

United States Patent

Cocca

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[54] **CO-FIRING PROCESS FOR MAKING A RESISTOR**

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[51] Int. Cl.**H01c 7/00**

[58] Field of Search**117/217, 212; 338/308, 262, 338/195; 29/620**

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[57]

ABSTRACT

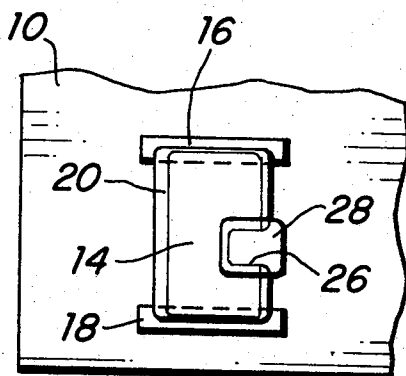
A resistor element and a process for manufacturing it including the steps of applying resistor material to a substrate; baking and drying the resistor material at approximately 125° centigrade; applying a glass coating on the resistor material; baking and drying the glass coating at approximately 125° centigrade; and co-firing the material at approximately 840° centigrade to form a resistor element.

[56] **References Cited**

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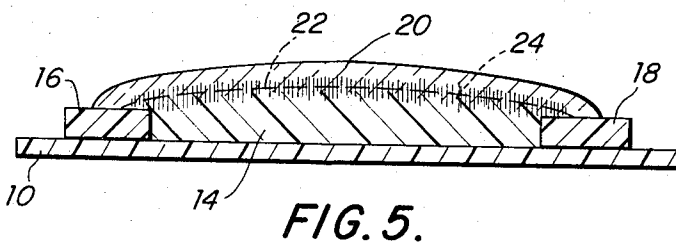
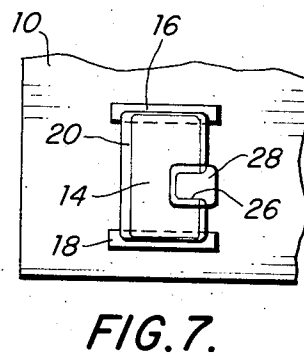
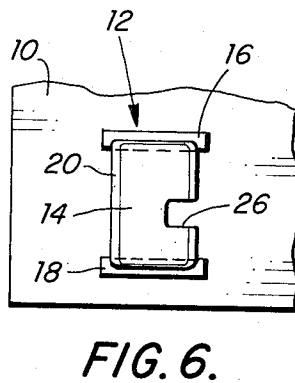
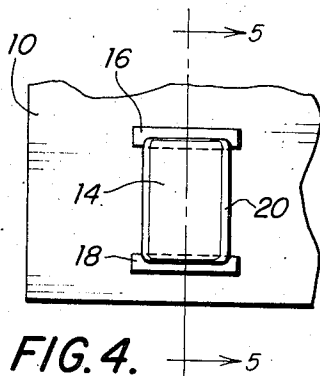
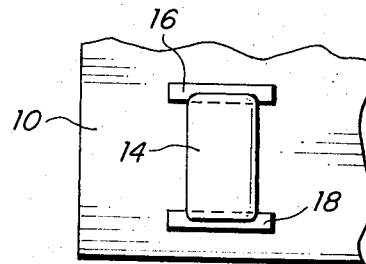
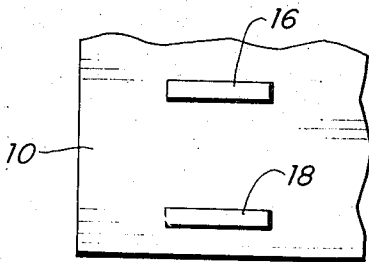
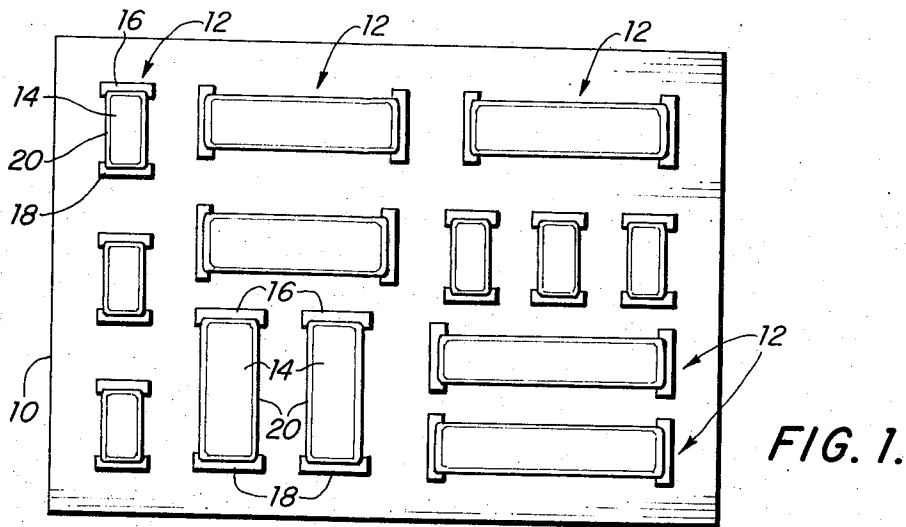
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1 Claim, 7 Drawing Figures



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CO-FIRING PROCESS FOR MAKING A RESISTOR

FIELD OF INVENTION

This invention relates to a co-firing process for manufacturing glass coated resistor elements.

BACKGROUND OF INVENTION

Typically, thick film resistor elements are manufactured by screening a resistor material onto a substrate, baking and drying the material and then firing it at a high temperature followed by screening a glass coating over the resistor material, baking and drying the coating and then firing it at a lower temperature. Originally, when this process was used with a good grade of resistor material such as DuPont 8000 resistor paste, resistor elements could be made having only a 2 - 5 percent variation in resistance over a period of 1,000 hours of cyclical temperature variation. As the technology advanced, better tolerances, in the range of 0.5 - 2 percent were demanded, and resistor pastes were developed which met these requirements. One such paste is DuPont Birox. But once again the technology demands even more precise resistance variation tolerances i.e. 0.02 - 0.05 percent. It has been determined that one reason for the resistance variation of such resistor elements is the different coefficients of expansion of the resistor paste and glass coating. That difference in expansion properties can cause stresses which produce strain in the resistor material that alter its resistive properties.

A second factor contributing to the resistance variation problem arises in the trimming operation. Typically, after a resistance element has been completed, i.e. fired, glass coated and fired again, its resistance is measured. If the resistance is too low a bit of the element is abraded away until the desired resistance value is reached. Then the exposed, abraded area is glass coated again and the resistor element is fired again. This firing softens the glass all over the element and results in unpredictable often quite substantial changes in the value of the resistance of the element.

SUMMARY OF INVENTION

It is therefore an object of this invention to provide a high precision, high reliability resistor element and a method for making it.

It is a further object of this invention to provide a method for making a resistor element which minimizes the sharp change in coefficient of expansion at the interface of the resistor material or paste and the glass coating.

It is a further object of this invention to provide a resistor element with a gradual change in coefficient of expansion between the resistor material and glass coating.

It is a further object of this invention to provide a method of applying a glass coating, to an area of a resistive element which has been trimmed, which minimizes any change in the value of resistances of the element.

This invention features a resistor element and a process for manufacturing that element. First, a resistor material is applied to a substrate; then the substrate is subjected to heat for baking or drying the resistor materials. Next, a glass coating is applied on the re-

sistor material and the substrate is again subjected to heat to bake and dry the glass coating. Finally, the resistor material and the glass coating are co-fired at approximately 840° centigrade to form the resistor element.

DISCLOSURE OF PREFERRED EMBODIMENT

Other objects, features and advantages will occur from the following description of a preferred embodiment and the accompanying drawings, in which:

FIG. 1 is a plan view of a substrate containing a plurality of resistor elements according to this invention.

FIG. 2 is an enlarged view of a portion of a substrate with two spaced conductors as it appears before the resistor material is applied.

FIG. 3 shows the substrate portion of FIG. 2 after the resistor material has been screened onto it.

FIG. 4 is a view of the substrate portion of FIG. 3 after the resistor material has been baked and dried and a glass coating has been screened onto it.

FIG. 5 is an enlarged cross sectional view taken along line 5-5 of FIG. 4.

FIG. 6 is a view of the substrate portion of FIG. 4 after the glass coating has been baked and dried, the resistor material and glass coating have been co-fired and a portion of the resistor material and surrounding glass coating have been removed in the trimming operation.

FIG. 7 is a view of the substrate portion of FIG. 6 after the area abraded away in the trimming operation has been resealed with a glass coating.

The co-firing technique of this invention is described herein with reference to thick film circuits, but this is not a limitation of the invention: the co-firing technique of this invention may be used for thin film circuitry, hybrid circuitry, and many other applications. There is shown in FIG. 1 a substrate 10 containing a plurality of resistor elements 12 according to this invention. Each resistor element 12 includes a resistor material or paste 14 applied between a pair of conductors 16, 18 and a high temperature dielectric glass coating 20 covering the resistor paste 14. Resistor paste 14 may be DuPont Birox paste or another Ruthenium oxide paste.

The co-firing technique of this invention may be best illustrated by step-by-step explanation of the construction of a single resistor element. Initially, a pair of conductors 16, 18 are established on a substrate 10, only a portion of which is shown in FIG. 2. Following this, resistor paste 14 is screened through a mask to fill the space between conductors 16 and 18, FIG. 3. Next, the conductors 16, 18 and resistor paste 14 supported on substrate 10 as shown in FIG. 3 are bake and dried, typically, at approximately 125° centigrade for approximately 30 minutes. After this baking a high temperature low dielectric glass 20, FIG. 4, is screened over the resistor paste 14 using a mask similar to the one used to apply the resistor paste. The substrate 10 with conductors 16, 18, resistor paste 14 and glass coating 20 is now baked and dried at approximately 125° centigrade for approximately 30 minutes. Following this baking, the entire substrate 10 as pictured in FIG. 4 is fired at 840° centigrade for approximately 10 minutes so that the glass coating 20 and the resistor paste 14 are both simultaneously co-fired. This co-firing process causes a merging of the glass coating 20 and the resistor paste

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14 at their interface 22, FIG. 7, instead of the sharp boundary 24, shown in phantom, which is obtained when the resistor paste 14 and the glass coating 20 are separately fired. This merging at interface 22 contributes to a more uniform gradient of the coefficient of expansion between resistor paste 14 and glass coating 20 which substantially reduces stresses between coating 20 and paste 14. The elimination of such stresses results in the reduction of strains in the paste 14 which can vary the resistor characteristics of paste 14. Another advantage of this process is that it results in a better, more predictable temperature coefficient of resistance of the resistor element.

A second advantage of the co-firing technique of this invention relates to the trimming operation to which most resistor elements are subject. Often after the final firing is completed the element 12 is submitted to a testing device which compares its resistance to that of some reference resistance. If the resistance of element 12 is lower than the reference resistance, a portion of paste 14 and the surrounding glass coating 20 is abraded away by techniques well known in the art, leaving a notch 26 in the resistor paste 14 in glass coating 20 which increases the resistance between conductors 16 and 18. Notch 26 leaves exposed a portion of resistor paste 14 which can now be sealed over with a

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lower temperature glass which sets at a temperature considerably lower than 840° centigrade, typically 525° centigrade. One such glass is DuPont 8185. After coating notch 26 with this low temperature glass 28, FIG. 5, substrate 10 can be fired to 525° for approximately 10 minutes to set the glass coating 28 without interfering with resistor paste 14 and glass coating 20 which was set at 840° centigrade, thereby eliminating the danger of disturbing the previously established resistance value of resistor paste 14.

Other embodiments will occur to those skilled in the art and are within the following claims.

What is claimed is:

1. A process for manufacturing resistor elements comprising the steps of: applying resistor material to a substrate; baking and drying the resistor material; applying a glass coating on the resistor material; baking and drying the glass coating; co-firing the material and coating at approximately 840° centigrade to form a resistor element; trimming the resistor element, applying a low temperature glass coating to the trimmed area, baking and drying the low temperature glass coating at approximately 125° centigrade and firing the resistor element and low temperature glass coating at approximately 525° centigrade.

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