THICK FILM VARISTOR AND METHOD OF MAKING THE SAME

Inventor: Clinton F. Jefferson, Norfolk, Nebr.
Assignee: Dale Electronics, Inc., Columbus, Nebr.

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Primary Examiner—C. L. Albritton
Attorney, Agent, or Firm—Zarley, McKee, Thomte & Voorhees

ABSTRACT
A thick film varistor comprising a substrate material having a varistor film or material printed thereon. Terminal conductors are electrically connected to the varistor film to terminate the varistor. The varistor material is comprised of a reacted material consisting of nickel oxide and lithium carbonate. The varistor material may also comprise glass frit material, solvent material and binder materials mixed with the reacted material. If desired, electrically conductive metal powders may be incorporated in the varistor material to vary the resistivity of the varistor material. The method of making varistor is also disclosed.

10 Claims, 4 Drawing Figures
THICK FILM VARISTOR AND METHOD OF MAKING THE SAME

BACKGROUND OF THE INVENTION

This invention relates to a thick film varistor and more particularly to a thick film varistor having the varistor film or material printed on a substrate material wherein the film is comprised of a reacted material consisting of nickel oxide and lithium carbonate.

The art of making thick film resistors is well known and is described in the prior art. This invention relates to an improved process and the formulations thereof for the preparation of thick film symmetrical nonohmic resistors, known to the industry as symmetrical varistors.

Therefore, is a principal object of the invention to provide an improved thick film varistor.

A further object of the invention is to provide a method of producing a thick film varistor having improved operating characteristics.

A further object of the invention is to provide an economical method of producing a thick film varistor.

A further object of the invention is to provide a thick film varistor wherein the varistor characteristics may be modified by the incorporation of a metal powder so as to modify the resistivity thereof.

These and other objects will be apparent to those skilled in the art.

BRIEF DESCRIPTION OF THE DRAWINGS

This invention consists in the construction, arrangements and combination of the various parts of the device, whereby the objects contemplated are attained as hereinafter more fully set forth, specifically pointed out in the claims, and illustrated in the accompanying drawings, in which:

FIG. 1 is a perspective view of a varistor produced by the method of this invention;
FIG. 2 is a perspective view of a modified form of the varistor;
FIG. 3 is a perspective view of a still further modified form of the varistor; and
FIG. 4 is a sectional view as seen along lines 4—4 of FIG. 2.

DESCRIPTION OF THE PREFERRED EMBODIMENT

In FIG. 1, the numeral 10 refers to one form of the varistor while the numerals 12 and 14 refer to other forms of the varistors in FIGS. 2 and 3 respectively. Varistor 10 comprises a pair of terminal conductors 20 and 22 having the varistor material 18 sandwiched therebetween. Conductors 20 and 22 and material 18 are positioned on a ceramic substrate body or material 16.

Varistor 12 comprises electrical conductors 26 and 28 having the varistor material 19 electrically connected thereto and extending therebetween. Conductors 26, 28 and material 19 are positioned on the ceramic substrate body or material 24.

With respect to FIG. 3, the numerals 30 refer to terminal conductors which are electrically connected by the varistor material. Conductors 30 and varistor material 32 are positioned on substrate body or material 34.

The varistor is prepared by the following process.

Conductive nickel oxide powder is prepared by ball milling nickel oxide powder with lithium carbonate powder in an acetone solution to obtain a homogeneous mixture which is then dried. The dried powders are then reacted at elevated temperatures between 1050°-1200°C to obtain a conductive nickel oxide. The amount of lithium carbonate in the mixture influences the conductivity of the resultant oxide powders, and percentages of 1 to 6 percent of lithium carbonate by weight have been found to be preferred. The reacted material nickel oxide and lithium carbonate is then ball milled in acetone until a desired particle size is obtained. The powders are then dried and screened through a 325 mesh sieve.

The nickel oxide-lithium carbonate mixture is then formulated into a thick film paste using procedures well known to those skilled in the art of formulating thick film resistor materials. Glass frit in the lead borosilicate system may be used if desired, as can other glass systems, with the choice of the glass system depending on the subsequent firing temperatures at which the thick film varistor is to be fired. Solvents and thixotropic binders may be used, such as butyl carbitol acetate, and ethyl cellulose, but the solvents and binders may be selected from other materials.

The resistivity of the material may be modified by the addition of conductive metal powder such as silver powder or nickel powder. The conductive metal powders control the value of k in the formula I = kV^n where I = Current in amperes, k = constant, V = Voltage and n = an exponent. The metal powders may be used in various amounts depending upon the value of k required. Silver powders are found to be the most effective in controlling the low-current value of the resistivity and weight ratios of Niₓ-xLiₓO₆:Ag of 100:0.0 to 50:50 have been found to produce excellent thick film varistor pastes.

The thick film varistor paste prepared according to the method described above is then printed on the substrate bodies 16, 24 or 34 (and conductors) in FIGS. 1, 2 and 3 respectively (such as Al₂O₃) in a manner familiar to the thick film industry. It should be understood that other suitable substrate materials known to the industry may also be used. The terminal conductors illustrated in FIGS. 1, 2 and 3 are used to terminate the varistor and may be comprised of such materials as Pt-Au, Pd-Au, Pd-Ag or Pt-Ag. It has been found that silver bearing conductors result in the best terminations and are the preferred embodiment. The thick film varistors are then dried and fired at temperatures of 600° to 950°C peak temperatures. The total furnace profile may vary from 20 minutes to 1 hour depending on the peak furnace temperature and the composition of the glass frit selected in the formulation.

The pattern used to print the thick film varistor may be varied and any conventional pattern currently used to print thick film varistors may be used. The selection of the pattern is based on the desired varistor characteristics. It has been found that for high current, low voltage applications, the pattern or embodiment shown in FIG. 1 is preferred while the design illustrated in FIG. 2 is preferred for low current applications. The parallel combination of varistors shown in FIG. 3 may be used when the current voltage characteristics of the parallel varistors are closely matched.

Depending on the configuration used for the varistor pattern, different varistor formulations are found to be desirable. The varistor configuration of FIG. 1 requires less conductive varistor paste than do the configura-
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Varistor formulations which have been found to be useful for the different varistor designs are shown in Table 1 below.

Table 1

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>For design of FIG. 1</th>
<th>For design of FIGS. 2 and 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ni$_{1-x}$LiO$_2$ powder</td>
<td>34.12</td>
<td>17.06</td>
</tr>
<tr>
<td>Ag or Ni powders</td>
<td>22.75</td>
<td>22.75</td>
</tr>
<tr>
<td>Glass Frit</td>
<td>7.84</td>
<td>7.84</td>
</tr>
<tr>
<td>Ethyl Cellulose</td>
<td>35.29</td>
<td>35.29</td>
</tr>
<tr>
<td>Butyl Carbitol Acetate</td>
<td>100.0</td>
<td>100.0</td>
</tr>
</tbody>
</table>

Thus it can be seen that a method has been provided for making a thick film varistor having improved operating characteristics. Thus it can be seen that the varistor and method of making the same accomplishes all of its stated objectives.

1. A thick film varistor, comprising, a varistor material positioned on said substrate material, terminal conductors electrically connected to said varistor material, said varistor material being comprised of a reacted material consisting of nickel oxide and lithium carbonate.

2. The varistor of claim 1 wherein said lithium carbonate comprises 1 to 6 percent by weight of the said reacted material and wherein said nickel oxide comprises 94 to 99 percent by weight of the reacted material.

3. The varistor of claim 1 wherein said varistor material also comprises a glass frit material mixed with said reacted material.

4. The varistor of claim 3 wherein said varistor material also comprises solvent and binder materials mixed with said glass frit material and said reacted material.

5. The varistor of claim 3 wherein said varistor material also comprises electrically conductive metal powders mixed with said glass frit material and said reacted material.

6. The varistor of claim 5 wherein said metal powder is silver powder.

7. The varistor of claim 5 wherein said metal powder is nickel powder.

8. The varistor of claim 4 wherein said solvent material is butyl carbitol acetate and wherein said binder material is ethyl cellulose.

9. The varistor of claim 1 wherein said varistor material approximately comprises 17.06 percent by weight nickel oxide-lithium carbonate; 17.06 percent by weight nickel powder; 22.75 percent by weight glass frit; 7.84 percent by weight ethyl cellulose; and 35.29 percent by weight butyl carbitol acetate.

10. The varistor of claim 1 wherein said varistor material approximately comprises 34.12 percent by weight nickel oxide-lithium carbonate; 22.75 percent by weight glass frit; 7.84 percent by weight ethyl cellulose; and 35.29 percent by weight butyl carbitol acetate.

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