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TAILORED VARIABLE ELECTRICAL RESISTANCE ELEMENT

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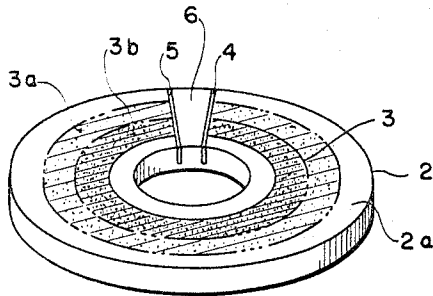


FIG. 1

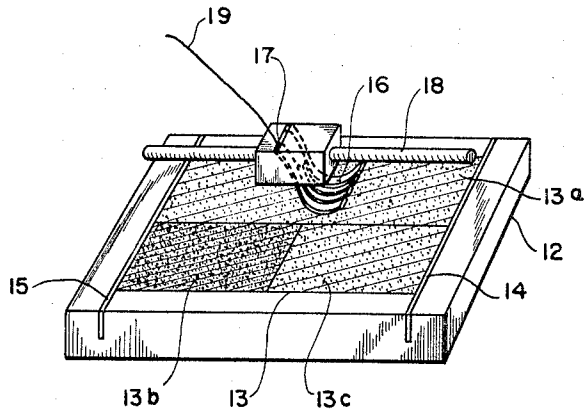


FIG. 3

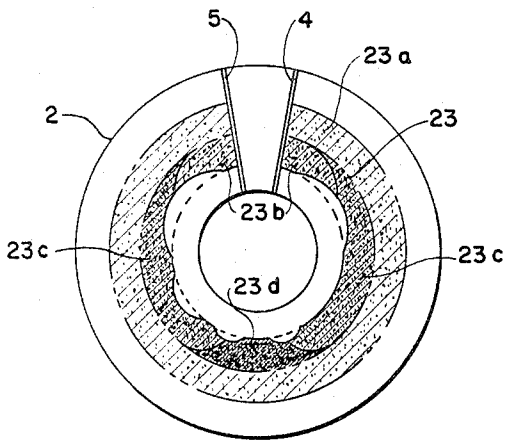


FIG. 2

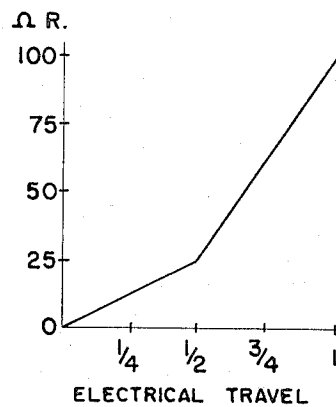


FIG. 4

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## TAILORED VARIABLE ELECTRICAL RESISTANCE ELEMENT

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### ABSTRACT OF THE DISCLOSURE

A deposited layer resistance element on a flat surface of a base member, the element being formed of at least two parallel tracks of different resistance materials applied to the base member, the tracks being in electrical contact throughout their length; one track providing a tailoring surface and the other track functioning solely as a path for a movable wiper which may be adapted to traverse the element.

The present invention relates to electrical resistance elements and to a method of making such elements and is more particularly directed to a resistance element of the type used in a variable resistance device having a movable electrical contact or wiper adapted to traverse the resistance element.

Variable resistance devices commonly use a resistance element formed of a resistance material which is applied as a thin layer or film on a nonconductive support or base. One such material is formed of a mixture of finely divided glass and metal particles, commonly called "cermet" resistance material. In a cermet resistance element the metals and glasses are deposited in a viscous mixture, dried, fired at high temperatures and, when cooled, form a homogeneous film which is hard and smooth. The present invention is particularly suitable for resistance devices made of cermet materials, a number of which materials are illustrated and described in U.S. patents, No. 2,950,995 and No. 2,950,996 issued in the name of Thomas M. Place, Sr., et al. and assigned to the same assignee as the present invention.

The resistance of a deposited cermet film element, formed of a particular cermet material, is a function of the element's length, width and thickness. However, inasmuch as the thickness is for the most part maintained constant at approximately .001 or .002 inch, the resistance is directly proportional to the length, and, inversely, proportional to the width of the film. It is common practice, in order to produce a particular function, or to obtain reasonably close linearity for a resistance element, to "tailor" the resistance film by laterally grinding away part of the width of the film to produce the desired resistance therein. Because the total width of the film is usually quite small and because a smooth uncut surface must be provided for contact with the movable electrical contact or wiper, the amount of functional change or the amount of electrical correction that may be accomplished by "tailoring" the resistance elements of the type heretofore manufactured was severely limited.

It is, therefore, an object of the present invention to provide, for a variable electrical resistance device, an improved resistance element having a smooth track surface adapted to be traversed by the movable wiper of the device yet having an area suitable for tailoring upon which large changes in electrical function may be accomplished.

It is a more specific object of the present invention to provide an improved cermet resistance element for a variable resistance device in which the element is formed of at least two parallel tracks of resistance materials, having different resistivity one track forming a smooth

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surface for contact with the movable wiper and the other track or tracks providing an additional resistance in parallel with the first resistance adapted to vary the function of the resistance element over the length of travel of the movable contact.

A further object of the present invention is to provide an improved method of forming a cermet resistance element.

Further objects and advantages of the invention will become apparent as the following description proceeds and the features of novelty which characterize the invention will be pointed out with particularity in the claims annexed to and forming a part of this specification.

In carrying out the objects of the present invention, there is provided a resistance element in the form of a non-conductive base member having a flat surface area thereon upon which is applied a first track or film of a first type of resistance material having a smooth glassy surface adapted to be traversed by a movable electrical wiper. At least one additional track or film of a different resistance material is applied to the base member parallel to and in electrical contact with one edge of the first resistance track thereby providing an area which is tailored to correct the linearity of the resistance element or to provide any particular function for the electrical output of the device.

As a further aspect of the present invention, there is provided a method of forming a cermet resistance element which comprises the steps of depositing a first track of cermet resistance material on a base member and depositing a second track of cermet resistance material on said base member parallel to the first track and in electrical contact with one edge thereof, firing the element to a temperature lower than the melting point of the metal particles of the respective cermet materials but exceeding the fusing temperature of the glasses of the two respective materials to provide a pair of resistance tracks in side by side relationship but in electrical contact throughout their coextensive length.

For a better understanding of these and further aspects of the invention, reference may be had to the accompanying drawing in which:

FIG. 1 is a perspective view of a resistance element embodying the present invention;

FIG. 2 is an enlarged top view of a resistance element illustrating in greater detail the tailoring of the inner resistance track; and

FIG. 3 is a perspective view of another embodiment of the invention arranged on a rectilinear substrate and having a movable wiper adapted to traverse one track of the resistance element.

Referring now to FIG. 1 of the drawing, there is shown a resistance element of the type adapted for use in a variable resistance device. The resistance element comprises a substrate base member 2 of dielectric material which may be in the form of a circular or rectangular disc or wafer. The member is usually formed of an unglazed, homogeneous, nonporous, ceramic material, such as steatite or alumina or other nonconductive material well known in the art. In conventional practice, the substrate or base member 2 is molded, fired and then ground or lapped to provide a smooth relatively flat surface area 2a for supporting a resistance element or layer thereon.

In the illustrated embodiment of FIGS. 1, 2 and 3, the resistance element is designated generally by the reference numeral 3 and comprises two or more tracks of resistance material arranged in parallel on the surface 2a of the nonconductive base member. The resistance layer 3 forms a conductive path for an electrical current, which is applied to the resistance layer through terminal members 4 and 5. In the illustrated embodiments of the invention, the terminal members, or conductors 4 and 5, are in

the form of metal ribbons or leads imbedded in the base member 2. These terminal conductors may also be in the form of a metal film deposited on the nonconductive base member. The noble metals, because of their resistance to oxidation, have been found best suited for use as terminal conductors and various alloys of gold, silver, platinum, palladium or rhodium are available with a coefficient of expansion that matches, to some extent, that of a ceramic base member.

The resistance element 3 is applied to the base member 2 in a configuration desired for the particular application of the resistance device. For example, in FIG. 1 the film or layer is annular or arc shaped and may be applied to the base member 2 by any suitable operation well known in the art such as brushing, spraying, stencilling or silk screening. FIG. 3 illustrates a rectilinear substrate 12 upon which there is deposited a longitudinal resistance element 13. End terminals 14 and 15 are conductor ribbons imbedded in the substrate similarly as those of the embodiment of FIG. 1. In the embodiment of FIG. 3, there is shown a movable wiper 16 adapted to move translationally back and forth across the resistance element 13 in a manner to be hereinafter explained. The movable wiper 16 is attached to a block 17 that is moved back and forth by a threaded drive shaft 18 in order to vary the output of the device. Electrical current is carried to or from the wiper 16 by means of flexible conductor 19.

When the resistance element is arcuate in shape, as in FIG. 1, it is sometimes the practice to deposit a bridging film or layer 6 of nonconductive material, such as glass, between the terminals 4 and 5 in order to provide a smooth surface for the passage of the electrical contact wiper from one end of the resistance layer to the other. In practice, the glass in the bridge section is usually similar to that used in the formation of the resistance mixture so that the materials in the bridge area fuse at the same or similar temperature as the resistance mixture.

The resistance layers or tracks forming the resistance element 3 are preferably formed of cermet resistance material which comprises a nonconductive glass binder material having minute particles of noble metal or metal alloy dispersed throughout the element and having trace amounts of other materials added when desired. Particular examples of cermet materials and their method of manufacture are fully explained in the aforementioned Place et al. patents, No. 2,950,995 and No. 2,950,996 assigned to the same assignee as the present invention. In cermet materials, the mixture of glass and metal particles, after fusion at a temperature below that of the metal constituent, forms a continuous element having a hard, smooth, glassy surface. This glass-metal cermet mixture is predominantly glass with relatively small percentages of metal therein, depending upon the particular value of the resistance desired. A range of resistance values may be obtained by varying the quantities or types of metals used in the mixture of cermet material and for resistance elements having a thickness of .001 to .005 inch it is possible to obtain resistances from less than an ohm/square to several thousand ohms/square.

Referring now to FIG. 1, it will be seen that the resistance element 3 of the present invention is formed of two separate tracks 3a and 3b deposited side by side on the base member. Track 3a contains a higher metal content preferably a different metal content than track 3b and, in the illustrated embodiment, the resistance material of track 3a is of a higher resistivity than the resistance material of track 3b. The adjacent edges of the individual tracks 3a and 3b are in electrical contact throughout their arcuate extent.

It is desirable that the higher metal content material, which in this embodiment is track 3a, be used for contact with the movable electrical wiper of the variable resistance device. In most cases there is better electrical contact with a lower electrical noise level when the cermet film contacted by the movable wiper has a high metal content.

The inner track 3b in FIG. 1 extends the full arcuate extent of the resistance element. Because, in this embodiment, both tracks 3a and 3b are formed of homogeneous resistance material, the resistance change for each incremental movement of an electrical wiper in contact with the element would be constant. Thus, the arrangement of FIG. 1 would produce a linear resistance element.

Of course, there are always small departures from linearity in any device utilized or small variations of the film deposited, etc. The advantage of the arrangement of the present invention is in providing the track 3b of different resistivity which may be tailored, in any well-known manner, to correct the variations from linearity. However, it is desirable to have the tailored track of a much lower resistivity than that of the wiper track in order to accomplish greater changes in electrical function by tailoring the low resistance track.

Referring now to FIG. 2, there is shown a variable resistance element 23 which is arcuate in shape and formed of an outer track 23a of cermet resistance material, which is deposited on the surface 2a of the substrate member, and a plurality of parallel inner tracks 23b, 23c and 23d. The outer track of cermet material 23a is first silk screened onto the substrate and then the inner tracks of material are deposited in a desired configuration adjacent to and contacting the inner edge of the outer track. After the layers of cermet material have been deposited, the base and cermet layers are, preferably, permitted to dry in a circulating warm air for a short period. The unit is then fired in a suitable kiln to raise the temperature above the melting temperature of the glass but below the melting point of the metal particles of the cermet material.

The temperature to which the layer and base are fired is critical in that firing at too low a temperature results in failure to achieve a continuous glassy phase in which the resistance material has a smooth, hard surface. Firing too high produces bubbles and blisters in the cermet material and causes the metal particles therein to agglomerate thereby completely interrupting the conduction path in the film. It is also possible to fire the outer track 23a separately, then deposit the inner track and fire it. When the layers or tracks are fired in separate steps, it is preferable to have the glass of the first-fired track be of a type having a higher melting or fusion point than the glasses of the inner tracks or last to be fired cermet materials. The last to be fired tracks should be fired at a sufficiently high temperature to cause fusion of the co-extensive edges of the respective tracks thereby providing good electrical conductivity between the adjacent tracks.

The required firing temperature depends upon the particular type of glass used in forming the cermet mixture. Various firing temperatures for various types of cermet materials are well described in the aforementioned Place Patents No. 2,950,995 and No. 2,950,996 and a further discussion thereof is not believed necessary for a full understanding of the present invention.

As will be noted in FIG. 2, the inner track is formed of a number of different cermet resistance materials adapted to produce a nonlinear output from the device during translation of the movable wiper from one terminal to the other. The particular values of the resistance material comprising the inner track may be varied to produce any desirable function. The function produced by the illustrated embodiment of FIG. 2 is a sine wave.

Note also that the inner track originally covered the areas of the substrate included within the dotted lines. In order to make corrections for variations in the electrical function desired, the inner track is tailored around its inner exposed edge by cutting away portions of the cermet resistance material thereby reducing the total width of the element 23 in certain regions and correcting the resistance change in these areas for each incremental movement of the electrical wiper.

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Referring now to FIGS. 3 and 4, it will be noted that the resistance element 13 comprises three tracks or sections of resistance material 13a, 13b and 13c. This arrangement is designed to produce a nonlinear function like that shown in the graph of FIG. 4 in which the resistance changes gradually for the first half of the electrical travel of the movable wiper 16 and then increases rapidly during the latter half of the electrical travel. In actual practice it was found possible to make tracks or sections 13a and 13c out of the same material having a high resistivity while track 13b is formed of a material having a much lower resistivity. In order to correct the electrical function, the exposed edges of tracks 13b and 13c may be tailored.

The resistance elements of the present invention make it possible to provide large changes in the electrical function without altering the wiper track. By making the inner or additional tracks of a resistance material having high sensitivity, it is possible to make substantial corrections to the electrical function in order to correct variations therein or to correct the linearity of the resistance element.

While in accordance with the patent statutes there has been provided what at present is considered to be the preferred embodiment of the invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention and it is, therefore, the aim of the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. An electrical resistance element for a variable resistance device having a movable electrical wiper contact for varying the electrical output of said device comprising:

- a nonconductive base member having a substantially smooth surface area thereon;
- a first track of cermet resistance material applied in a thin layer on said flat surface of said base member, said track having a smooth surface for receiving the wiper contact; and
- at least one additional track of cermet resistance material having a different resistivity than said first track of cermet resistance material applied to said base member parallel to one edge of said first track of cermet resistance material, said respective tracks of cermet resistance material being fused together along their adjoining edges so that said tracks are in continuous electrical contact along said adjoining edge thereof for varying the resistance change of said resistance element as said wiper traverses said first track in the region thereof adjacent said additional track of cermet resistance material.

2. An electrical resistance element for a variable resistance device having a movable electrical wiper contact for varying the electrical output of said device comprising:

- a nonconductive base member having a substantially smooth surface area thereon;
- a first track of cermet resistance material applied in a thin layer on said flat surface of said base member, said track having a smooth surface for receiving the wiper contact;
- a plurality of additional tracks of cermet resistance materials applied to said base member parallel to one edge of said first track of resistance material, said additional tracks of resistance material having a different resistivity than said first track of resistance material, said additional tracks being fused with said first track and in electrical contact with said first track along said one edge thereof, said additional tracks of resistance material being tailored by having portions selectively removed along their length to produce a nonlinear change in the electrical output of said resistance device as said wiper traverses said

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track in the regions thereof adjacent said additional tracks.

3. An electrical resistance element for a variable resistance device having a rotatable electrical wiper contact for varying the electrical output of said device comprising:

- a nonconductive base member having a substantially smooth surface area thereon;
- a first arcuate track of cermet resistance material applied in a thin layer on said flat surface of said base member, said first track having a smooth surface for receiving the wiper contact; and

at least one additional arcuate track of cermet resistance material applied to said base member parallel to the inner edge of said first track of cermet resistance material, said additional track of cermet resistance material being fused with said first track and in electrical contact with said first track along said inner edge thereof and being tailored by having portions selectively removed along its length to produce nonlinear changes in the electrical output of said resistance device as said wiper traverses said first track from one end thereof to the other.

4. A method of making a nonlinear resistance element for use in a variable resistance device having a movable electrical contact for varying the electrical output of the device comprising the steps of:

providing a nonconductive substrate member having a substantially flat surface area thereon;

depositing on said flat surface of said substrate member a first track of first resistance material in the form of a thin film of finely divided electrical conductive metal particles dispersed in a fusible bonding material;

depositing at least one additional track of second resistance material in the form of a thin film of finely divided electrical conductive metal particles dispersed in a fusible bonding material, said second resistance material having a resistivity differing from the resistivity of said first resistance material, said second track of resistance material being deposited closely adjacent one edge of said first track and in contact therewith; and

firing said member with said deposited tracks to a temperature lower than the melting point of said metal particles in said first and second tracks and exceeding the fusion temperature of said fusible bonding material thereby to provide at least two tracks of resistance layers of differing resistivities fused together along their respective adjoining edges and arranged electrically in parallel throughout at least a portion of their lengths.

5. A method of making a nonlinear resistance element for use in a variable resistance device having a movable electrical contact for varying the electrical output of the device comprising the steps of:

providing a nonconductive substrate member having a substantially flat surface area thereon;

depositing on said flat surface of said substrate member a first track of cermet resistance material in the form of a thin film of finely divided electrical conductive metal and glass particles;

depositing at least one additional track of a second cermet resistance material in the form of a thin film of finely divided electrical conductive metal and glass particles, said second cermet resistance material having a resistivity differing from the cermet resistivity of said first resistance material, said second track of cermet resistance material being deposited closely adjacent one edge of said first track and in contact therewith;

firing said tracks on said base member to a temperature lower than the melting point of said metal constituent of said cermet materials and higher than the melting point of said glass constituent of said cermet materials thereby to provide parallel tracks of cermet

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resistance material attached to the surface of said base member and fused together along their respective adjoining edges and in electrical conductivity throughout at least a portion of their length; and tailoring the edge regions of one of said tracks in order to correct variations from a desirable electrical function for said resistance element.

6. A method of making a nonlinear resistance element for use in a variable resistance device having a movable electrical contact for varying the electrical output of the device comprising the steps of:

- providing a nonconductive substrate member having a substantially flat surface area thereon;
- depositing on said flat surface of said substrate member a first track of cermet resistance material in the form of a mixture of finely divided electrically conductive metal and glass particles;
- firing said cermet resistance material onto said base member to a temperature exceeding the fusion temperature of said glass particles thereby to provide a track of cermet resistance material attached to said base member;
- depositing at least one additional track of a second cermet resistance material in the form of a mixture of finely divided metal and glass particles, said second resistance material having a resistivity differing from the resistivity of said first cermet resistance material, said second track of cermet resistance ma-

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terial being deposited closely adjacent said edge of said first track and in contact therewith;

firing said second track of resistance material to a temperature lower than the melting point of said metal particles in said first and second resistance materials but exceeding the fusion temperature of said glass in said second resistance material thereby to provide at least two tracks of resistance materials having differing resistivities arranged in parallel on said base member and in electrical contact throughout their lengths; and

tailoring said second track of cermet resistance material from the outer edge thereof to correct variations in a desired electrical function for the cermet resistance element.

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UNITED STATES PATENT OFFICE  
CERTIFICATE OF CORRECTION

Patent No. 3,379,567

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It is certified that error appears in the above identified patent and that said Letters Patent are hereby corrected as shown below:

Column 6, line 66, cancel "cermet"; line 67, after "first" insert -- cermet --.

Signed and sealed this 9th day of September 1969.

(SEAL)

Attest:

Edward M. Fletcher, Jr.

Attesting Officer

WILLIAM E. SCHUYLER, JR.

Commissioner of Patents