

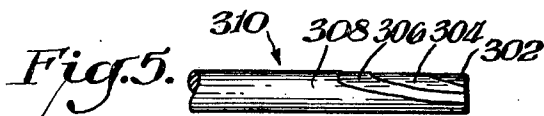
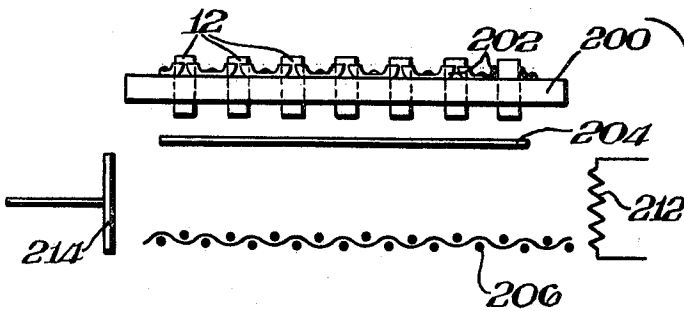
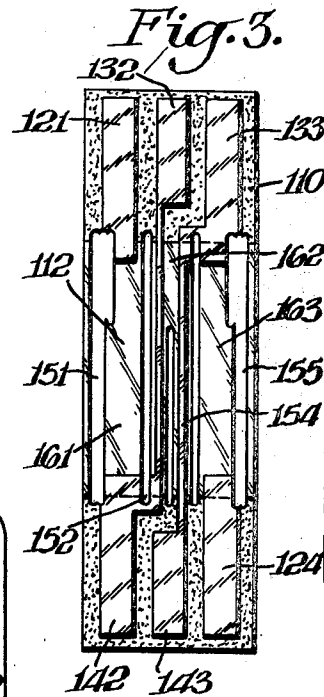
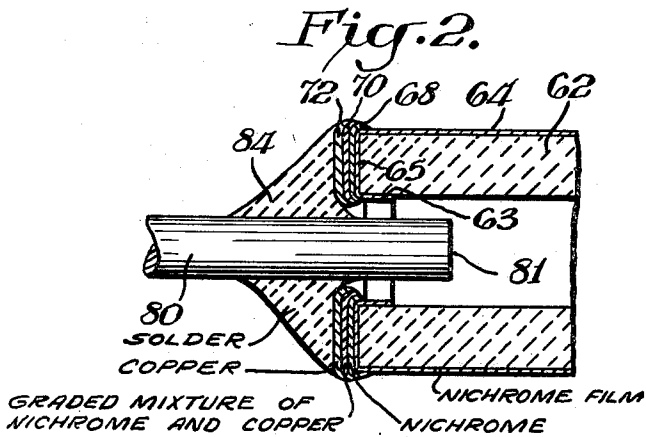
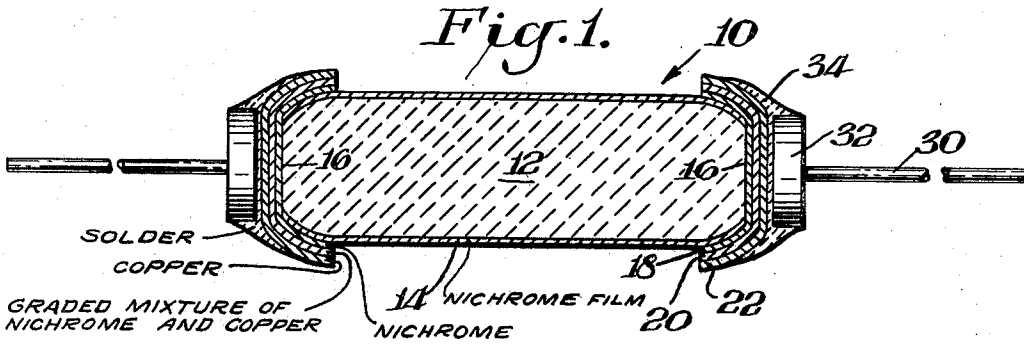
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3,496,513

FILM RESISTOR WITH SECURELY SOLDERED LEADS

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3,496,513

FILM RESISTOR WITH SECURELY SOLDERED LEADS

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Continuation-in-part of applications Ser. No. 584,892, Oct. 6, 1966, Ser. No. 618,370, Feb. 24, 1967, and Ser. No. 652,451, July 11, 1967. This application Nov. 17, 1967, Ser. No. 684,034

Int. Cl. H01c 7/00, 1/14

U.S. Cl. 338—308

4 Claims

ABSTRACT OF THE DISCLOSURE

Nichrome film resistor has solderable sites provided on Nichrome by a graded layer having Nichrome bottom and copper top, with gradually varying mixtures of copper and Nichrome between them. Leads can be soldered to the copper tops with high temperatures solder or brazing alloy. Graded layer can be applied by combination of sputtering the Nichrome and evaporating the copper. Solderable sites are similarly provided on aluminum leads of electrolytic capacitors and the like.

The present application is in part a continuation of applications Ser. No. 584,892 filed Oct. 6, 1966, now U.S. 3,422,386 issued Jan. 14, 1969; Ser. No. 618,370 filed Feb. 24, 1967; and Ser. No. 652,451 filed July 11, 1967.

The present invention relates to terminal leads for electrical resistors in which the resistive component is a film of Nichrome. Resistors of this type have achieved a dominant position in the art because the Nichrome film is admirably suited for such use. However, the provision of terminal connections for such films has been complicated by the fact that it has been awkward to make any kind of a connection to them.

Among the objects of the present invention is the provision of novel terminal connections as well as methods for applying them.

The foregoing as well as additional objects of the present invention will be more fully understood from the following description of several of its exemplifications, reference being made to the accompanying drawings wherein:

FIG. 1 is a longitudinal sectional view of a Nichrome film resistor having terminal leads in accordance with the present invention;

FIG. 2 is a similar detail view of a modified construction illustrative of the present invention;

FIG. 3 is a plan view of a further form of resistor showing another terminal arrangement pursuant to the present invention;

FIG. 4 illustrates (partly in section) one technique used in providing the terminal leads in accordance with the present invention; and

FIG. 5 is a plan view of a portion of a terminal lead illustrating a further embodiment of the present invention.

It has been discovered that a very durable and effective lead connection can be applied to Nichrome resistor films without requiring any precious metal and without requiring pinch-type endcaps or similar mechanically anchored connectors, by providing on a suitable por-

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tion of the Nichrome film a graded layer having a Nichrome bottom, a copper top and gradually varying mixtures of copper and Nichrome between them. Leads can be directly and securely soldered to the copper tops using a solder having a melting point that can be as low as that of ordinary solders or as high as that of brazing alloys. For most purposes the solder connection should have a melting point above 250° C. so as to withstand the temperatures to which the resistors can normally be subjected.

One very desirable technique for providing the graded layer is to sputter the Nichrome and condense the copper from copper vapor, beginning the operation with the sputtering alone, gradually introducing more and more copper condensation, and then discontinuing the sputtering when the gradation is completed so that the copper condensation continues and builds up an upper stratum.

Referring now to the drawings, FIG. 1 shows resistor 10 having a cylindrical ceramic core 12 on which is coated the Nichrome resistor film 14. Film 14 can extend over the entire surface of the core but it is shown in this construction as essentially confined to its cylindrical surface, leaving the end faces 16 uncoated. Over these ends 16 the graded layer of the present invention is applied in such a way as to make good contact with the ends of the Nichrome film 14. The lowermost stratum 18 of the coated layer is Nichrome, the uppermost stratum 22 copper, and the intermediate stratum 20 the graded mixture of Nichrome and copper which varies from essentially all Nichrome close to the lower stratum 18 to essentially all copper close to the uppermost stratum 22. To the copper surface stratum 22 a tinned copper terminal lead 30 having a nail-head end 32 is soldered as shown at 34 with a silver solder which is a eutectic alloy of lead and silver having a melting point of 304° C. No special protection or other covering is needed for the resistor terminal construction, or for that matter for the balance of the resistor except that it is the commercial practice to protect the resistor film 14 as by covering it with a silicone varnish, or molding around it a sheet of protective resin, enamel, or the like.

The copper surface stratum 22 is preferably of substantial thickness such as ½ to 3 microns, so as to help make sure that the copper is not completely dissolved by the solder and thus effectively removed. With thinner copper strata there would be increasing danger of such copper removal so that the soldering then requires substantially more attention and it becomes more and more necessary to limit the time during which this stratum is in contact with molten solder.

Strata 18 and 20 do not have a corresponding minimum thickness requirement and so can be made much thinner. The Nichrome stratum 18 provides exceptional adhesion to the core as well as to the Nichrome film 14, and such adhesion is extremely effective with a 200 angstrom thickness for this stratum. The graded stratum 20 can also be made as thin as 200 angstroms and provide all the gradation needed to securely anchor the copper outer stratum 22. While these strata 18 and 20 can be made as thick as 1000 angstroms or even thicker, the extra material provides no advantages and takes longer and costs more to apply so that they are not preferred.

The strata 18 and 22 are shown in the drawing as sharply distinguished from each other but in actual prac-

tice the entire gradation including stratum 18 as well as the lowest face of stratum 22 gradually changes in composition through its thickness and upon examination one sees a layer that looks like it is all copper but has a discoloration in its lowest portion. Indeed, the strata 18 and 20 are so thin that they do not materially add to the thickness of stratum 22 when measured. Thus the entire graded layer can be considered as having a thickness essentially corresponding to the $\frac{1}{2}$ to 3 micron thickness of copper stratum 22.

The Nichrome film 14 is best baked in air at about 425° C. for 15 minutes before the terminal layers are applied inasmuch as this stabilizes the resistance film so that it shows less change in resistance during use. During such baking treatment the surface of film 14 becomes oxidized, but such oxidation does not prevent the Nichrome stratum 18 from not only adherently anchoring itself to the Nichrome film 14, but in addition the Nichrome stratum 18 establishes itself in very good electrical connection with the oxidized film 14. When the Nichrome stratum 18 is applied by sputtering, as described below for example, the resistance of the connection between lead 30 and film 14 is less than $\frac{1}{50}$ of an ohm with an overlap between stratum 18 and layer 14 as little as ten square millimeters.

The graded layers of the present invention need no heat treatment and are preferably kept from any elevated temperatures to avoid oxidizing the copper surface before a lead is soldered to it.

FIG. 2 illustrates a modified construction in which the terminal lead can merely be a length of wire that does not have to be in any special shape. In this construction the resistor body is a cylindrical tube 62 of steatite or similar ceramic with the Nichrome resistance film 64 applied over its entire outer surface and extending part way into its tubular interior, as shown at 63. The graded terminal layer has its strata 68, 70 and 72 confined essentially entirely to the end face 65 of the body 62 but they can extend a little bit over the end of the cylindrical outer face as well as of the tubular interior. Terminal lead 80 is simply a tinned copper wire having one end 81 inserted into the tubular interior of body 62 a short distance and soldered to the graded layer by the solder connection 84. A number 18 lead wire soldered with the eutectic lead-silver solder in this manner to the annular surface of a graded layer having an outer diameter of 0.2 inch and an inner diameter of 0.05 inch, withstands a pull of 10 to 15 pounds without damage to the soldered joint, the graded layer, or to the adhesion between the graded layer and the resistor body.

FIG. 3 shows a Nichrome film resistor of the planar type, which resistor is similar to that illustrated in the aforementioned U.S. 3,422,386. A rectangular ceramic body 110 has a resistor film 112 extending across its width but severed into separate portions 161, 162, 163 by machining out gaps 151, 152, 154 and 155 as by means of an electron beam. The graded layers of the present invention are applied to form at each end of the body 110, terminals 121, 132, 133, 124, 143, 142. These terminals extend partially over the resistor film 112 and are interconnected to provide leads to both ends of the resistors formed by film sections 161, 162, 163 and also to join these films together in a series connection, all as shown in U.S. 3,422,386. Leads are then soldered to the individual terminal coatings as desired. Either wire-type or foil-type terminal leads can be soldered to the terminal coatings.

FIG. 4 illustrates one technique for applying the graded layer in accordance with the present invention. A plurality of resistor bodies 12, as in the construction of FIG. 1, are positioned with their longitudinal axes vertically in openings in a supporting plate 200. The upper ends of each resistor body are frictionally gripped by a set of spring fingers 202 secured around each opening on the upper surface of plate 200, so that the end faces 16 of

the resistor bodies are exposed below the plate. All these faces 16 can be arranged at approximately the same level immediately above a shutter 204. About two inches below the shutter, a Nichrome screen 206 is horizontally disposed and a substantial distance below that is a melt container 208 holding a quantity of copper 210. Horizontally spaced from the screen 206 near one portion of its edge is a tungsten heater filament 212 and on the opposite side is positioned an anode 214.

The entire apparatus is contained in an evacuation chamber and the application of the graded layer is started by first pumping down the interior of the chamber to a pressure of about 10^{-6} torr, and with the shutter 204 in the blocking position shown in the figure heat is applied to the copper 210 to melt it and remove any accumulated oxides or gasses. A Temescal electron beam heater also positioned in the chamber makes a very effective heater for the copper. After the copper is all molten the heating is terminated and the copper charge permitted to cool. Argon is next caused to leak into the chamber to bring the pressure up to 10^{-3} torr, the tungsten filament 212 then heated to electron-emissive temperature, and the anode 214 polarized at about 90 volts positively with respect to the filament. The Nichrome screen 206 is then rendered about 800 volts negative with respect to the filament, thus causing a sputtering of the Nichrome to take place. After a few minutes of sputting to remove surface contaminants from the Nichrome, the shutter 204 is retracted exposing the faces 16 of the resistor bodies to the Nichrome sputtering. About two minutes of this exposure is all that is needed to build up the sputtered stratum 18, and heat is then applied to the copper 210. A 1 kilowatt electron beam is sufficient to start the copper evaporating so that copper vapors are then deposited over the strata 18 along with sputtering Nichrome. The electron beam power is gradually increased to $1\frac{1}{2}$ kilowatts, causing the copper concentration in the deposit to gradually increase. All this time the argon continues to leak into the chamber but the 10^{-3} torr pressure is maintained by continued evacuation.

About one minute of copper deposition is enough to provide a graded stratum 20 of the desired characteristics, and the argon leak is then stopped. This terminates the sputtering but the continued copper condensation causes a heavy stratum of copper to deposit in the next few minutes. Heating of the copper is then discontinued and the entire assembly permitted to cool after which the chamber is opened and the resistor bodies inverted in their holder for a repetition of the treatment in order to coat their opposite end faces. After both end faces have had their coated layers applied, leads are soldered to them and the resistors can be used as such or they can be coated for protective purposes or helixed to increase their resistance with or without a protective coating.

Other masking means can be used to keep the graded layer from depositing in undesired locations. For example, in the construction of FIG. 3 a metal foil stencil can be punched out to provide openings of the desired shape and the stencil then laid over the body 110. The sides of the stencil can be bent back to provide grips for securing the stencil to the side edges of the body against which it is positioned. Portions of the stencil sides can also be extended to act as suspending means so that the body carried by the stencil can be held at an appropriate location in the coating chamber.

A feature of the construction of the present invention is that it does not use any precious metal. Prior commercial constructions generally use precious metal, as shown for example in U.S. 3,422,386, as well as in U.S. Patent 3,283,587 granted Dec. 20, 1966. Also as shown in the last-mentioned patent, endcaps generally provided in the prior art commercial resistors are crimped around the ends of the resistor body so that they punch into or even through the resistor film.

Gradation of connection strata has been suggested previously, as in British patent specification 1,010,111. This prior suggestion prefers the use of gold which is a particularly precious metal, pointing out that copper is an undesirable substitute for gold because of the need for annealing. The terminal coating of the present invention does not require annealing.

The sputtered Nichrome stratum of the present invention is of unusually high adherence to the oxidized Nichrome resistor film, appreciably more so than an evaporated Nichrome stratum. The sputtered Nichrome also has a more uniform composition inasmuch as the different constituents of the Nichrome will vary in their deposition rate when the Nichrome is deposited by evaporation and condensation. On the other hand, the evaporated copper stratum is much better suited for soldering than a sputtered copper stratum and in addition evaporation is much more rapid than sputtering so that the copper is more conveniently applied by evaporation. The mixed sputtering-evaporation described above is accordingly much more effective than the graded evaporation suggested in the above-mentioned British specification and is also much better than a graded sputtering arrangement.

The Nichrome used for the purposes of the present invention can have from 60 to 80% nickel and the balance chromium. Small amounts of iron with or without manganese, can also be present as long as the nickel content is at least 60% and the chromium content at least about 11%.

The resistor films 14, 64 and 112 can be deposited by evaporation or sputtering or both. While sputtering has some advantages it is preferred to deposit these films by evaporation on a tumbling mass of resistor cores held in a tumbling barrel having sides made of metal screening. Screening having mesh sizes as small as 18 by 18 wires to the inch adequately expose the cores to the deposition of Nichrome from vapor generated a few inches away, even when the openings between the wires are 1 millimeter in width. A hexagonal tumbling drum about ¼ filled with resistor cores and revolving around an axis tilted about 15 degrees from the drum's longitudinal axis, makes a very effective tumbling arrangement that provides fairly uniform coating of all the tumbled cores in a relatively short time. Some of the film-forming vapors also condense on the drum and gradually build up the thickness of the screening, but because the film thickness desired on the cores is so small, generally below 1500 Angstroms, a hundred or more coating operations can generally be carried out before the openings in the screening become small enough to make the coating too inefficient. The resistor bodies of FIG. 2 are conveniently made by such tumbling.

The resistor bodies of FIG. 1 can have their resistor film 14 applied as by fitting the bodies between flat holders that engage the end faces 16 and prevent deposition in those locations. Tubular resistor cores can also be strung on supporting wires to hold them in coating position with their end faces covered or uncovered.

For sputtering Nichrome, pressures of 10^{-4} to 10^{-1} torr can be used with an atmosphere of any inert gas, and the temperature can vary from -50 to $+500^{\circ}\text{C}$. The use of room temperature for such coating avoids complicating the coating apparatus.

Where the leads of the present invention are to be welded in place on the terminal sites, the sites can be built up in thickness to at least about 200 microns, as by continuing the vapor deposition of the copper outer layer, or by electroplating a further coating on these sites. Brazing the leads to the sites is preferably accomplished on graded layers having the copper surface layer more than 1 micron thick, but soldering even with solders melting at 325°C ., can be effectively carried out with copper layers only ½ micron thick.

FIG. 5 shows a modified lead construction which can be used in an arrangement such as illustrated in FIG. 2.

The lead 310 of FIG. 5 is an aluminum wire 302 on which is deposited the graded layers 304, 306, 308. Layer 304 is a Nichrome stratum, 306 a mixed copper-Nichrome stratum, and 308 a copper surface layer, all formed in the same way as described above. The Nichrome stratum 304 has been found to adhere very well to aluminum, even when that aluminum is somewhat oxide-covered, and to effect good electrical contact with the aluminum. The lead 310 can accordingly be used as a terminal wire in place of lead 80 in the construction of FIG. 2, and will solder in place just as effectively. Such a substitute lead is essentially all aluminum and accordingly weighs much less than a copper wire lead so that it is particularly desirable where weight must be minimized. In a satellite carrying thousands of resistors for example, reducing the weight of each resistor by ½ gram effectuates a significant weight saving. The leads 310 are also readily soldered at their coated surfaces to the circuits in which the resistors are to be connected.

Terminal leads such as shown in FIG. 5 can also be used for other electrical components such as capacitors and inductors. Indeed inductors can have entire windings made of wire coated as in FIG. 5 to provide a light-weight construction. Both electrolytic and non-electrolytic capacitors can have the foregoing coated leads, and such coated leads can be in the form of tabs or foils rather than wires, if desired.

In some lead constructions the coating of the present invention can be confined to an end section of the lead, as for example to keep the coating from detracting from the effectiveness of the aluminum core of the lead. Thus in a so-called dry electrolytic capacitor a mass of film-forming metal particles can be sintered to an uncoated portion of an aluminum wire, after which the metal mass is filmed, impregnated, fired, etc., to make the dry electrolytic capacitor and the balance of the lead which carries the coating of the present invention is used as a readily solderable terminal.

For coating on an aluminum wire or foil, the Nichrome stratum can be replaced by aluminum as can the Nichrome portion of the graded stratum. Such a modified coating is applied by the same technique described above using an aluminum screen in place of the Nichrome screen 206 for example. The copper coating can be tinned to even further simplify soldering. In fact tin can replace copper in the graded stratum as well as in the surface stratum for coatings on leads. The use of tin in place of copper is not desirable for coatings on resistor bodies because of the relatively low melting point of tin.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is, therefore, to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

What is claimed:

1. A film resistor comprising an essentially nickel-chromium resistance film, a nickel-chromium oxide on the surface of said film, spaced terminations having a thickness of about ½ to 3 microns on said film, said terminations having a graded composition from a copper exterior through copper-nickel-chromium mixtures to a nickel-chromium interior in adherent contact with said film through said oxide, a terminal lead securely affixed to said terminations by high temperature solder.

2. The combination of claim 1 wherein said terminal lead comprises an aluminum wire one end of which has a graded coating having a solderable copper exterior and graded through mixtures of copper and nickel-chromium to a nickel-chromium stratum on the surface of the aluminum.

3. The combination of claim 2 in which the copper exterior is ½ to 3 microns thick, the graded mixture is 100 to 400 Angstroms thick, and the nickel-chromium stratum is 100 to 400 Angstroms thick.

4. The combination of claim 2 in which the resistor film is on a tubular support, and the terminal lead is inserted into an end of the tube.

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E. A. GOLDBERG, Primary Examiner

U.S. Cl. X.R.

338—322, 329, 331

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,496,513 Dated February 17, 1970

Inventor(s) Walter Helgeland

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

Column 1, line 20, "temperatures" should be
-- temperature --
Column 1, line 63, "siutable" should be -- suitable --
Column 2, line 30, "startum" should be -- stratum --
Column 4, line 70, "3,283,587" should be -- 3,293,587 --
Column 5, line 68, "these" should be -- those --
Column 7, line 7, "2,638,573" should be -- 2,638,523 --
Column 8, line 6, "1966" should be -- 1956 --

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Attest:

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Commissioner of Patents