

May 4, 1948.

J. W. JIRA

2,440,691

ALLOY METAL FILM RESISTOR

Filed March 7, 1945

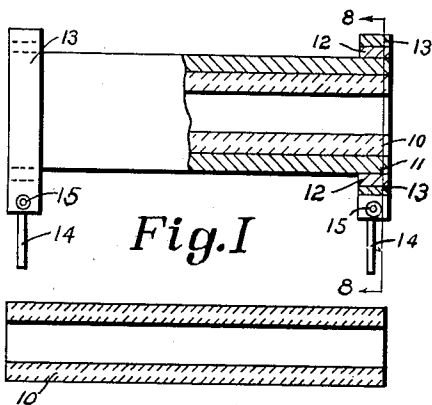


Fig. 1

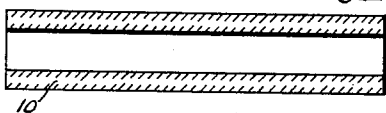


Fig. 2

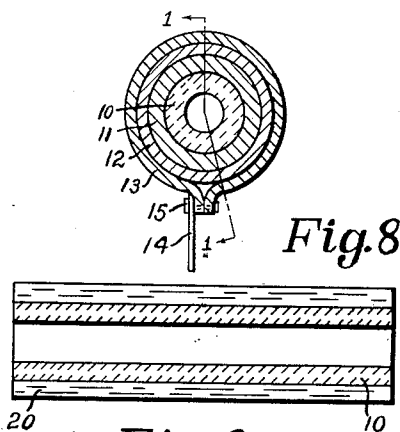


Fig. 3

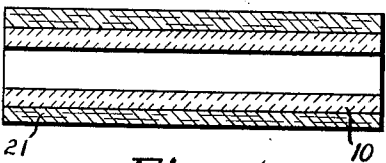


Fig. 4

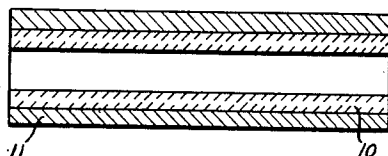


Fig. 5

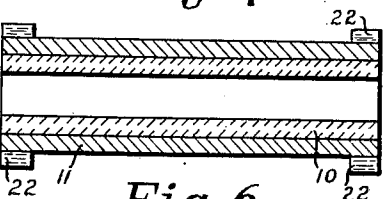


Fig. 6



Fig. 7

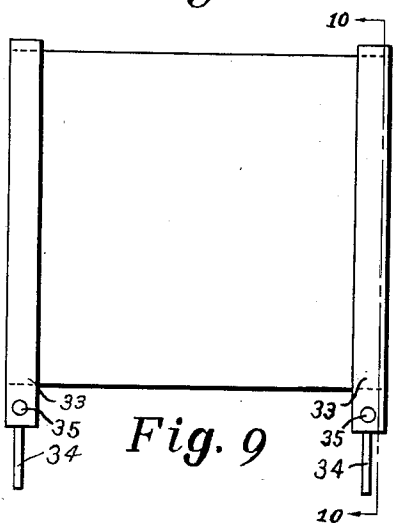


Fig. 9

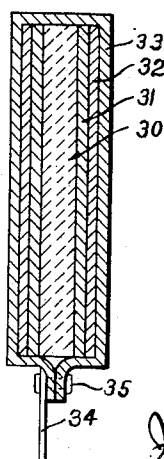


Fig. 10

INVENTOR.
Joseph W. Jira
BY
Shadling and Krost.
attys.

UNITED STATES PATENT OFFICE

2,440,691

ALLOY METAL FILM RESISTOR

Joseph W. Jira, Newburgh Heights, Ohio, assignor
to Continental Carbon, Inc., a corporation of
Ohio

Application March 7, 1945, Serial No. 581,545

17 Claims. (Cl. 201-76)

1

My invention relates in general to resistance units and heating units, and more particularly to precision resistance units and heating units employing a thin film on a nonconductive carrier. However, for the sake of expediency and clearness the following description will be made with reference to a precision resistance unit, but will be understood to include resistance heating units as well.

The basic conception of applying a thin metallic film upon a nonconductive carrier to serve as a resistance unit, has long been known. Although metal itself is well known for its good conductive properties, it is applied in such exceedingly thin coating, that in fact only a limited amount of electricity can be conducted thereby, and the unit therefore, serves effectively as a resistor. However, it has been exceedingly difficult to obtain a continuous metallic film of suitably thin dimensions which would adhere properly to the carrier, be evenly dispersed, and resist deterioration during use. Further, methods which are known today for applying thin metallic film to a non-conductive carrier are expensive, difficult to control, and in particular are not adapted to producing a resistance unit of a relatively low ohmic value without transgressing the boundary and becoming a conductor i. e. offering exceedingly low fractional ohmic resistance values.

Therefore, an object of my invention is to construct a metallic film resistance unit possessing all the qualifications of a precision resistor.

Another object of my invention is to construct a resistance element by automatically depositing a thin alloy film of metal upon the surface of a non-conductive carrier.

Another object of my invention is to construct a resistance element by coating a non-conductive carrier with a mixture of two or more thermally decomposable metallic compounds and heating same to atomically deposit a thin alloy film of the metals upon the non-conductive carrier and to drive off and remove the residual decomposition products.

Another object of my invention is to provide a method of controlling the thickness of the thin metal alloy film deposited upon the non-conductive carrier.

Another object of my invention is to provide a resistance unit employing a thin alloy film of metal upon the surface of a non-conductive carrier which has an ohmic resistance from a fraction of an ohm to a value running into several hundreds of ohms.

Another object of my invention is the method

2

for constructing a low ohmic value metallic alloy resistance unit in which the temperature coefficient of resistance may be controlled by the selection of the percentages of the various metals constituting the thin alloy film.

Another object of my invention is the method of producing a resistance unit of a thin alloy film upon a non-conductive carrier by the selection of at least two metals to be deposited on the non-conductive carrier which will form an alloy in order that higher processing temperatures may be used without driving off the metal of the film and causing discontinuities to raise the resistance of the unit.

Other objects and a fuller understanding of my invention may be had by referring to the following description and claims, taken in conjunction with the accompanying drawings, in which:

Figure 1 shows a longitudinal view of the resistance unit embodying the features of my invention, partly in section along the lines 1-1 of Figure 8;

Figures 2 to 8 inclusive, show the steps by which my improved alloy resistor is constructed, the Figure 8 being a section taken transversely to the terminal connection;

Figure 9 is a side elevational view of a plate type resistor which may be used as a heating element; and

Figure 10 is a cross-sectional view taken along the line 10-10 of Figure 9.

With reference to the Figure 1, my resistance unit comprises a non-conductive carrier 10, a thin metal alloy film 11 deposited upon the outer surface of the non-conductive carrier 10, a body of thin metal deposit 12 upon each end portion of the thin metal alloy film 11, and a terminal member 13 having a lead 14 connected to the body of the thin metal deposit 12 upon each end of the resistor.

The non-conductive carrier 10 may be constructed of any suitable material and may comprise a rod or a hollow tube as shown in Figure 2 and be made of ceramic material which will withstand thermal shock and which possesses a very low moisture absorbing characteristic. In actual practice, I find that a ceramic material like Isolantite or its equivalent is suitable and preferable for resistors. A material that will withstand thermal shock and stand up under high temperature is required for units used for heating.

The thin metal alloy film 11 is atomically deposited upon the outer surface of a non-conductive carrier 10 by coating the outer surface

with a mixture of at least two organo-compounds of a substantially stable and substantially non-oxidizable metal and heating the same. By non-oxidizable metal is meant a metal which is normally resistant to oxidation at a temperature which is sufficient to cause the rapid oxidation of carbonaceous materials. Before applying the organo-compound mixture to the ceramic tube 10, the outer surface is subjected to a degreasing or cleaning operation. This may be done by the suspending or immersing of the ceramic tube in a solution containing 50% carbon tetrachloride and 50% ethylene dichloride by volume, or a boiling solution of trisodium phosphate may be used, and the tube suspended therein for approximately ten minutes. Thereafter, the non-conductive carrier is permitted to air dry before being subjected to the film forming operation. It is understood of course, that numerous other chemical cleaning agents are adapted for use in the cleaning operation and the foregoing are cited only by way of example. It is usually necessary to wash the ceramic tubes five or six times in clear running water before drying in order to remove excess cleansing solution.

Upon the drying of the ceramic tube 10, a thin coating of the mixture of organo-compounds comprising organic resins of stable and substantially non-oxidizable metals is applied to the ceramic tube by either dipping, brushing or spraying. The term "substantially stable and substantially non-oxidizable metal" comprises those metals principally of the noble group although not limited thereto. The metal must remain substantially stable and be substantially non-oxidizable under high temperatures sufficient to burn out any residue or decomposition products remaining after the decomposition of the metal upon the ceramic tube. Under the general class of compounds known as the resins, are included the constituents of natural occurring resins, resin exudations from trees, and synthetic preparations. In preparing my metallic organo-compounds for the mixture, the metal is substituted into or added to the organo-resinate. Of the metals, I find that palladium, platinum, gold and silver are among the metals which may be substituted into or added to the resinate giving the respective metal resinate. My invention will hereinafter be described in connection with gold and palladium resinate but it will be understood that it includes similar stable and non-oxidizable metals or equivalents. Also, my invention is broad enough in scope to include other types of compounds which may not be organic in nature, and which may result in volatile decomposition products, or decomposition products of a nature other than that of being carbonaceous.

The resistance for a definite size resistor as produced by this invention is lower than that produced by my Patent No. 2,281,843. The low ohmic values are produced in this invention by the combination of physical properties of two metals, in this illustration—gold and palladium. It is found that by combining gold and palladium resinate in such proportions as would produce an alloy film containing 72% gold and 28% palladium as an example, the resistance obtained was between .05 ohm and .1 ohm when the film was deposited on a ceramic tube one inch long and $\frac{3}{8}$ of an inch in diameter. Whereas, for the same size tube, palladium gave a minimum value of substantially 1000 ohms and platinum gave a minimum value of substantially 10 ohms. Even with very careful work, gold was found to be very

difficult to apply to the carrier, and a minimum value of 5 ohms was obtained. The reason for the minimum values does not seem to be the same for all metals. In the case of gold which is a highly non-oxidizable material, it was found that temperatures used to burn off the residual carbonaceous material vaporized portions of the extremely thin atomic deposit of gold. Therefore, discontinuities were encountered which tend to increase the ohmic value of a gold resistor high above the value which it should obtain. On the other hand, palladium is found to oxidize to a certain percentage of the total palladium present, and tends to reach an equilibrium at that point. Therefore, when using palladium on a carrier, an extremely low ohmic value could not be obtained because of this described equilibrium. However, palladium normally has a high vapor pressure at the processing temperatures and therefore, does not tend to vaporize from the carrier. The direct interaction between two alloyable materials, as set forth herein, appear to stabilize one another and produces highly desirable effects.

Another very desirable feature accomplished by the alloying of two metals having different properties, is the control of the temperature coefficient of resistance. Resistors made with pure gold film are found to have a high positive temperature coefficient of resistance. On the other hand, when making resistors of palladium film, it is found that with an increase in the amount of palladium, as before described, an increase in the amount of oxide of palladium is formed. This oxide of palladium is found to produce a high negative temperature coefficient of resistance. Therefore, by the variation of the amount of palladium and gold in the alloy film, the negative and positive coefficient of resistance can be balanced one against the other to produce a resistor having exactly the desired amount of temperature coefficient.

By varying the percentage of gold in the alloy of this example, from substantially 1% to substantially 99% of the total, it was found that the temperature coefficient of resistance could be controlled within a range from substantially minus 5% to substantially positive 5% of the zero temperature coefficient of resistance.

It is difficult to obtain a commercially feasible resistor by applying a substantially saturated mixture of the metallic resinate, without an appropriate carrier or thinner, to the ceramic carrier. Even though attempts to apply by brushing or dipping a substantially saturated mixture of the resinate, in the absence of a thinner, as thinly as possible upon the carrier, yet the atomically deposited metallic alloy film results in too great a thickness to give the desired ohmic value of resistance. A thinner functions as a medium for carrying the resinate, so that the said resins are evenly distributed or dispersed in an even coating upon the ceramic carrier 10. That is to say, the organoresinates are usually dispersed in the carrier or thinner, and when applied to the ceramic carrier gives in effect, a reduced amount of the metal. Of the suitable thinners, I find that a compounded thinner as disclosed in my application for Letters Patent filed concurrently herewith, entitled "Thinner for organoresinate" is quite satisfactory. This thinner (or solvent as the case may be) is comprised substantially of two relatively high boiling ketones coupled by an intermediate agent, and supplemented by a tacky oxidizable material. Namely, the thinner is comprised of from 5% to 20% acetophenone, 10% to

30% fenchone, 10% to 25% nitrobenzene, and the remainder pinene or its equivalent, which may be turpentine of the steam distilled variety. In the practice of my invention, a good thin metal alloy film is obtained by adding a sufficient amount of the thinner to the mixture of resin so that the amount of metal is substantially 1% of the total thin mixture.

Upon decomposition, the metals of metallo-organosols tend to precipitate therefrom in the form of minute flakes. These minute flakes have a tendency to curl at their edges and therefore be out of contact with its neighboring flakes. In other words, if the flakes are not held tightly to the carrier during the manufacturing steps they will not be bonded thereto as one continuous film, but will have many interruptions in the continuity thereof which tend to cause a higher value of resistance. Therefore, the turpentine is added to the thinner to produce an oxidized binder whereby after the thinner has dried and the organosols decomposed, the flakes are tightly held against the carrier until they can be bonded thereto.

After the coating comprising the mixture of resins and the thinner, which is represented by the reference character 20, in Figure 3, is applied to the ceramic carrier 10, it is then permitted to dry in air for about 30 minutes at a temperature of approximately 20° to 25° centigrade. The thickness of the coating is exaggerated in the drawing. Upon drying, the ceramic carrier and coating is given a first stage of heat treating to effect thermal decomposition of the metallic resins and deposit the metals upon the carrier. The precipitation of the pure metals from the resin mixture starts at temperatures ranging anywhere from approximately 200° centigrade to 400° centigrade. The time was found to vary anywhere from 15 to 30 minutes, depending upon the surface area of the ceramic carrier and the thickness of the applied coating. When using organo-resins, the precipitation of the metals is accompanied by the formation of ash or decomposition product on the carrier mixed with the pure metal which comprises essentially carbon and is represented by the reference character 21 in Figure 4. At this stage, the turpentine is oxidized into a tough film to hold the precipitated metal tightly to the carrier.

The second stage heating is to completely oxidize the ash or residue and to drive off any volatile decomposition products as well as to insure a complete precipitation of the virgin metals. The second stage heating may range from 400° centigrade to 750° centigrade for about one hour. The Figure 5 shows the ceramic tube after the residue is thoroughly oxidized and removed by volatilization to leave the thin alloy film 11 which may be characterized as the basic resistance. The metallic film possesses unusually good bonding properties. In fact, the metal bonding characteristic is such that the only means of removal from the ceramic carrier is by grinding. The ceramic and the deposited metals are virtually one.

The next general series of steps in my process is to connect the terminal members 13 having leads 14 to the end portions of the thin metal film 11. To do this, I first deposit a body of thin metal 12 upon the end portions of the alloy film 11 as shown in Figures 1 and 7. The body of the thin metal 12 may be physically deposited upon the end portions of the alloy film 11 by coating the end portions with a band of colloidal silver

as indicated by the reference character 22 in Figure 6 and heating the same at approximately 500° centigrade to 600° centigrade for 30 minutes or thereabouts.

After the band of silver 12 is deposited about the end portions, the terminal members 13 comprising preferably thin strips of copper metal are clamped thereon as shown in Figures 1 and 8, making a good electrical contact with the silver. The terminal members 13 may be securely clamped about the silver deposit by fastening the free ends together by means of a rivet 15. The leads 14 may be connected to the terminal members 13 by the same rivets that hold the free end of the terminal members 13 together. The connection at the rivet may also be soldered.

The silver is ideally suited in this part of the process since it possesses a low thermo-electric effect against either the alloy or the copper metal of the terminal members. This type of contact is of extremely low resistance, thus reflecting its advantages in producing a resistor possessing a minimum noise and voltage characteristic.

To complete the resistance unit, it may or may not be spiralled depending upon the resistance value desired. This spiralling procedure has the effect of increasing the total effective resistive path and by doing so increases the resistance value of the unit manifold. As an example, a resistance having a basic value of 100 ohms when ground with a helical path equally along the periphery of the carrier for a period of 5 revolutions will produce a controlled value from 1000 to 10,000 ohms. Therefore, by utilizing five or six basic values a great number of various resistance values are possible. The resistor is then given a coat of moisture-proof lacquer which when dried completes the process. In my invention, the heating to burn out the ash or residue is below the melting point of the precipitated metal and also below the oxidizing temperature of the metal, giving a good stable and continuous film.

The initial basic resistance value of the alloy film 11 may be controlled by the number of coats applied to the ceramic carrier or by varying the amount of the metallic resins in the applied coating. In the event an additional number of coatings are applied, they may be added at different stages in the process. As a first example, the additional coatings may be applied on top of the coating 20 in Figure 3, after each applied coating is allowed to dry. After the several coatings are dried, the process is then carried out as above explained. As a second example, an additional coating may be applied on top of the coating 21 in Figure 4, which means that two first stage and one second stage firings are required. Under the second example, any number of coatings may be applied by repeating the procedure. After the additional coatings have been added under the second example, the general process is then completed as previously described. As a third example, an additional coating may be applied on top of the metal film 11 in Figure 5, which means that two first stage and two second stage firings are required. Under the third example, any number of coatings may be applied by repeating the procedure. After the additional coatings have been added under the third example, the general process is then completed as previously described.

With reference to the Figure 9, I illustrate a substantially flat plate unit, which may be made by my improved method. The Figure 10 is a cross-sectional view taken along the lines 10-10

of Figure 9. In this embodiment of my invention, the figure 30 indicates a substantially flat plate non-conductive carrier having a thin metallic alloy coating 31 thereon. Although the coating 31 is illustrated as being on both sides of the carrier 30, it is understood that this coating may be placed on only one side thereof if desired. A body of thin metal deposit 32 is placed upon each end portion of the metal alloy film 31, and terminal members 33 having lead wires 34 are connected to the body of the thin metal deposit 32 upon each end of the unit. In all respects, the method of producing a unit of this type is substantially similar to that described in connection with the tubular type. It has been found, that a construction of the type illustrated in Figure 9 is suitable for a resistance unit or as a heating unit. When properly constructed, this plate type unit was found to radiate sufficient heat to serve as a toaster unit, or as a heater unit. However, it is not essential to provide leads as described. The unit may be provided to insert into suitable clips if desired.

Due to the fact that the conducting medium of my invention is metal, many of the difficulties arising from the use of carbon were completely eliminated. The first of these deficiencies was temperature coefficient of resistance. It is well known that carbon possesses a negative temperature coefficient, a factor partly responsible for resistor failures when subject to normal or twice rated wattage.

Since gas carbon is now chiefly employed in carbon composition type resistors, it exerts a certain amount of influence upon the water repellency of the manufactured unit. Since gas carbon is hygroscopic it prevents the manufacture of a resistor possessing a stable shelf life or a low humidity characteristic, even if thoroughly impregnated in wax under reduced pressure.

Furthermore, since the conventional carbon composition resistor is an admixture of carbon and a bonding agent, usually a polymerizable resin, it is more or less prone to carbonization and therefore deterioration while under the influence of heat, a factor chiefly responsible for resistor failure.

By virtue of the bonding medium and countless particles of carbon that do not contribute towards the resistance value (undispersible conductor) hundreds of minute capacities are formed which exert a pronounced influence upon the high frequency characteristic of the unit.

All the above shortcomings of the carbon type resistor were completely rectified by the metal film resistor.

The new resistor not only possessed all the desirable electrical characteristics of a wire wound unit, but for a given value and wattage rating was one-tenth the size, a factor of commercial importance.

The most difficult steps encountered in fabricating a resistor of the type were the following:

(1) The applied metallic organo-film had to be evenly distributed over the surface of the carrier, otherwise areas of uneven density appeared over the periphery of the unit and caused erratic resistance fluctuations during the spiralling operation.

(2) Temperatures had to be carefully controlled otherwise nonadhering or only partly adhering metallic films resulted.

(3) The deposited metallic film had to be of sufficient thickness to prevent discontinuous electrical paths resulting from a difference in the

linear coefficients of expansion of the metal film and the ceramic carrier.

(4) Holding the deposited metallic flakes in place until bonded to the carrier.

(5) The control of the temperature coefficient of resistance.

While I have described my invention with reference to resistance units and heaters, it is essentially a current conducting element and is not limited in scope to resistance units and heaters as commonly defined in the commercial industry.

Although I have described my invention with a certain degree of particularity, it is understood that the present disclosure has been made only by way of example and that numerous changes in the details of construction and the combination and arrangement of parts may be resorted to without departing from the spirit and the scope of the invention as hereinafter claimed.

I claim as my invention:

1. The process of constructing a metallic film on a non-conductive carrier, comprising providing a mixture of at least two metallic organo-compound resins of substantially stable and non-oxidizable alloyable metals, adding a thinner to the mixture to evenly distribute said resins, said thinner comprising substantially 5% to 20% acetophenone; 10% to 25% nitrobenzene; 10% to 30% fenchone; and the remainder being a compound selected from the class consisting of pinene or turpentine, coating the non-conductive carrier with the thinned mixture, drying the coated carrier, and thereafter heating same to decompose the organoresins and precipitate the metals therefrom as an alloy upon the non-conductive carrier and to remove any carbonaceous residue remaining after said precipitation.

2. The process of constructing a metallic film on a non-conductive carrier comprising providing a mixture of at least two thermally decomposable compounds of substantially stable and non-oxidizable metals which are alloyable with one another, said decomposable compounds being decomposable to the extent of precipitating the virgin metal therefrom, adding a thinner to the mixture to evenly distribute same, coating the said carrier with the thinned mixture, drying the coating thereon, thereafter heating said coating to decompose said decomposable compounds and deposit said metals as an alloy film upon the said carrier, and thereafter heating said coating to remove and drive off any residual decomposition products.

3. The process of constructing a metallic film on a non-conductive carrier, comprising providing a mixture of thermally decomposable compounds of substantially stable and non-oxidizable metals, said mixture of compounds containing at least one thermally decomposable compound of gold and at least one thermally decomposable compound of palladium, said decomposable compounds being decomposable to the extent of precipitating the virgin gold and the virgin palladium therefrom, adding a thinner to the mixture to evenly distribute same, coating the said carrier with the thinned mixture, drying the coating thereon, thereafter heating said coating to decompose said decomposable compounds and deposit the said gold and the said palladium as an alloy film upon the said carrier, and thereafter heating said coating to remove and drive off any residue decomposition products.

4. The process of constructing a metallic film on a non-conductive carrier, comprising providing a mixture of thermally decomposable com-

pounds of substantially stable and non-oxidizable metals, said mixture of compounds containing at least one thermally decomposable compound of gold and at least one thermally decomposable compound of palladium said decomposable compounds being decomposable to the extent of precipitating the virgin gold and the virgin palladium therefrom, adding a thinner to the mixture to evenly distribute same, coating the said carrier with the thinned mixture, heating the coated non-conductive carrier to first thermally decompose the said decomposable compounds and deposit a thin alloy film of the gold and palladium upon the non-conductive carrier and to secondly remove and drive off any residual decomposition products, and providing suitable terminals to connect with the said thin alloy film.

5. The process of constructing a metallic film on a non-conductive carrier, comprising providing a mixture of thermally decomposable compounds of substantially stable and non-oxidizable metals, said mixture of compounds containing at least one thermally decomposable compound of gold and at least one thermally decomposable compound of palladium, said decomposable compounds being decomposable to the extent of precipitating the virgin gold and the virgin palladium therefrom, adding a thinner mixture, drying the coating thereon, thereafter heating said coating substantially within a range of temperature between 200° centigrade and 400° centigrade to decompose said decomposable compounds and deposit the said gold and the said palladium as an alloy film upon the said carrier, and thereafter heating said coating substantially within a range of temperature between 400° centigrade and 750° centigrade to remove and drive off any residual decomposition products.

6. The process of constructing a metallic film on a non-conductive carrier, comprising providing a mixture of at least two metallic organo-compound resins of substantially stable and non-oxidizable alloyable metals, coating the non-conductive carrier with the mixture, drying the coated carrier and thereafter heating same to decompose the organoresins and precipitate the metals therefrom as an alloy upon the non-conductive carrier and to remove any carbonaceous residue remaining after said precipitation.

7. The process of constructing a metallic film on a nonconductive carrier comprising providing a mixture of at least two thermally decomposable compounds of substantially stable and non-oxidizable metals which are alloyable with one another, said decomposable compounds being decomposable to the extent of precipitating the virgin metal therefrom, coating the said carrier with the mixture, drying the coating thereon, thereafter heating said coating to decompose said decomposable compounds and deposit said metals as an alloy film upon the said carrier, and thereafter heating said coating to remove and drive off any residual decomposition products.

8. The process of constructing a metallic film on a non-conductive carrier, comprising providing a mixture of thermally decomposable compounds of substantially stable and non-oxidizable metals, said mixture of compounds containing at least one thermally decomposable compound of gold and at least one thermally decomposable compound of palladium, said decomposable compounds being decomposable to the extent of precipitating the virgin gold and the virgin palladium therefrom, coating the said carrier with the mixture, drying the coating

thereon, thereafter heating said coating substantially within a range of temperature between 200° centigrade and 400° centigrade to decompose said decomposable compounds and deposit the said gold and the said palladium as an alloy film upon the said carrier, and thereafter heating said coating substantially within a range of temperature between 400° centigrade and 750° centigrade to remove and drive off any residual decomposition products.

9. The process of constructing a metallic film on a non-conductive carrier, comprising providing a mixture of thermally decomposable compounds of substantially stable and non-oxidizable metals, said mixture of compounds containing at least one thermally decomposable compound of gold and at least one thermally decomposable compound of palladium, said decomposable compounds being decomposable to the extent of precipitating the virgin gold and the virgin palladium therefrom, coating the said carrier with the mixture, heating the coated non-conductive carrier to first thermally decompose the said decomposable compounds and deposit a thin alloy film of the gold and palladium upon the non-conductive carrier and to secondly remove and drive off any residual decomposition, and providing suitable terminals to connect with the said thin alloy film.

10. The process of constructing a metallic film on a non-conductive carrier, comprising providing a mixture of thermally decomposable compounds of substantially stable and non-oxidizable metals, said mixture of compounds containing at least one thermally decomposable compound of gold and at least one thermally decomposable compound of palladium, said decomposable compounds being decomposable to the extent of precipitating the virgin gold and the virgin palladium therefrom, adding a thinner to the mixture to reduce the concentration of the gold and palladium, coating the said carrier with the thinned mixture, drying the coating thereon, thereafter heating said coating substantially within a range of temperature between 200° centigrade and 400° centigrade to decompose said decomposable compounds and deposit the said gold and the said palladium as an alloy film upon the said carrier, and thereafter heating said coating substantially within a range of temperature between 400° centigrade and 750° centigrade to remove and drive off any residual decomposition products.

11. The process of constructing a metallic film on a non-conductive carrier, comprising providing a mixture of thermally decomposable compounds of substantially stable and non-oxidizable metals, said mixture of compounds containing at least one thermally decomposable compound of gold and at least one thermally decomposable compound of palladium, said decomposable compounds being decomposable to the extent of precipitating the virgin gold and the virgin palladium therefrom, adding a thinner to the mixture to reduce the concentration of the gold and palladium therein to substantially 1%, coating the said carrier with the thinned mixture, drying the coating thereon, thereafter heating said coating substantially within a range of temperature between 200° centigrade and 400° centigrade to decompose said decomposable compounds, and deposit the said gold and the said palladium as an alloy film upon the said carrier, and thereafter heating said coating substantially within a range of temperature between 400° centigrade and 750°

centigrade to remove and drive off any residual decomposition products.

12. The process of constructing a metallic film on a non-conductive carrier, comprising providing a mixture of thermally decomposable compounds of substantially stable and non-oxidizable metal, said mixture of compounds containing at least one thermally decomposable compound of gold and at least one thermally decomposable compound of palladium, said decomposable compounds being decomposable to the extent of precipitating the virgin gold and the virgin palladium therefrom, adding a thinner to the mixture to evenly distribute same and reduce the concentration of the gold and palladium, coating the said carrier with the thinned mixture, drying the coating thereon, thereafter heating said coating substantially within a range of temperature between 200° centigrade and 400° centigrade for a period of in a range from 15 to 30 minutes to decompose said decomposable compounds and deposit the said gold and the said palladium as an alloy film upon the said carrier, and thereafter heating said coating substantially within a range of temperature between 400° centigrade and 750° centigrade for a period of time of substantially one hour to remove and drive off any residual decomposition products.

13. The process of constructing a metallic film on a non-conductive carrier, comprising providing a mixture of thermally decomposable compounds of substantially stable and non-oxidizable metals, said mixture of compounds containing at least one thermally decomposable compound of gold and at least one thermally decomposable compound of palladium, said decomposable compounds being decomposable to the extent of precipitating the virgin gold and the virgin palladium therefrom, adding a thinner to the mixture to evenly distribute same, coating the said carrier with the thinned mixture, heating the coated non-conductive carrier to first thermally decompose the said decomposable compounds and deposit a thin alloy film of the gold and palladium upon the nonconductive carrier and to secondly remove and drive off any residual decomposition products other than said alloy film, said heating being below the temperature at which the vapor pressure of said alloy film becomes equal to the atmospheric pressure.

14. An article of manufacture comprising a non-conductive carrier, an alloy film of at least two substantially stable and non-oxidizable metals tightly bonded to said carrier, and electrical terminal means for said alloy film.

15. An article of manufacture comprising a non-conductive carrier having a tightly bonded

conductive film thereon, said film comprising an alloy of at least two materials, one of said at least two materials having a positive coefficient of resistance, and the other of said at least two materials having a negative coefficient of resistance, said materials being proportioned in said alloy to produce a resultant coefficient of resistance of a predetermined value.

16. A current conducting article comprising an alloy of at least two materials, one of said at least two materials having a positive coefficient of resistance, and the other of said at least two materials having a negative coefficient of resistance, said materials being proportioned in said alloy to produce a resultant coefficient of resistance of a predetermined value in a range of plus and minus 5% of the zero temperature coefficient of resistance.

17. The process of constructing a metallic film on a non-conductive carrier, comprising selecting at least one compound from the group including thermally decomposable compounds of metals that are substantially stable and non-oxidizable and having a positive coefficient of resistance, selecting at least one compound from the group including thermally decomposable compounds of metals that are substantially stable and non-oxidizable but forms upon heating a small amount of oxide which has a negative coefficient of resistance, said decomposable compounds being decomposable to the extent of precipitating the virgin metal therefrom, mixing the said decomposable compounds, adding a thinner to the mixture to evenly distribute same, coating the said carrier with the thinned mixture, drying the coating thereon, thereafter heating said coating to decompose said decomposable compounds and deposit said metals as an alloy film upon the said carrier, and thereafter heating said coating to remove and drive off any residual decomposition products.

JOSEPH W. JIRA.

REFERENCES CITED

45 The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
50 1,896,193	Corson	Feb. 7, 1933
2,281,843	Jira	May 5, 1942
1,717,712	Loewe	June 18, 1929
2,205,306	Olshevsky	June 18, 1940
1,970,084	Feussner	Aug. 14, 1934
55 1,765,413	Fruth	June 24, 1930
2,021,661	Kisfaludy	Nov. 19, 1935
1,339,505	Fahrenwald	May 11, 1920