

[54] **FILM-TYPE POWER RESISTOR**

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 [21] Appl. No.: **40,308**

Related U.S. Application Data

- [63] Continuation-in-part of Ser. No. 847,783, July 18, 1969, abandoned, which is a continuation-in-part of Ser. No. 820,538, Apr. 30, 1969, abandoned.
 [52] U.S. Cl. **338/260, 338/51, 338/275, 338/309, 338/320, 338/328**
 [51] Int. Cl. **H01c 1/02**
 [58] Field of Search **338/308, 309, 295, 260, 275, 338/320, 57, 226, 328, 262**

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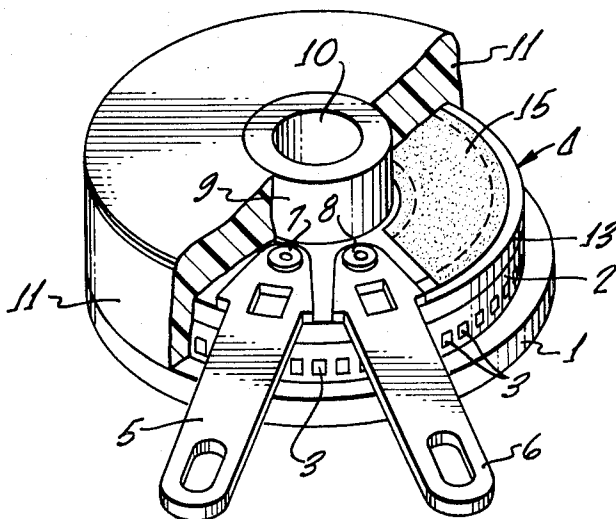
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[57] **ABSTRACT**

A film-type power resistor consists of a ceramic wafer or washer having a central opening, one side of such washer being printed at its outer and inner edges with generally annular traces of termination metal. An electrically resistive film is printed on such one side over all portions of, and between, the termination metal, excepting for predetermined adjacent end portions which are connected to radially outwardly extending terminal lugs or leads. In one embodiment, the metal traces are continuous, whereas in another embodiment they are interrupted in order to create series-related resistor portions. The washer (and its associated films) are mounted over a metal base and are embedded in a thermosetting synthetic resin, the base having an upwardly extending central post which passes through the opening in the washer to the upper surface of the resin.

In accordance with the method, the planar surface of a ceramic substrate is first printed with termination film traces, following which such traces are overprinted with electrically resistive film. The ceramic (with its associated coatings) is then fired in order to cure the resistive film. Thereafter, the entire outer surface of the resistive film is uniformly abraded by means of a jet of abrasive particles, the abrading continuing in a uniform manner until the resistive film is within the required tolerance. During the abrading step, the terminal regions of the terminal film traces are masked. Thereafter, terminal lugs or leads are connected to such terminal regions.

14 Claims, 10 Drawing Figures



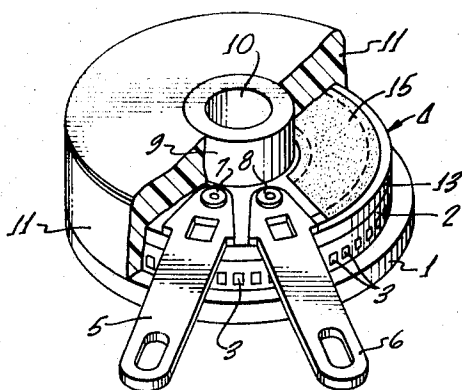


FIG. 1.

FIG. 2.

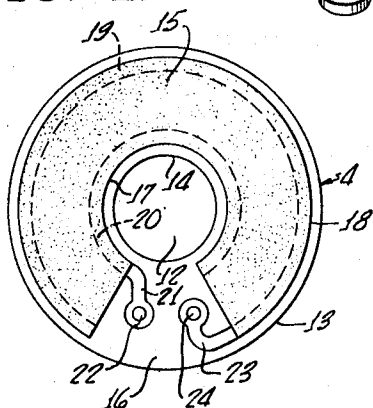


FIG. 2a.

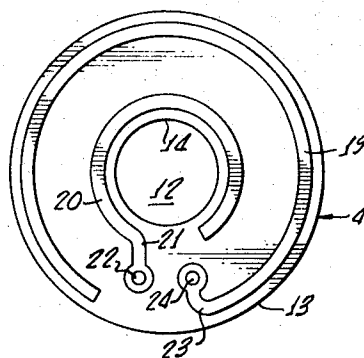
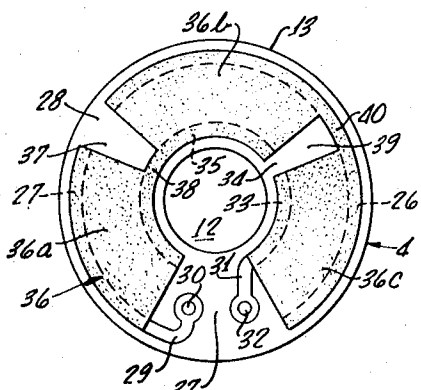


FIG. 3.

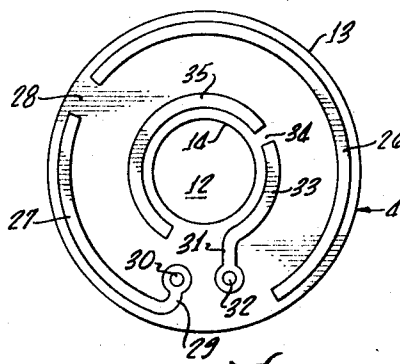


FIG. 3a.

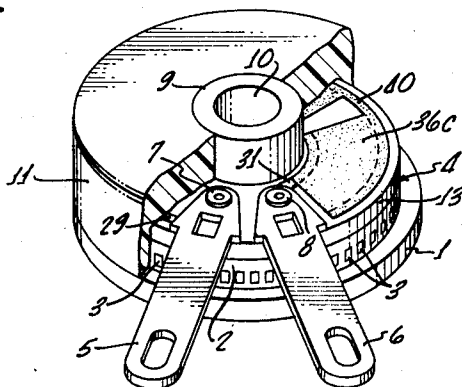


FIG. 4.

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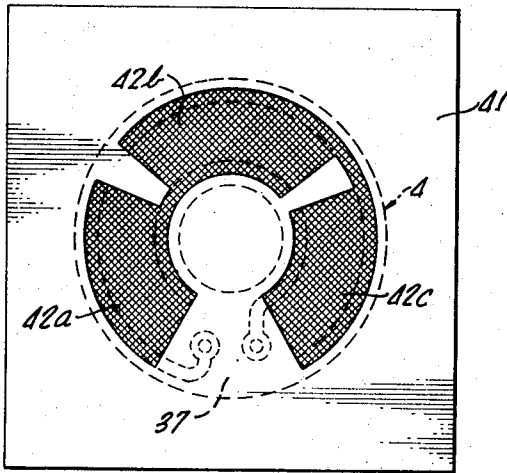


FIG. 5.

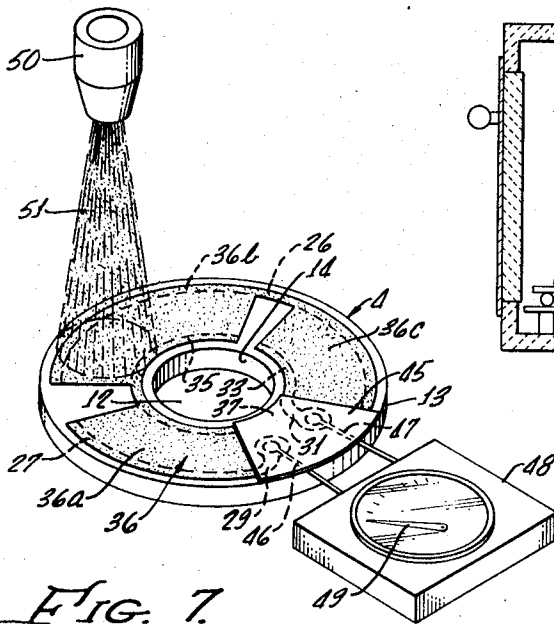


FIG. 7.

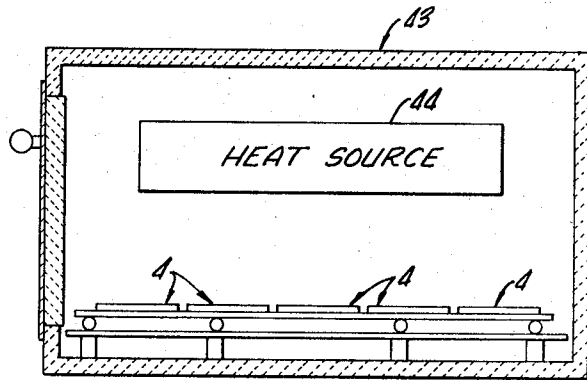


FIG. 6.

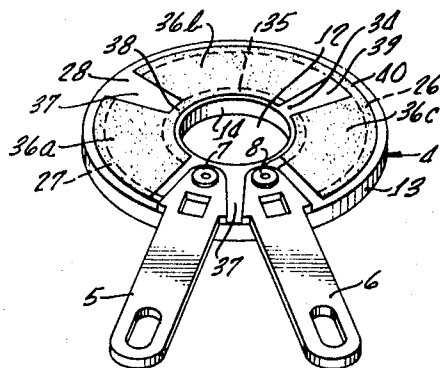


FIG. 8.

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FILM-TYPE POWER RESISTOR

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a continuation-in-part of application Ser. No. 847,783, filed July 18, 1969, for Power Resistors, by the present applicant, and now abandoned. Said application is, in turn, a continuation-in-part of patent application Ser. No. 820,538, filed Apr. 30, 1969, for Power Resistors by the present applicant, and now abandoned.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to the field of film-type power resistors, of the type described in copending patent application Ser. No. 40,218 filed on even date herewith, and of methods of making them.

2. Description of Prior Art

It has previously been known to provide resistors of the film type and incorporating divergent radial flow of electric current, and it has also been known to effect overprinting of terminal film traces with film-type resistor material. However, the prior art has not achieved planar power resistors characterized by divergent radial flow and having adjacent outwardly extending terminal elements, central openings for stack or other mounting to a chassis, a wide range of predetermined resistance values ranging from (for example) one-tenth square to one square, and other advantages. In addition, the prior art has not suggested combining such power resistor elements with metal bases, particularly in combination with upwardly extending central posts, and molded and embedded in masses of thermosetting synthetic resin.

Relative to the method, the prior art has employed numerous ways to vary the value of a film-type resistor. These have included changing the quantity of conductive material in the film in proportion to the quantity of nonconductive material therein, applying films of different thicknesses to the substrate, employing abrasive blast or other means to notch completely through portions of the film to thereby adjust the resistance of the film, and changing the materials employed. It has also been known to apply a resistive film to a cylindrical substrate and then uniformly abrade the substrate by means of an abrasive jet in order to regulate the resistance of the film, but such abrading of the cylindrical substrate was not commercially practical or successful.

The prior art has not provided, insofar as applicant is informed, a method of manufacture whereby a film of resistive material is overprinted on termination metal on a planar substrate of insulating material, following which the film is uniformly abraded in order to achieve a desired close tolerance relative to resistance value. In addition, the prior art has not provided such a method in combination with a masking method for end terminations, and wherein the mask serves additionally to protect leads to an ohmmeter which determines when the desired resistance has been achieved. Furthermore, the art has not provided such a method in combination with the attaching of radially outwardly extending terminal lugs or leads.

SUMMARY OF THE INVENTION

The power resistor of the invention includes a wafer or washer (substrate) formed of insulating material and having a central hole therethrough, and also having annular traces of termination metal film on one surface thereof and adjacent, respectively, the inner and outer marginal edges of the wafer. In accordance with one embodiment, the annular termination traces are interrupted only at the terminal ends thereof, and to which radially outwardly extending terminal lugs or leads are attached. In another embodiment, the annular termination traces are interrupted at predetermined points creating series-related resistors. On such one surface of the washer is provided, over and between the annular termination traces except at the terminal ends thereof, a film of electrically resistive material. In the second of the above-mentioned embodiments,

the film is provided with radial gaps to achieve the indicated series relationship. The resistor element is mounted on a metal base having an upwardly extending post which passes through the hole in the wafer or washer, and the wafer, terminal lugs or leads, etc., are molded in a thermosetting synthetic resin.

In accordance with the method, the planar surface of an insulating substrate is provided with termination traces of metal or other highly conductive material, following which a film of resistive material is overprinted on such traces and on other portions of the substrate. The substrate and associated films are then fired to cure the resistive material, following which a jet of abrasive material is employed to effect uniform abrasion of all portions of the resistive film. The abrading step is continued until the desired resistance is achieved, such resistance being determined by connecting an ohmmeter or the like to the terminal ends of the termination traces at a region which is masked to shield the same from the abrasive blast. Terminal lugs or leads are then connected to the terminal ends of the traces, and extend radially outwardly.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view, with portions broken away, showing a first embodiment of a power resistor manufactured in accordance with the present invention;

FIG. 2 is a top plan view of the resistive element incorporated in the embodiment of FIG. 1;

FIG. 2a is a view corresponding to FIG. 2 but omitting a showing of the resistive film, so that only the substrate and the termination traces are shown;

FIG. 3 is a view corresponding to FIG. 2 but showing a second embodiment of the invention, wherein a plurality of segments are provided in series relationship;

FIG. 3a corresponds to FIG. 3 but with the resistive film omitted;

FIG. 4 shows the embodiment of FIGS. 3 and 3a as incorporated in a power resistor including a metal base, an upstanding central post and a mass of thermosetting synthetic resin;

FIG. 5 illustrates one of the first steps in the method of the invention, and schematically represents a silk-screen mask employed to print an insulating substrate with resistive film;

FIG. 6 schematically represents the firing of the film-bearing substrate after printing thereof;

FIG. 7 schematically represents the masking of the terminal ends of the termination traces, the connection of the ohmmeter or the like to such terminal ends at a region below the mask, and the uniform abrading of the resistive film by means of a jet of abrasive material; and

FIG. 8 represents the element manufactured in accordance with FIGS. 5-7, but after completion of a subsequent step whereby terminal lugs are riveted or otherwise secured to such element.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

In a copending patent application, filed on even date herewith, for Power Resistor, and Method of Making the Same, there is described one form of a film-type resistor which generates a higher temperature at the center of the device than at the periphery thereof, with consequent favorable temperature gradient and high rate of dissipation of the generated heat. The present application describes (FIGS. 1-4, inclusive) several other types of film resistors which generate favorable temperature gradients, and which are employed for different ranges of resistance values. In addition, the present application describes (FIGS. 5-8) a method of manufacturing the specified film-type resistors and also other forms of film-type resistors having planar surfaces.

Referring first to FIG. 1, the illustrated power resistor is identical to one described in detail and in said copending patent application filed on even date herewith, particularly relative to FIGS. 6, 7, 9 and 10 thereof, except for the configurations of the resistive film and of the associated termination traces (of film). Thus, the resistor comprises a disc-shaped

metal base 1, preferably formed of anodized aluminum, the upper edge of which is radially inwardly indented to form a smaller-diameter cylindrical wall 2 having a plurality of recesses 3 spaced circumferentially therearound. A wafer or washer 4 of ceramic, such as aluminum oxide or beryllium oxide, has planar upper and lower surfaces, the latter being disposed in flatwise heat-transfer relationship to the planar upper surface of base 1.

The resistive film provided on the upper surface of wafer 4, and which is described below relative to FIG. 2, is associated with film-type termination traces or strips which connect, respectively, with radially outwardly extending terminal lugs 5 and 6. These are, respectively, riveted to wafer 4 by means of rivets 7 and 8 as described in detail relative to FIG. 10 of the cited copending application of even date. In place of the terminal lugs 5 and 6, the terminal conductors may comprise flexible leads enclosed in insulating material, as described relative to FIGS. 17 and 18 of the cited copending application of even date. The lugs or leads may also be directly brazed to the terminal ends of the termination traces.

The metal base 1 is integral with an upwardly extending tubular post 9 having a central opening 10 therethrough, the latter communicating with a corresponding opening in the center of the base 1. Thus, a mounting bolt may be inserted clear through the base 1 and post 9 for mounting of the resistor to an underlying metal chassis plate, and also for mounting of a plurality of resistors in stacked relationship and in alternation with heat-transfer fins.

A mass 11 of thermosetting synthetic resin, preferably a silicone thermosetting resin, is molded around post 9 and over washer 4 and its associated termination and resistive films, and also over the inner ends of the terminal lugs 5 and 6. The resin mass 11 extends downwardly around the smaller-diameter cylindrical wall 2 and into the recesses 3 to effect locking of the resin relative to the base, against both rotational and axial movements. The outer wall of the resin mass 11 is preferably cylindrical, and the upper surface of the resin is perpendicular to the axis of post 9 and flush with the upper end of the post. Such upper surface of the resin mass is parallel to the planar lower surface of base 1, to thereby facilitate stacking of the assemblies as indicated above.

The wafer or washer 4 has a central opening 12 therein to receive the post 9. Thus, in addition to its parallel and planar upper and lower surfaces, each wafer or washer 4 has concentric cylindrical outer and inner edge surfaces 13 and 14, respectively. The outer cylindrical surface, No. 13, is the peripheral surface or edge and is concentric with the inner edge surface 14 which marks the inner boundary or margin of the wafer.

A major aspect of the present invention relates to film and termination trace configurations whereby a very large proportion of the upper surface of wafer 4 may be covered with resistive film, while still creating a wide range of resistance values. In addition, and very importantly, the configurations are such that the terminal lugs 5 and 6 (or corresponding leads) may be located adjacent each other on one side of the resistor (and on one side of post 9) and may both extend radially outwardly, there being no need for central connections.

The films described herein create radial conduction paths for the electrical current, and (additionally) result in divergent flow or "fanning-out" of the radially flowing current. The result is a markedly higher current density at the portions of the film closer to central opening 12. Therefore, and since the power varies with the square of the current, but only linearly with the resistance, it follows that more power is present adjacent the opening 12 than adjacent the peripheral edge 13. The temperature generated at the central region is thus higher than at the periphery, with consequent favorable temperature gradient as stated in the copending patent application filed on even date herewith.

FIGS. 2 and 2a relate to a first configuration of the divergent radial-flow film resistor. Such FIGS. 2 and 2a illustrate the element and associated termination and resistive films incorporated in the completed resistive device of FIG. 1.

The resistive film 15 of the embodiment of FIGS. 1, 2 and 2a is generally C-shaped, there being a gap 16 in the otherwise annular configuration. The inner edge of the film 15 is shown at 17 and spaced outwardly a slight distance from the inner boundary 14 of wafer 4. Correspondingly, the outer edge 18 of film 15 is spaced somewhat inwardly from the peripheral edge 13 of the wafer.

Film 15 is adherently provided on the upper surface of wafer 4 by any one of various techniques, including painting, spraying, etc. Preferably, film 15 is applied by silk screening and as indicated hereinafter relative to FIG. 5. The resistive film, which is preferably a complex metal oxide in a glass matrix, is fired and otherwise treated (after the screen-printing operation) as stated in the method portions of this specification.

As best shown in FIG. 2a, outer and inner concentric annular termination traces or strips 19 and 20, respectively, are provided on the upper surface of wafer 4 beneath film 15 (such film being screened over the traces 19 and 20). Each of such traces 19 and 20 is continuous except in the vicinity of gap 16 on the film. At such gap, one end of the inner trace 20 bends outwardly at 21 and terminates at a hole 22 through the wafer 4. Correspondingly, the other end of the outer trace 19 bends inwardly at 23 and terminates at a hole 24 in wafer 4. Such holes are adapted to receive the above-indicated rivets 7 and 8, respectively. Each trace end position 21 and 23 ends in a circular trace region (which forms the terminal end of the termination trace) around the associated hole 22 or 24, to thereby increase the degree of electrical contact between terminal lugs 5 and 6 (or the flexible leads) and the traces.

The traces or strips 19 and 20, etc., are films of metal or other highly conductive material, as indicated in the method portions of this specification.

With the described configurations of film 15 and of traces 19 and 20, the length of the current path between the terminals is equal to the radial distance between inner trace 20 and outer trace 19. Because of the generally annular configuration of the resistor, the current diverges as it flows outwardly (or converges as it flows inwardly). The distances shown in FIG. 2 are approximately such that the indicated radial path is only about one-tenth of the average circumference of the annular film (excluding the gap 16). Accordingly, the described configuration produces about one-tenth square of resistive film. Since the pattern produces about one-tenth square, and assuming that the thickness and other characteristics of the film are such that the film has a resistance value of 100 ohms per square, then the configuration of FIGS. 2 and 2a produces a resistance value of approximately 10 ohms.

EMBODIMENT OF FIGS. 3, 3a AND 4

In the embodiment of FIGS. 3, 3a and 4, all components correspond to the ones described in the embodiment of FIGS. 1, 2 and 2a except as specifically stated. Thus, there are outer and inner concentric traces overprinted by a resistive film, but such traces and film are interrupted in a predetermined manner as stated below.

As best illustrated in FIG. 3a, the outer trace or strip has a first section, numbered 26, which extends for more than one-half a circle, namely about 200°. A second section 27 of the outer trace is separated from the first section by a gap 28 and extends for a much smaller distance, for example through an angle of about 100°. The end of second section 27, remote from gap 28, turns inwardly at 29 and extends to a hole 30 in wafer 4, namely the hole for rivet 7 or for a connector to a flexible lead.

Referring next to the inner trace, this comprises a portion 31 which extends from a hole 32 in wafer 4 and then connects to a relatively short trace portion 33 (extending, for example, through about 90°). There is then a gap 34, located radially inwardly from an intermediate region of trace section 26. A second inner trace portion 35 extends, for example, through about 200°. An intermediate region of such second portion 35 of the inner trace is disposed radially inwardly from gap 28 in the outer trace.

A resistive film 36 is printed over the specified traces, in interrupted C-shaped configuration (the gap in the "C" being at the terminal region and indicated at 37), as shown in FIG. 3.

Film 36 is also interrupted (formed with a radial gap) at the region of gap 28 and radially inwardly thereof, but the film is not interrupted at any region above the second trace portion 35. Stated otherwise, a film region 38 is provided (FIG. 3) above trace portion 35 and radially inwardly from gap 28 in the outer trace. Thus, in the region 38 the resistive film is overprinted on the inner trace 35, and the parallel combination of such overprint 38 and the inner trace 35 form the sole electrical connection between two adjacent segments 36a and 36b of film 36.

Another radial gap, numbered 39, is provided in film 36 between portions 36b and 36c at the region of, and radially outwardly from, gap 34 in the inner trace. However, the resistive material is overprinted on all of the outer trace portion 26, including the part indicated at 40 in FIG. 3. Thus, the parallel combination of the resistive overprint 40 and the underlying region of outer trace 26 form the sole connection between the two adjacent segments 36b and 36c of resistive film 36.

It will thus be seen that the pattern of FIG. 3 results in three segments of resistive film, each being such that there is a divergent radially outward or radially inward flow of the electrical current. Assuming, for example, that the terminal connected to the wafer 4 at hole 30 is the positive terminal, current flows through trace portion 29 to trace section 27 and thus to the outer edge of film section 36a, then flows radially inwardly in convergent manner to the leftmost region (FIG. 3) of second trace portion 35, then flows through the parallel-related overprint 38 and trace portion 35 to the rightmost region of trace portion 35, then flows radially outwardly in divergent manner through film section 36b to the leftmost region of trace 26, then flows through the overprint 40 and adjacent region of outer trace portion 26 to the rightmost region of the latter trace portion, then flows radially inwardly in convergent manner through resistive film section 36c to trace portion 33, and then flows through trace section 31 to the terminal connected to the wafer at hole 32.

The three segments of radial conduction 36a, 36b and 36c are thus in series-circuit relationship relative to each other. Each segment 36a, 36b and 36c has a "length" that is approximately one-third of its "width," so that each segment provides approximately one-third square. The three segments being connected in series, it follows that the total is approximately one square, which is equal to about 100 ohms if 100 ohms per square resistive film material is employed.

The radial-flow embodiments described above are characterized by very high rates of heat dissipation, by an efficient use of the upper surface of the wafer 4, and by terminations which permit radially outwardly extending conductors (such as terminal lugs 5 and 6) to be utilized.

DESCRIPTION OF THE METHOD

The method of the invention will be described relative to the manufacture of the element shown in FIG. 3 (the embodiment of FIGS. 3, 3a and 4) but it is to be understood that such method may also be performed relative to the embodiment of FIGS. 1, 2 and 2a, relative to the embodiment shown in the cited copending application filed on even date herewith, and relative to various other film-type resistor configurations wherein the film is provided on a planar surface.

As the first step in the method, the ceramic wafer 4 is formed in a press and in the illustrated annular shape, having the central opening 12. Such press preferably incorporates means to form the holes 30 and 32 and also the counterbores described relative to FIGS. 7 and 10 of the cited copending application filed on even date herewith. As above indicated, the ceramic may be, for example, aluminum oxide or beryllium oxide. After pressing, the ceramic wafer is fired.

The next step in the method is to provide the termination traces, such as 26, 27, 33 and 35, on the upper planar surface

of wafer 4 and as best illustrated in FIG. 3a. This may be done by silk-screen printing techniques in the general manner shown schematically in FIG. 5 except using a screen which corresponds to the indicated termination traces instead of to the openings for the resistive film. Alternatively, the traces may be applied by vacuum deposition, or by using a ceramic matrix print having the metal incorporated therein. After the trace metal is applied, by any of the indicated (or other) methods, the wafer or base is fired to further bond the metal thereto. The firing may be effected, for example, in the oven shown schematically in FIG. 6.

The metal of the termination traces or strips should have good electrical conductor characteristics and may be, for example, either gold or a gold-platinum alloy.

As the next step in the method, and as indicated schematically in FIG. 5, the resistive film, such as 36, is provided on the base or wafer 4 and in overprinted relationship to all portions of the terminal traces except at the gap 37 in the resistive film. The resistive film may be applied by silk screening, painting, spraying, etc.

FIG. 5 shows a mask 41 having screen openings 42a, 42b and 42c therein and corresponding, respectively, to the film segments 36a, 36b and 36c (and interconnecting portions 38 and 40) shown in FIG. 3. The screen in openings 42a, 42b and 42c may be, for example, 250 mesh (U.S. Standard Sieve Series). Alternatively, and when a thicker deposit of resistive film is required, as relative to the low-resistance embodiment of FIGS. 1, 2 and 2a, the size of the screen may be 100 mesh.

After application of the resistive film as indicated relative to FIG. 5, the wafer 4 with films thereon is again fired in an oven, for example the oven 43 schematically represented in FIG. 6 and which contains a heat source schematically indicated at 44.

Referring next to FIG. 7, a segment-shaped mask 45 is mounted over the gap 37 in the resistive film, that is to say over the exposed terminal ends 29 and 31 (FIG. 3a) of the traces, in order to prevent the abrasive blast from abrading the trace metal at such termination ends. The present method further employs the use of probes (electrically conductive) which are mounted on the underside of mask 45 (in mutually insulated relationship relative to each other). The probes connect, respectively, to trace portions 29 and 31 (and associated circular trace ends, adjacent holes 30 and 32), when the mask 45 is in position.

Probes 46 and 47 connect to the terminals of an ohmmeter represented schematically at 48 and which is indicated as having a readout needle 49. The ohmmeter 48 may be a Wheatstone bridge (or other) arrangement electrically associated with the abrasive blast means, described in the following paragraph, to automatically terminate the abrasive blast when the resistive value of the film 36 on wafer 4 reaches the desired tolerance range.

The abrasive blast is delivered from a nozzle represented schematically at 50 (and which connects to a suitable source of abrasive), emanating therefrom in the form of a jet 51 in the diameter of which, at the substrate or wafer 4, is approximately equal to the distance between the inner diameter of wafer 4 and the outer diameter thereof. Means, not shown, are provided to scan or move the nozzle relative to the wafer in such manner that all portions of the resistive film on wafer 4 are uniformly abraded. The scanning means may move the nozzle relative to the wafer, or may move the wafer and associated mask 45 while leaving the nozzle 50 stationary.

The abrasive blast or jet 51 from nozzle 50 is directed against the planar upper surface of resistive film 36 (and the planar upper surface of wafer 4) in a direction perpendicular to such upper surface. Therefore, the abrasive particles bounce backwardly and may be readily retrieved by vacuum or other means.

After the desired resistive value has been achieved, as indicated by ohmmeter 48 or an equivalent circuit, it is merely necessary to connect to wafer 4 the terminal lugs 5 and 6 (or corresponding flexible leads) by means of the rivets 7 and 8.

Such terminal lugs may be, for example, gold-plated brass or "Monel." There is shown in FIG. 8 the completed resistive element and associated terminals. Such completed resistive element is then, in accordance with the next step, mounted on base 1 (FIG. 4). The thermosetting synthetic resin 11 is then

molded over the resistive element, as described in detail in the copending patent application filed on even date herewith, in order to complete the resistor.

The resistive film configuration shown in the embodiment of FIGS. 3, 3a and 4 may produce a resistance range, for example, of from 100 ohms to 1,600 ohms (or a much different range depending upon the type of resistive material, etc.). The resistive film shown relative to the embodiment of FIGS. 1, 2 and 2a may produce a resistance value in the range of about 10 ohms to about 160 ohms (or other range where different materials, etc., are employed).

The use of the term "wafer," as employed in the present specification and/or claims, is not intended to denote or imply that the insulating substrate for the resistive and metal films is circular or round.

I claim:

1. A film-type resistor, which comprises
a wafer formed of electrically insulating material and having a central opening therein,
outer and inner traces of electrically highly conductive material adherently provided on the upper surface of said wafer and in encompassing relationship to said opening, said outer trace being relatively remote from said opening,
said inner trace being relatively adjacent thereto,
said outer trace having a terminal end disposed on one side of said opening,
said inner trace having a terminal end disposed on said one side of said opening, and
a film of electrically resistive material adherently provided on said upper surface of said wafer and in encompassing relationship to said opening,
said resistive film having a gap therein at said opening,
said resistive film being in electrical contact with said outer and inner traces throughout at least the great majorities of the lengths thereof,
whereby electric current may flow radially inwardly through said film between said outer and inner traces in convergent manner or radially outwardly therebetween in divergent manner.
2. The invention as claimed in claim 1, in which first and second terminal conductors are connected, respectively, to said terminal ends of said outer and inner traces and extended outwardly from the resistor for connection in an electrical circuit.
3. The invention as claimed in claim 1, in which said outer trace is continuous between said terminal end thereof and another end also disposed on said one side of said opening, and in which said inner trace is continuous between said terminal end thereof and another end also disposed on said one side of said opening, whereby a single low-resistance resistor is formed by said resistive film between said terminal ends of said inner and outer traces.
4. The invention as claimed in claim 1, in which said outer trace is interrupted at at least one point between said terminal end thereof and the other end thereof, said other end of said outer trace being disposed on said one side of said opening, in which said inner trace is interrupted at at least one point between said terminal end thereof and the other end thereof, said other end of said inner trace being disposed on said one side of said opening, and in which portions of said resistive film are interrupted at the trace interruptions and also at the adjacent regions between said inner and outer traces, said interruptions being such that at least three series-related radial-flow film-type resistors are formed by said resistive film between said terminal ends.
5. The invention as claimed in claim 1, in which at least one of said inner and outer traces is interrupted at a region

between said terminal end thereof and the other end thereof, said other end thereof being disposed on said one side of said opening, and in which said resistive film is correspondingly interrupted at the trace interruption and also at the adjacent region between said inner and outer traces, said interruptions being such that at least two film-type radial-flow resistors are provided by said resistive film between said traces and in series-circuit relationship relative to each other between said terminal ends.

6. The invention as claimed in claim 5, in which the connection between said two series-related resistors is formed by the other of said inner and outer traces, said other trace being overprinted with said resistive film, whereby current flow between said series-related resistors is through the parallel combination of said other trace and the resistive overprint thereon.

7. The invention as claimed in claim 1, in which said wafer has concentric inner and outer edges each of which is circular, said inner edge defining said opening in said wafer, and in which said inner and outer traces are parallel to and respectively adjacent said inner and outer edges.

8. The invention as claimed in claim 1, in which said resistive film is overprinted over said traces at all portions of said traces except at said terminal ends thereof.

9. The invention as claimed in claim 1, in which said wafer is formed of ceramic, said traces are metal films, and said resistive film is a complex metal oxide in a glass matrix.

10. The invention as claimed in claim 1, in which first and second terminal conductors are connected, respectively, to said terminal ends of said outer and inner traces and extend outwardly from the resistor for connection in an electrical circuit, and in which said terminal conductors are first and second terminal lugs secured, respectively, to said terminal ends and lying generally in the same plane as said resistive film.

11. The invention as claimed in claim 1, in which the lower surface of the wafer is planar and is mounted in flatwise engagement with the planar upper surface of a metal base having a central opening therein corresponding to said opening in said wafer, and in which a mass of thermosetting synthetic resin is provided over said wafer to embed the same and provide environmental protection, said mass of resin having an opening therein over said central opening in said base.

12. The invention as claimed in claim 11, in which said metal base has an upwardly extending central post which extends through said opening in said wafer and through said opening in said resin, said post being embedded in said resin except at the upper end of said post, said post having an opening therethrough registered with said base opening and adapted to receive a mounting bolt.

13. The invention as claimed in claim 1, in which the lower surface of said wafer is planar and is mounted in flatwise engagement with the planar upper surface of a metal base having a central opening therein corresponding to said opening in said wafer, in which radially outwardly extending terminal conductors are connected, respectively, to said terminal ends of said traces, in which a mass of thermosetting synthetic resin is molded over said wafer and over the inner portions of said terminal conductors to embed the same and provide environmental protection, in which said outer trace is continuous between said terminal end thereof and another end also disposed on said one side of said opening, and in which said inner trace is continuous between said terminal end thereof and another end also disposed on said one side of said opening, whereby a single low-resistance resistor is provided by said film between said terminal conductors.

14. The invention as claimed in claim 1, in which the lower surface of said wafer is planar and is mounted in flatwise engagement with the planar upper surface of a metal base having a central opening therein corresponding to said opening in said wafer, in which radially outwardly extending terminal conductors are connected, respectively, to said terminal ends of said traces, in which a mass of thermosetting synthetic resin

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is molded over said wafer and over the inner portions of said terminal conductors to embed the same and provide environmental protection, in which said outer trace is interrupted at at least one point between said terminal end and the other end thereof, said other end being disposed on said one side of said opening, in which said inner trace is interrupted at at least one point between said terminal end thereof and the other end thereof, said other end of said inner trace being disposed on

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said one side of said opening, and in which portions of said resistive film are interrupted at the trace interruptions and also at the adjacent regions between said inner and outer traces, said interruptions being such that at least three series-related radial-flow film-type resistors are formed by said resistive film between said terminal conductors.

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