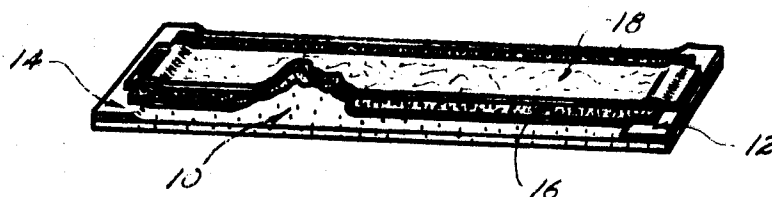


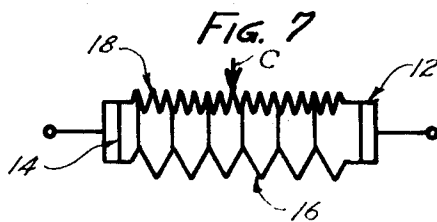
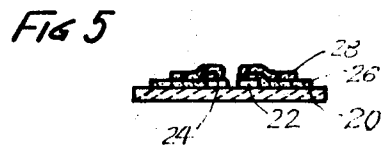
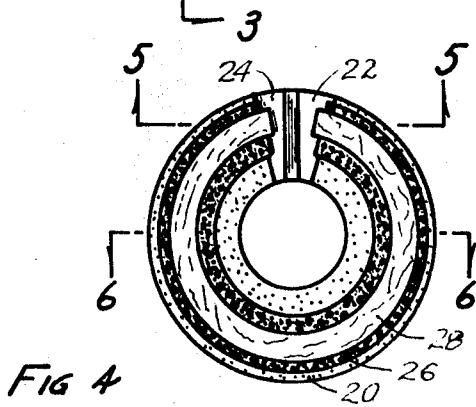
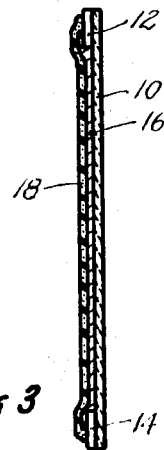
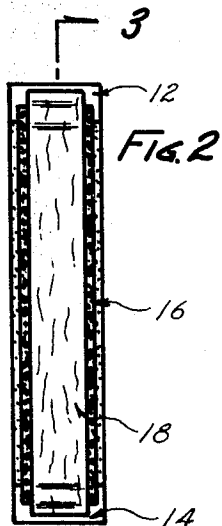
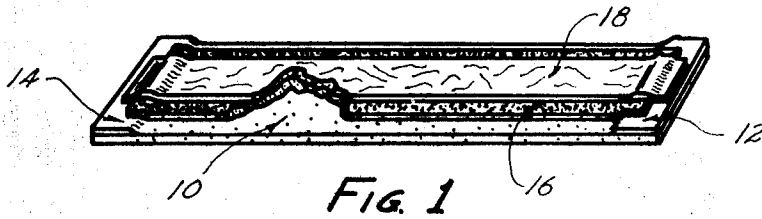
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[54] **HYBRID ELEMENT VARIABLE RESISTOR**  
**1 Claim, 7 Drawing Figs.**  
 [52] U.S. Cl. .... **338/9,**  
                   **338/162, 338/308, 338/319, 338/322**  
 [51] Int. Cl. .... **H01c 7/00,**  
                   **H01c 9/00**  
 [50] Field of Search. .... **338/9, 308,**  
                                   **322, 162, 319; 174/68.5**

**ABSTRACT:** A resistance element comprising an insulative base bearing first and second spaced-apart conductive terminals between which terminals extends a cermet component adherent to the base and a superposed conductive plastic component adherent to the cermet component and intimately in electrical contact therewith, both components having electrical connection at their first and second ends to respective ones of the terminals.





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## HYBRID ELEMENT VARIABLE RESISTOR

## BACKGROUND OF THE INVENTION

Resistance elements of other than wirewound types and employed in variable resistors such as potentiometers that are used to adjust potentials or to trim electronic circuits are classified in two general principal classes, namely carbonaceous or "conductive plastic," and metallic such as metal film and cermet. Each of those classes of elements is characterized by its respective desirable features and undesirable features. For example, the conductive plastic elements are characterized by excellent resistance to wearing and low contact resistance variation (CRV), at least in lower and intermediate total resistance (TR) ranges. But, as offsetting undesirable features, such elements are characterized by relatively high negative temperature coefficient of resistivity ( $-T_c$ ), poor temperature stability, and low-power ratings. On the other hand, cermet resistance elements having acceptable contact wear or low abrasiveness have generally bad CRV characteristics, and are limited to low and intermediate TR ranges, since in the high TR range they are very abrasive. Cermets are, further, generally much more abrasive than conductive plastic elements of any TR range, and so cause relatively severe wearing problems in potentiometers in which extensive movements of the wiper or contact occurs. In general, cermet resistance elements are characterized by low to medium positive  $T_c$ , in contrast to the high negative  $T_c$  of conductive plastic elements; and they have good temperature stability and power ratings.

In the prior art, selection of one or another of the noted types of elements was made, depending upon the TR range into which the element was desired to fall, and compromises made in respect of characteristics and specifications desired to be met. Very high values of TR were substantially impossible of attainment in elements of either type in elements of very small physical dimension and which had satisfactory uniformity, CRV, durability and load-carrying ability. Thus undesirable minimum physical dimensions were imposed on elements in the high TR range. On the other hand, attainment of very low values of TR was difficult and sporadic in the manufacture of elements of either type, having otherwise acceptable characteristics. Thus, in general, compromises between  $+$  and  $-T_c$ , durability, high and low CRV, etc. were made; and neither cermet nor conductive plastic elements could be made to cover all of low, intermediate and high total resistance ranges without involving one or more rather grossly undesirable characteristics at one or the other extreme of the total resistance ranges.

## SUMMARY OF THE INVENTION

The present invention eliminates or greatly reduces the magnitude of all of the aforementioned undesirable characteristics of variable resistor elements and permits notable meritorious improvements in the field of nonwirewound resistance elements, by disposing in intimate contact a cermet resistance element component possessing the noted characteristics of that class of elements, and a conductive plastic component. In any case, selection of the cermet and of the conductive plastic components may be such that optimization of one or another of the noted characteristics is attained as well as improvement in others. Thus, for example, very low or zero  $T_c$  may be attained, or very high TR attained with great wear resistance and high-power rating. As thus combined into a unitary resistance element, the two components are in a sense disposed in parallel electrical relationship between end terminals but are also intimately connected each to the other throughout their effective lengths by what may be considered to be a multitude of conductive connectors each of very low value of resistance but collectively of resistance dependent upon the resistivity of the components. Preferably, and as herein described with respect to an exemplary preferred physical embodiment, an elongate cermet component is formed upon an appropriate surface of an insulative base or substrate such as a

chip or wafer of alumina, and an elongate component of conductive plastic is formed along and upon the exposed surface of the cermet component. While the electrical lengths of the thus superposed components are the same or substantially so, the widths and/or cross-sectional dimensions as well as the compositions are susceptible of variations to permit attainment of optimum or desired characteristics such as TR,  $T_c$ , CRV, durability, etc. By "tailoring" or judicious proportioning of the compositions and dimensions, etc., of the two components of the thus-produced unitary hybrid resistance element, substantially zero value of  $T_c$  may be attained while desirably low CRV and great contact wear resistance are concurrently secured. Also, the previously impractical highly abrasive very high TR cermet component with its high-power rating is rendered usable and given low  $T_c$  and great wear resistance by combination with the superimposed conductive plastic component. Other meritorious improvements will hereinafter be more fully explained. An exemplary variable resistor hybrid element in two physical shapes is illustrated in the accompanying drawings.

## DESCRIPTION OF THE DRAWINGS

FIG. 1 is a pictorial view of an elongate rectangular hybrid resistance element according to the invention, to no particular dimensional scale and with sections of superposed cermet and conductive plastic elements broken away to illustrate details, film thickness and film interrelationships being somewhat exaggerated for purposes of illustration;

FIG. 2 is a plan view of the element depicted in FIG. 1, to a reduced scale;

FIG. 3 is a sectional view, taken as indicated by directors 3—3 in FIG. 2;

FIG. 4 is a plan view of an arcuate hybrid resistance element formed on a circular substrate and adapted for use in a single-turn rotary potentiometer;

FIGS. 5 and 6 are sectional views of structure depicted in FIG. 4, the sections being as indicated by directors 5—5 and 6—6, respectively, in FIG. 4; and

FIG. 7 is a schematic diagram illustrating schematically the electrical relationships of the laterally cross-connected resistive components of the hybrid element of either of FIGS. 2 and 4.

## DESCRIPTION OF THE ILLUSTRATED STRUCTURES

In FIGS. 1, 2 and 3, 10 denotes an insulative base or substrate of ceramic material such as alumina or steatite. At each end portion of the substrate there are initially formed respective first and second terminals 12, 14, which may be, for example, of silver reduced from applied silver-bearing ink or paint, the reduction being by firing, as in a reducing or inert atmosphere in a kiln. Other modes and means of producing such adherent conductive terminal means, well known in the art, may be employed. As will be evident to those skilled in the resistor art, the terminals may be very thin, for example of the order of 1 mil, or other thickness; and for purposes of illustration are shown of exaggerated thickness in the drawings.

Applied by conventional cermet film-producing techniques is an elongate cermet resistive layer or film 16 (FIGS. 1, 2 and 3) which overlies at its ends respective areas or portions of the terminals 12 and 14, whereby the cermet component is electrically connected at its electrical ends with the terminals. Overlying all (or a portion only as depicted) of the cermet film 16, and overlying also portions of the terminals 12 and 14 is a second resistive component of the type commonly referred to as "conductive plastic." The latter layer or film is thus directly connected at its electrical ends to the terminals 12 and 14, and is intimately cross connected, throughout its effective electrical length, to the cermet component 16. The conductive plastic resistive component may be of any stable synthetic resin material with finely divided conductive particles thoroughly mixed therein, the film or layer being applied while the mixture is plastic or inklike, and cured in situ on the previ-

ously described structure to form the composite or hybrid resistance element. Typical conductive particles are finely divided carbon, finely divided metals such as silver, gold, ruthenium, platinum and the like. Resins such as phenol formaldehyde, Bakelite, urea resins and heat-curable synthetic resins, with volatile solvents if necessary to control viscosity, may be used.

Following completion of the hybrid resistance element comprising the base or substrate 10, terminals 12 and 14, cermet component 16 and conductive plastic component 18, the element may be subjected to desirable tests and inspection, and incorporated into one or another of conventional variable resistors, or in the case wherein the element is used as an adjustable fixed-value resistor having zero or negligible Tc, the element may be potted or provided with other adjuncts such as a housing or other mechanical protection. Since incorporation of the element in a housing and/or combining it with adjunct means is not per se of the present invention, and since such housing and adjunct means are known in the resistor art, they are not further herein described nor illustrated.

In FIGS. 4, 5 and 6 there is illustrated the application of the principles of the invention to an element for a single-turn rotary potentiometer. Therein, 20 denotes a ceramic disc or substrate, 22 and 24 denote respective conductive filmlike terminals of the same character as terminals 12 and 14, and 26 and 28 denote, respectively, cermet and conductive plastic arcuate filmlike strips each of which at its ends contacts the terminals, as indicated in FIG. 5. Other than in respect of physical shape and dimensions, the unit and its conductive and resistive components may be substantially identical to the comparable components of the unit illustrated in FIGS. 1, 2 and 3.

In FIG. 7, there is a purely schematic representation of the electrical arrangement of the conductive and resistive components of either of the previously described units, the reference numerals referring to the unit depicted in FIG. 1 by way of example only. In the electrical schematic diagram, an elongate conductive plastic component 18 of relatively high resistivity or TR and an elongate cermet component 16 of relatively low resistivity or TR are interconnected along their active extents by numerous conductors, and each of the cermet and conductive plastic components is in electrical contact with a terminal (12, 14) at either end. As employed, for example, in a potentiometer, a movable wiper or contact, C, is adjusted along the hybrid element in contact with the conductive plastic component of the hybrid element.

As herein employed, the term hybrid element is intended to mean a two-component resistance element not of the wirewound type which element comprises a cermet component overlaid by a conductive plastic component which is in intimate contact with the cermet component along an elongate zone between two conductive terminals which define electrical ends of the zone and of the components.

Typical variable resistor constructions in which hybrid resistance elements as hereinabove described are usable are illustrated in the following numbered U.S. Pat. Nos. 2,926,324; 2,976,507; 3,178,664 (adaptable for the construction depicted in FIGS. 1, 2 and 3); 2,917,721; 2,958,839; and 3,111,640 (adapted for use with constructions shown in FIGS. 4, 5 and 6).

In the case of prior art cermet elements, attainment of higher and still higher TR is accompanied by commensurate

increases in abrasiveness of the element surface and consequent decrease in effective lifespan (number of cycles of wiper contact operation) due to increasing rapidity of wearing away of the wiper contact. This undesirable feature intensifies or is accentuated as physical size of the element is decreased, as is necessary in the continuing effort to reduce the volume and weight of electronic components. Thus when attempts have been made to produce cermet elements of very high values of TR and of commercially acceptable dimensions, the effective lifespan was reduced to very low values and so low as to render the product commercially unacceptable. For example, in rotary potentiometer cermet elements it is desirable to have effective lifespan of the order of several millions of rotational cycles of operations; and in attempts to obtain cermet elements having a TR in the range from 1 to 10 megohms the lifespan average was reduced to values in the range from a few thousand cycles to a few hundred thousand cycles, far below the desirable minimum. As a consequence of that situation, resort to other types of elements was had in all cases wherein long lifespan was a requisite, with resultant lower load capacity, less desirable CRV and lower maximum operating temperature. Conductive plastic elements, as is well known, are characterized by low load capacity and low maximum operating temperature, as well as change of TR with passage of time. By application of the present invention, using cermet components that are otherwise entirely too abrasive for use and with lifespan capability of very low order and with undesirable +Tc, elements are made not only capable of enduring many millions of operational wiper cycles, but with additional meritorious and unobvious improvement in Tc and CRV. Thus, hybrid elements according to the invention not only retain the previous advantageous and desirable characteristics of high-power rating and high operating temperature rating of cermet elements, while concurrently extending the practical total resistance (TR) range and reducing the Tc to near zero or negligible values, but further are characterized by extremely high lifespan figures. These features are illustrated by typical hybrid rotary potentiometer elements which, for example, operated through millions of operational cycles before element or wiper contact failure.

We claim:

1. A resistance element, said element comprising:  
an insulative base;

first and second spaced-apart conductors on said base providing first and second terminals;

a cermet resistive component on said base, extending between said first and second terminals and electrically contacting at least a portion of each of said terminals; and  
a conductive plastic resistive component overlying and in intimate physical and electrical contact with said cermet resistive component between said first and second terminals and in electrical communication with said terminals;

the terminal-to-terminal resistance of said cermet resistive component being greater than that of the said conductive plastic resistive component

whereby said element possesses desirable characteristics of said cermet resistive component and desirable characteristics of said conductive plastic resistive component and is characterized by marked reduction of undesirable characteristics of said resistive components.