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3,167,451

METHOD OF RESISTOR PRODUCTION

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FIG. 1

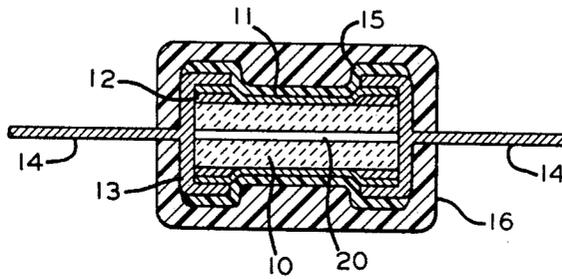


FIG. 2

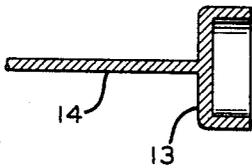


FIG. 4

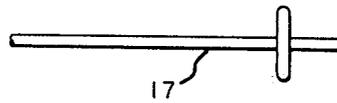
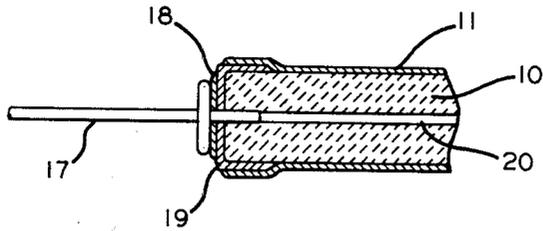


FIG. 3



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METHOD OF RESISTOR PRODUCTION

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The present invention relates to a method of making metal film resistors and more particularly to an evaporation method of metal film resistor production.

Electrical resistors having resistance films on inert electrically non-conductive bases are useful because they possess various distinctive characteristics, such as low temperature coefficient of resistance and high stability throughout long periods of time under load. It is important in such a device that the correct thin film of a conductive material be properly applied to the inert base. The procedure for forming the film on the inert base is critical to the properties of the finished device. Various methods of applying this film have been practiced and some of these methods have resulted in satisfactory metal film resistors. The methods are troublesome calling for continuous supervision to determine the nature of the applied film. This type of procedure requires a high degree of supervision and experience in the production of metal film resistors. This is undesirable for a number of reasons one of which is the difficulty of maintaining the exact conditions in repeated production. Another is the sensitivity of the method to inaccuracies or errors.

It is an object of this invention to produce metal film resistors by a process which determines the amount of deposition of the film in a metal film resistor.

It is another object of this invention to determine the alloy composition of the deposited film prior to its application to the inert base of a metal film resistor.

Still another object of this invention is the accurate application of a determinable amount of an alloy composition having the proportions of an alloy source onto an inert base of a metal film resistor.

These and other objects of this invention will become more apparent upon consideration of the following description taken together with the accompanying drawings in which:

FIG. 1 is an axial section of a metal film resistor produced according to the process of this invention; and

FIG. 2 is a longitudinal section of the end cap assembly and lead of the embodiment of FIG. 1.

FIG. 3 is an axial section of a modified metal film resistor produced according to this invention.

FIG. 4 is a side elevation of a pigtail lead of the embodiment of FIG. 3.

The generic aspect of this invention may be considered as a process of predetermining the exact alloy composition of the metal resistance film in a metal film resistor by placing the desired amount of each metallic constituent on a common element prior to a process of completely evaporating the alloy composition from the common element onto the inert non-conductive base of the resistor.

The nickel and chromium of one type of metal film may be deposited on a suitable base such as a ceramic rod to produce a film having a desired resistance value. The total weight of the nickel-chromium alloy to be deposited on the ceramic base is determined by the geometry of the finished resistor and the electrical resistance value desired. It will be understood that this can be widely varied. However, referring to a specific type of construction, a ceramic core has applied to it according to this invention a desired alloy composition. This alloy composition is applied in a vacuum system which contains the insulator base and the alloy composition to be deposited thereon in the exact proportions desired. The

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alloy composition is initially positioned on a suitable element such as a tungsten filament by suitable deposition means, such as electroplating. The pressure in the vacuum system is reduced and the filament carrying the alloy composition is heated to effect complete evaporation of the alloy composition from the filament so as to provide the alloy deposit on the insulator base. The deposit on the base has the constituents in the same proportions as in the alloy composition on the tungsten filament. The quality of the alloy deposited on the base is initially the quality on the filament. The coated units are then subjected to heat stabilization and suitably processed to provide the complete metal filament resistor.

This invention is illustrated by reference to FIG. 1. FIG. 1 shows a ceramic core 10 upon which has been applied a metal resistive film 11. The metal film element 11 is suitably provided with means for electrical connection. Gold terminations 12 are provided at each end of the core 10 and the metal film 11 is deposited over terminations 12. A lead cap assembly (FIG. 2) composed of cap 13 and lead 14 is forced onto each end of the coated rod and is in electrical connection with the film 11 and gold terminations 12. A protective varnish 15 overlies the caps 13 and the metal film element 11. The entire unit is encased in a molded case 16 so that only the lead wires 14 protrude.

Film thicknesses of element 11 and terminations 12 are very thin; the thicknesses are greatly exaggerated in FIG. 1 for illustrative purposes. Coating 15 is also magnified to facilitate a clear understanding of the construction. It should be understood that the metal thicknesses are less than measurable for all practical purposes.

The sectional view of FIG. 2 shows the cap 13 and portion of lead wire 14 mechanically and electrically connected to each other, and disassembled from the resistor. The cap 13 is cup shaped and has a polygonal skirt which girdles the side of the core 10 and contacts film 11 and termination 12 when in position in the resistor.

The process of this invention includes the preparation of the plural metal platings on the tungsten filament, the provision of terminations on ceramic cores, and the vaporization in a vacuum of the platings from the filament onto the cores. It is a novel feature of this invention that vaporization to exhaustion (complete vaporization of all metal from the filament) provides a resistance coating on the cores that is both determinable and reproducible.

The terminations on the ceramic cores are preferably obtained by applying gold resinate paint to the ends of the cores 10. The paint is fired at temperatures from 450° C. to 950° C. to form adherent conductive end bands 12.

It is preferred that the metals making up the resistance coating be applied to a tungsten filament by electroplating. For purposes of illustration, the resistance composition will be described in terms of a nickel chromium alloy. The nickel content can vary from 0 to 50% depending on the desired value of the resistance coating in accordance with well-known formulae in the art. The total weight of the material to be plated on the filament is governed only by the geometry of the equipment and the desired value, and hence can be varied from a few milligrams to several hundred milligrams.

A plurality of ceramic cores 10 with end terminations 12 are mounted in a planetary rotation jig. This mounting can be effected by passing stiff wire rods through axial bores in the ceramic cores. A planetary jig found advantageous in the process of this invention is geared so that the rods turn on their axes at about 1000 r.p.m., while rotating at about 100 r.p.m. in a cylindrical orbit. The electroplated tungsten filament is mounted along the axis of the cylinder.

The planetary rotation jig is positioned on the base plate of a high vacuum system that is provided with a conventional bell jar cover member. The pressure within the closed system is reduced to about 0.05 mm. of mercury to facilitate a cleaning operation in which the vacuum chamber and its contents are subjected to ion bombardment by applying 1000 to 3000 volts between two internal (inside the chamber) electrodes for about 5 minutes.

After the discharge cleaning step has been accomplished, the evaporation of the metals from the tungsten filament is conducted by reducing the pressure to between 1×10^{-4} and 1×10^{-6} mm. of mercury. At this pressure, evaporation of the metals is accomplished, by heating the tungsten filament by passing a high (30 to 55 amperes) current therethrough. At such currents sufficient heat is produced to evaporate all the electroplated metal in from about 2 to 15 seconds. While this evaporation is complete for all practical purposes, it is advantageous to keep the filament hot for an additional 2 to 4 minutes to ensure evaporation to exhaustion. This additional heat-time within the vacuum also provides an effective heat treatment of the resistance coating on the ceramic cores. It should be noted that since the entire amount of the electroplated metals is evaporated, the resistance alloy composition on the ceramic cores is the same as was deposited on the tungsten filament, and the quantity deposited on each core is proportional to the quantity initially on the filament.

The coated ceramic cores are then removed from the vacuum chamber and subjected to a heat stabilization treatment at temperatures from 250° C. to 450° C. and for times varying from a few minutes to several hours.

The resistance value of the vapor deposited coating on the cores can be adjusted at this point in the process by the expedient well-known to this art of cutting spiral grooves in the coating so as to increase the resistance between the gold termination bands.

Terminals are then applied to the cores to make electrical contact with the gold bands. The terminals may take the form of the end cap assembly shown in FIG. 2, or the wire lead construction shown in FIG. 4. The assemblies of FIG. 2 are preferably press-fitted onto the cores, while the leads of FIG. 4 are cemented in place by a conductive adhesive which is heat cured.

A protective coat of silicone or silicone alkyd varnish is then applied. For optimum results, two coats should be employed and the coats should be cured separately. The units are then molded in a resin that is stable at high temperatures. Suitable resins include alkyd, epoxy, and polyester, with diallyl phthalate as the preferred resin.

The product of the process of this invention may be produced in accordance with the following specific example, which is set forth as merely illustrative:

Example

A ceramic core had applied to each of its ends a gold resinate paint which was fired on at a temperature of approximately 650° C. to form a conductive end paint on the core. Nickel and chromium in proportions of 25% Ni and 75% Cr were electroplated onto a tungsten filament to provide an exact alloy composition on the filament. The ceramic core carrying the conductive end bands was positioned in a planetary rotation jig with stiff wires passing through an axial hole in the core. On this jig the core was rotated at about 1000 r.p.m. The electroplated filament was positioned in a vacuum system parallel to the rotating ceramic core along the axis of planetary rotation. At a pressure of about 50 microns, the rods and devices were cleaned by means of a 2000 volt potential applied between spaced electrodes positioned within the vacuum apparatus for about 5 minutes. The pressure in the vacuum system was then reduced to 1×10^{-5} mm., at which point the electroplated alloy was heated by passing a 40 ampere current through the tungsten filament. The passage of high current through the

tungsten filament effected complete evaporation of the plated metals for all practical purposes in about 8 seconds. To ensure complete evaporation to exhaustion, the current was maintained for an additional 4 minutes. The metal film applied to the core had the proportions of the alloy composition originally present on the filament and the amount was proportional to the amount initially on the filament. The coated units were removed from the vacuum chamber and subjected to heat stabilization at approximately 400° C. for about 40 minutes. Values of the units are greatly increased and brought into close tolerance by cutting a spiral groove in the deposited film, thereby increasing path length and reducing path width. End cap-lead assemblies were then applied to the ends of the coated ceramic core. Then a protective coat of silicone alkyd varnish was applied and cured at an elevated temperature. The units were then enclosed in a molded casing of diallyl phthalate.

The units provided by this process of manufacture have a high degree of electrical accuracy. They stand up under load for a long period of time and withstand other appropriate tests. By proper selection of alloy compositions and weights and control of evaporation conditions, temperature coefficients of resistance can be kept below ± 50 p.p.m./° C. and generally below ± 25 p.p.m./° C.

In FIG. 3 a modified construction produced according to this invention is illustrated. The ceramic core 10 carrying the resistive film 11 described above has applied to each end, and extending a short distance down each side, a fired-on gold termination 19. In this modification, the lead-cap assembly of FIG. 2 is replaced by a pigtail shouldered lead 17 which is electrically connected to the gold termination 19 by a conductive adhesive 18 applied at the contact area between the lead shoulder and the gold. The pigtail lead 17, as shown in FIG. 4, has a short end which extends into a central passage 20 of the core 10 as shown in FIG. 3.

It is a feature of this invention that by careful control of alloy composition, evaporation and aging conditions, the temperature coefficient of resistance in the metal film resistor produced according to this invention can in turn be controlled. For example, a temperature coefficient below ± 50 p.p.m./° C. over the range of -65° C. to +165° C. may be obtained. The resistor produced by this invention shows good performance in life tests; the resistance varying less than 0.5% in 1000 hours at 125° C. with rated power applied. The produced devices also have good shelf life and are capable of withstanding severe temperature cycling, moisture cycling and short time overload when in use.

As many apparently, widely different embodiments described may be made without parting from the spirit and scope thereof; it is to be understood that the invention is not limited to the specific embodiments described except as defined in the appended claims.

What is claimed is:

1. A process for making a metal film resistor which comprises the steps of depositing metals on a filament, positioning said filament and an inert non-conductive base in a vacuum system, and evaporating the entire metal deposits from said filament to exhaustion, so that a known quantity and quality of said metal deposits is vapor deposited on said base.

2. A process as in claim 1 wherein said metals are high temperature resistance metals, said filament is tungsten, and the evaporation is effected by passing current through said filament.

3. A process as in claim 1 wherein the vacuum system and contents are subjected to discharge cleaning prior to the evaporation step.

4. A process for making a metal film resistor having a resistance film of an alloy composition which comprises the steps of depositing an alloy composition on a filament, positioning said film and an inert non-conductive base in the vacuum system and evaporating the entire metal de-

posits from said filament to exhaustion so that a predetermined amount of said alloy composition is vapor-deposited on said base with the constituents of the alloy composition in the same proportion as initially on the filament.

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