	49K7	+24%
	B	2	15K4	−2K7	12K7	+27%	59K	+47%
	C	1	17K	−2K8	14K2	+42%	65K2	+63%
1K	A	1	1K4	−0K5	0K9	−10%	5K1	+28%
	A	2	1K1	−0K16	0K94	− 6%	4K24	+ 6%
	B	1	1K3	−0K07	1K23	+23%	5K13	+28%
	B	2	1K35	−0K15	1K2	+20%	5K25	+32%
	D	1	1K35	−0K23	1K12	+12%	5K17	+29%
100R	A	1	166R	−86R	80R	−20%	578R	+45%
	A	2	111R	−17R	94R	− 6%	427R	+ 7%
	B	1	113R	−10R	103R	+ 3%	442R	+11%
	B	2	119R	−13R	106R	+ 6%	463R	+16%

designs resistors to 75% of value, then the 4 mm long resistor prints and fires over nominal. It is hence unusable.

This effect is repeated many times through the table. Paste suppliers names have not been listed, as the point of this paper is to provoke discussion, not criticise the paste industry which has historically provided great help to the hybrid manufacturer. It can be seen that some products appear better than others, but even in the case of Product B the second batch of 10K material will cause severe problems. If resistor sizes are further reduced, to say 0.7 mm long then the problem becomes even more severe.

3. CONCLUSIONS AND PROPOSALS

It can be concluded that the standard procedure of qualifying paste using a single resistor size is not appropriate to modern production methods. With automatic print equipment it is not viable to blend paste to fit narrow margins enforced by termination resistance variation. The hybrid manufacturer needs a material which can be used consistently from batch to batch, with no changes in circuit designs, and the absolute minimum of blending.

To overcome the problem paste suppliers must provide more details with their materials and control the materials accordingly. The author would make the following proposals:-

a) Slope resistance (R_s) and termination resistance (R_t) should be quoted on data sheets.

b) Both figures should be quoted for specific conductors.

c) Paste should be supplied with information giving the values of R_s and R_t for that batch.

d) The value of R_s should be controlled within certain percentage limits, as at present. Further, R_t variations should be constrained to some percentage of R_s rather than R_t. Ideal figures would be respectively 10% and 5%, reflecting the fact that on short resistors R is more significant than R_s.

Logically the hybrid manufacturer must also set up a QA system which qualifies pastes to his own specification which must be written in conjunction with the paste supplier. The author's company has established a system which uses a standard test substrate with resistors of varying length. After printing and firing a substrate with the material to be qualified the network is then plugged into a computer based test system which measures all resistors and computes and prints out values for R_s and R_t. Such a system is readily installed and guarantees the suitability of the resistor material.

One further interesting point that arises from the requirement to qualify paste thoroughly is that it is arguably more important to have fully qualified material for volume production work. In the past, both paste suppliers and users have tended to accept large lot to lot variation in resistivity to ensure the most economic product. However, it is the author's opinion that the way to produce an economic product is to achieve excellent manufacturability. This can only occur with a thoroughly specified and qualified resistor material. In return for a little more effort in resistor specification, both productivity and yield can be improved to the overall benefit of the industry.

ACKNOWLEDGEMENTS

The author gratefully acknowledges the assistance of Mr. Ossama Khabbaz who carried out the many measurements reported in this paper.