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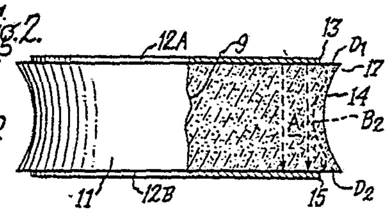
(54) Zinc oxide varistor with reduced fringe current effects.

(57) A zinc oxide varistor disc is provided with a reduced cross section in the vicinity of the rim to deter the transport of fringing current in the vicinity of the edges of the electrodes which are of a lesser diameter than the varistor disc. One emobodiment comprises a varistor disc having a plurality of grooves formed circumferentially around the disc perimeter.

Fig.2.



EP 0 058 336 A2

ZINC OXIDE VARISTOR WITH REDUCED FRINGE CURRENT EFFECTS

BACKGROUND OF THE INVENTION

U.S. Patent 3,913,056 discloses a method for preventing currents from channeling through preferred current paths within zinc oxide varistors.

Zinc oxide varistors, as currently manufactured, comprise a sintered disc of zinc oxide material having a pair of electrodes on opposing surfaces of the disc. The perimeter of the disc is covered with an insulating layer of glass or ceramic material to prevent the transport of current across the outside surface of the disc perimeter. When the electrodes are applied to the flat faces of the disc, a portion of the disc material in the vicinity of the disc rim is not covered with the electrode material because the physical transition from the flat disc surface to the peripheral rim may not be well defined. During varistor operation, current transports directly through the zinc oxide material covered by the electrode material. However, in actuality some current also transports through the zinc oxide material in the vicinity of the rim not covered by electrode material. This current is referred to as "fringing current" and can be a source of failure when the varistor is operated during conditions of overload. The transport of fringing current in the rim portion of the disc not covered by electrode material causes a concentration of current at the edges of the disc electrodes. The current concentration at the electrode edges causes an excess electrical stress in this area which leads to premature disc failure during overload conditions.

The purpose of this invention is to provide a zinc oxide varistor having substantially reduced fringing current effects and consequently a greater overload capability.

SUMMARY OF THE INVENTION

Zinc oxide varistors are provided with a reduced cross section in the vicinity of the rim. One or more circumferential grooves formed around the disc perimeter substantially reduces the effects of fringing current during varistor operation.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGURE 1 is an end view of a zinc oxide varistor in partial section showing the transport of varistor current and fringing current;

FIGURE 2 is a side view in partial section of a zinc oxide varistor having a reduced cross sectional area in the vicinity of the varistor rim; and

FIGURE 3 is a side view in partial section of a zinc oxide varistor having a pair of circumferential grooves extending around the disc perimeter.

DESCRIPTION OF THE PREFERRED EMBODIMENT

A zinc oxide varistor 10 having the composition disclosed within U.S. Patent 3,928,245 is shown in FIGURE 1. Varistor 10 comprises a sintered zinc oxide disc 11 having a pair of top and bottom metallic electrodes 12A, 12B on opposing surfaces. Electrodes 12A, 12B extend across disc 11 leaving a top portion D_1 between edge 13 of top electrode 12A and edge 14 of disc 11. A portion D_2 on the bottom of disc 11, between edge 15 of bottom electrode 12B and edge 14 of disc 11, is also not covered by electrode material. The height of disc 11 is defined by D_3. Dotted path

16 extending between top electrode 12A and bottom electrode 12B through disc 11 defines "fringe" area S_1 through which fringe current B_1 transports in the direction indicated by arrows. The direction of ordinary current transport between electrodes 12A, 12B is depicted by arrow A. As described earlier, the transport of current through fringe area S_1 causes damage to the disc material near the edges 13 and 15 of top and bottom electrodes 12A and 12B respectively.

Dotted paths A and B_1 of FIGURE 1 represent filaments of current flowing from top electrode 12A to bottom electrode 12B due to a difference of potential between the two electrodes. The relationship between current density J and electric field E in a zinc oxide disc is approximately given by the equation $J = KE^n$ where K is a constant of proportionality and n is an exponent which ranges between approximately 15 and 60. When dotted paths A and B_1 of FIGURE 1 represent paths of constant current density, the field along each path is constant and inversely proportional to the path length.

For example, when path B_1 is 2 percent longer than path A, the field along path B_1 is 0.98 times as great as path A. For a value of exponent n equal to 15, the current density along path B_1 is $(0.98)^{15}$, which equals 0.74 times path A. For a value of exponent n equal to 40, the current density along path B_1 is $(0.98)^{40}$, which equals 0.45 times path A. When the field is reduced to 0.96 times path A, by increasing the path length by 4 percent, the current density along path B_1 is $(0.96)^{40}$, which equals 0.20 times path A for a value of exponent n equals to 40. This shows, therefore, that the higher the value of exponent n, or the longer the average effective fringing current path B_1, the lower the fringing current density.

FIGURE 2 shows a zinc oxide varistor 10 having a top electrode 12A and a bottom electrode 12B with areas D_1 and D_2 between electrode edges 13 and 15 and disc periphery 14. Perimeter 14 in this embodiment is concave such that the minimum disc diameter approximates that for the electrodes 12A, 12B. Fringing current path B_2, as shown, is greater than fringing current path B_1 of FIGURE 1. Consequently, the fringing current density is greatly reduced for the embodiment depicted in FIGURE 2.

A disadvantage with the embodiment of FIGURE 2 is that the disc corners 17 are sharp and become subject to damage by chipping.

A further embodiment having reduced fringing current is shown in FIGURE 3 to consist of a zinc oxide disc 11 similar to that of FIGURE 1, with at least one circumferential groove 18 formed by abrading, machining or mold-forming techniques. For the embodiment shown in FIGURE 3 two grooves 18 are shown, one proximate the top and the other proximate the bottom of disc 11 and extending within disc 11 to a distance approximately in line with electrode edges 13 and 15. The fringing current path B_3 is seen to be greater than B_1 of FIGURE 1, such that the fringing current density is proportionately reduced. It is to be clearly understood that the arrangement of grooves 18 can be modified depending upon the desired results. One or more grooves 18 can be employed, and the shape and depth of the grooves can be designed to accommodate various manufacturing techniques.

A specific example containing two grooves 18, such as shown in FIGURE 3, and ranging from 0.06 to 0.10 inches in radius extending entirely around the perimeter of disc 11 was manufactured having the following dimensions. Height D_3 measured 1.375 inches and separation distances D_1 and D_2 for top and bottom electrodes 12A and 12B measured approximately 0.086 inches. The maximum electric strength measured higher for this example than any previous varistors having the configuration shown in FIGURE 1.

Varistor 10 also contained an insulating coating of glass or ceramic material 9 around the perimeter of the disc and covering the zinc oxide material within grooves 18. In some instances, where the voltage demand across varistor 10 is not too high, a plurality of grooves 18 extending along the disc perimeter can increase the voltage "creep" to the extent that no glass or ceramic coating 9 need be employed. The addition of a glass or ceramic coating 9 over discs having a plurality of grooves 18 further increases the breakdown voltage capability of varistor 10.

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CLAIMS

1. A zinc oxide varistor having reduced fringing current off the electrode edges comprising:

a sintered disc of zinc oxide material;

a pair of electrodes, one on either face of said disc for providing electrical connection with said disc;

said disc having a reduced diameter intermediate said electrodes to reduce the amount of zinc oxide material between the edges of said electrodes and the perimeter of said disc.

2. The varistor of Claim 1 wherein said disc perimeter defines a concave configuration.

3. The varistor of Claim 1 wherein said reduced area is provided by at least one groove extending around said disc perimeter.

4. The varistor of Claim 2 wherein said reduced area is provided by a pair of grooves, one groove proximate each of said electrodes.

5. The varistor of Claim 1 further including a glass or ceramic collar on said disc perimeter to improve the voltage withstand capability of said varistor.

6. A method for providing a zinc oxide varistor having reduced fringing current comprising the steps of:

providing a sintered disc of zinc oxide material having a reduced diameter intermediate the opposing faces of said disc; and

providing an electrode on each of said disc faces.

7. A method of Claim 6 including the steps of providing a layer of glass or ceramic material around the perimeter of said disc to increase the voltage withstand capability of said varistor.

8. The method of Claim 7 including the step of providing a concave configuration to the perimeter region of said disc.

9. The method of claim 6 including the
The method of claim 6 including the

provision of at least one groove extending circumferentially around the perimeter of said disc material.

10. The method of Claim 9 including the steps of providing a plurality of said grooves around the perimeter of said disc to improve the voltage withstand capability of said disc.

11. The method of Claim 10 including the step of providing a coating of glass or ceramic material to said disc perimeter to further increase the voltage withstand capability of said disc.

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Fig.1.

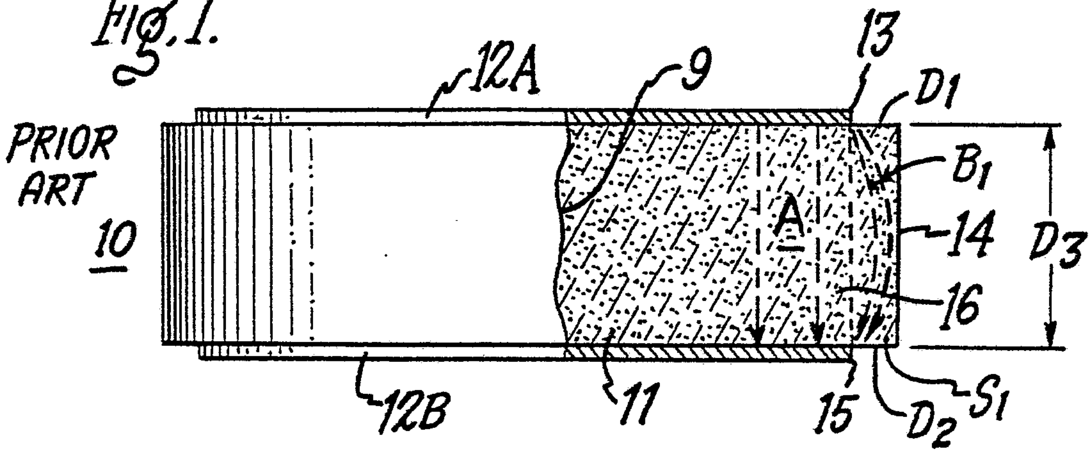

Fig.2.

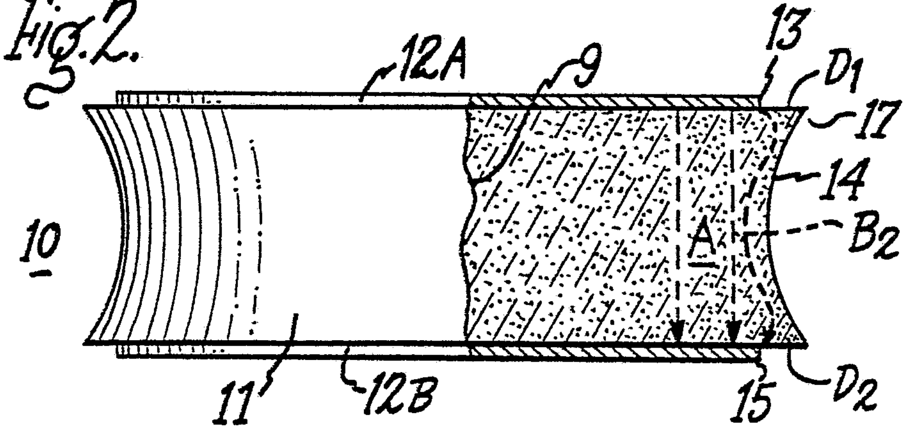

Fig.3.