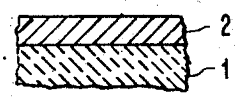
METAL FILM RESISTOR

Filed Sept. 20, 1968

FIG.1A



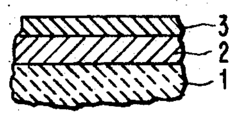


FIG.1B

FIG.2

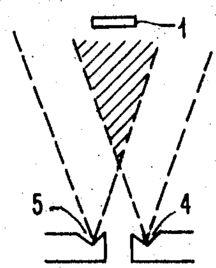


FIG.3

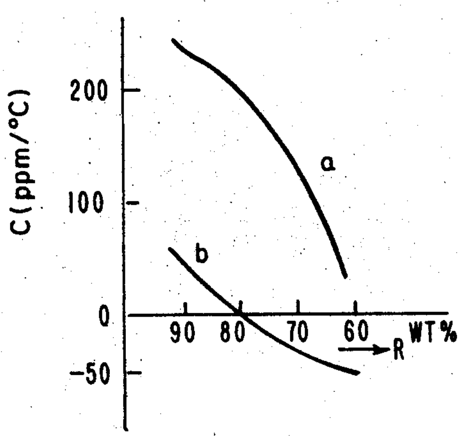


FIG.4

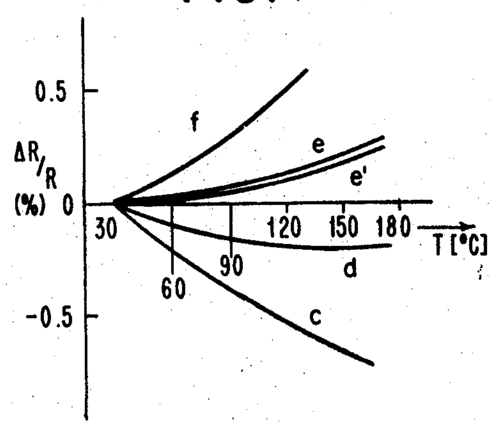
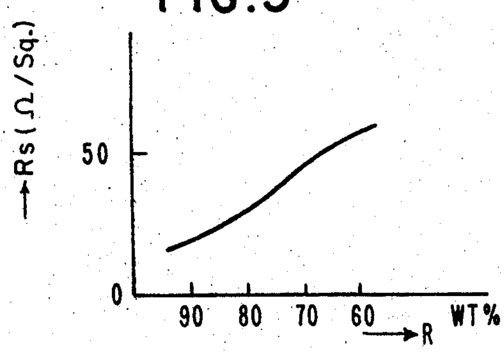


FIG.5



United States Patent Office

3,578,420

Patented May 11, 1971

3,578,420

METAL FILM RESISTOR

Yasuro Nishimura, Machida-shi, and Masao Tanaka, Tokyo, Japan, assignors to Fujitsu Limited, Kawasaki, Japan

Filed Sept. 20, 1968, Ser. No. 761,050

Claims priority, application Japan, Sept. 23, 1967, 42/61,093

Int. Cl. B32b *15/04;* H01c *7/00*

U.S. Cl. 29—195 2 Claims

ABSTRACT OF THE DISCLOSURE

Our invention relates to a metal film resistor comprising evaporated thin films of small specific resistance and temperature coefficient of resistance. The metal film resistor comprises a first evaporated thin film including nickel, chromium and gold and, when necessary, other metals and an electrically stable second evaporated thin film provided on said first evaporated thin film. The second film prevents diffusion and precipitation of gold in the first evaporated thin film and protects the first evaporated thin film.

Our invention relates to a metal film resistor comprising evaporated thin films of small specific resistance and temperature coefficient of resistance.

In general, an alloy of large specific resistance can constitute an electrically stable resistor with a small temperature coefficient. Therefore, an electrically stable low resistor with a small temperature coefficient has heretofore been fabricated by the evaporation of such alloy. In order, however, to fabricate a low resistor using an alloy of large specific resistance, it is necessary to utilize a thick film, consequently prolonging the time required for the evaporation, during which time the ratio between composition readily changes by the difference between the vapor pressure of components and the temperature tends to become large. In order to eliminate this defect, the evaporation is conventionally stopped before the ratio between composition of the evaporated film obtained is greatly varied. The evaporation is repeated many times until a low resistance metal film resistor comprising multilayer evaporated films is obtained. It is, however, extremely difficult to obtain a metal film resistor of uniform characteristics since the ratio between composition of the evaporated film varies greatly in accordance with the length of time for the evaporation as a result of differences between the vapor pressure of the metals constituting the alloy. This difficulty is increased by the necessity for multilayer evaporation. It is thus completely impossible to make the evaporation conditions, such as the material of the evaporation source and the heating temperature of the evaporation source, constant throughout the evaporation process. Consequently, the lack of uniformity of the characteristics of films on base bodies is greatly increased. In the practical evaporation process, it is troublesome and undesirable to repeat evaporation many times.

It is the object of our invention to eliminate the troublesome and difficult evaporation process in the conventional method and to provide an electrically stable metal film resistor of small specific resistance and temperature coefficient of resistance. In order to achieve said object, we provide a metal film resistor by first evaporating a thin film including nickel, chromium, gold or other additive metals and provide an electrically stable second evaporated thin film on said first evaporated thin film. This second film prevents diffusion and precipitation of

gold in the first evaporated thin film and protects the first evaporated thin film.

The invention will now be described in greater detail. According to our invention, the first evaporated thin film is fundamentally constituted of nickel, chromium and gold and can include other additives such as, for example, aluminum and copper. The gold content of the first evaporated thin film is not so intimately related to the ratio of nickel and chromium and constitutes 60 to 95% by weight. Consequently, the temperature coefficient of resistance of the first evaporated thin film becomes small and the specific resistance also becomes very small. The time required for evaporation of the first evaporated thin film can, therefore, be shortened and the influence of the ratio between compositions during evaporation can be reduced. As described above, gold is the chief constituent of the resistor thin film. However, the temperature coefficient of resistance can be greatly reduced because the rate of nickel and chromium is regulated. The crystal state of the first evaporated thin film immediately after evaporation has many defects and lacks stability and therefore requires a heat treatment. It was found, however that this heat treatment causes gold, which is the chief constituent of the first evaporated thin film, to diffuse and precipitate on the surface. Consequently, the great temperature coefficient of resistance of the gold causes the temperature coefficient of resistance of the first evaporated thin film to become relatively large within the range of the desired specific resistance.

In view of the above, we further provide, on the first evaporated thin film, a second evaporated thin film for impeding or damping the diffusion and precipitation of gold. An object of the second evaporated thin film in addition to the above objects is to protect the first evaporated thin film from air. The second evaporated thin film must not disturb the electrical characteristic of the first evaporated thin film. The thickness of the film is at least the minimum possible thickness capable of realizing said effect. In order to achieve this object, the second evaporated thin film will be of the metals constituting the first evaporated thin film, except for gold. This constitution will further simplify the manufacture of the metal film resistor, because the second film can be formed by evaporating only the molecules of a nickel chromium alloy by stopping the evaporation of gold or impeding the evaporated gold molecules by a shutter after the formation of the first film. This method is simpler than one of forming the second evaporated thin film by using an additional evaporation source. It will be evident in view of the aforementioned that the second thin film need not only be a nickel chromium alloy but may also contain metals as can be used as the first thin film.

The first and second evaporated thin films are formed on an insulating base body. Any material used in the conventional evaporation technique, such as, for example, glass or ceramic, can be used as said base body. As described above, the metal film resistor of this invention can be manufactured by the use of the well known vacuum evaporation apparatus. Evaporation sources, i.e., gold, nickel chromium alloy, nickel chromium gold alloy or alloys containing other metals, for constituting the evaporated thin films are evaporated by thermionic beam heating or resistance heating. Evaporation and accumulation can also be accomplished by ion bombardment.

As described above, in accordance with this invention, a resistance film of small temperature coefficient of resistance and specific resistance can be obtained. Further, the period of time for evaporation can be greatly shortened compared to the conventional manufacturing method and therefore the ratio between composition of the resistance thin film is not greatly varied and a metal film resistor of uniform characteristics can be obtained.

An embodiment of the invention will be described with respect to the drawing, in which:

FIG. 1 shows at A and B the constitution of the resistor of the invention;

FIG. 2 shows the arrangement of an evaporation source in vacuum evaporation apparatus to obtain a thin film constituting the resistor of this invention;

FIG. 3 shows the relationship between the gold content and the temperature coefficient of resistance in an example of this invention;

FIG. 4 shows the relationship between temperature and resistance in an example of this invention; and

FIG. 5 shows the relationship between the gold content of a thin film and the sheet resistivity in an example of this invention.

As shown in FIG. 1A, a first evaporated thin film **2** of nickel, chromium and gold was formed on a ceramic base body **1**. The thin film **2** can be formed as shown in FIG. 2. A crucible containing a Nichrome alloy block **4** in which the ratio of nickel to chromium is 80 to 20 by weight and a crucible containing gold **5** are provided in a single vacuum chamber. The temperatures, that is the vapor pressure of materials in the two crucibles, are adjusted independently one from the other. In this embodiment, the crucible containing the Nichrome alloy block was kept at about 1350° C. by resistance heating and the crucible containing gold was also kept at about 1350° C. by resistance heating. The percentage of gold by weight in the first evaporated thin film is determined by the temperature of the evaporation source, the mass of the metal added from said evaporation source and the distance between said evaporation source and the base body. Therefore, by previously measuring the amount of attachment by evaporation of gold, nickel and chromium on the base body separately from each other under a certain condition of evaporation, it becomes possible to know indirectly the percentage by weight of gold under the condition of evaporation. In the instant embodiment, the evaporation conditions were varied in order to obtain the relationship between the gold content and the temperature coefficient of resistance. The vacuum chamber of the vacuum evaporation apparatus was held to a vacuum of 5×10^{-5} torr and the thin film was evaporated on the base body **1** from the two evaporation sources to a thickness of 300 A. over 40 to 150 seconds. In the instant embodiment, the temperature of the base body was kept at the room temperature. The thin film thus obtained was heated to stabilize the electrical characteristic. The heating temperature is correlated to the duration of the heat treatment and can be 150° C. to 350° C.

After the first evaporated thin film, the chief constituent of which is gold, is heated for 10 hours at 250° C., the temperature coefficient of resistance is varied as shown by curve *a* in FIG. 3. In this figure, the abscissa R indicates the gold content (percent by weight) of the thin film and the ordinate C indicates the temperature coefficient of resistance (p.p.m./° C.). As is evident from this figure, in order for the temperature coefficient of resistance of the thin film to be set at a value required in an ordinary resistor, for example a value within ±50 p.p.m./° C., the gold content must be about 60% by weight. This value must be controlled correctly. Now, with the gold content set at about 60% by weight, the sheet resistivity of the thin film can be varied as shown in FIG. 5. This FIG. 5 shows the relationship between the gold content R (percent by weight) and the area resistance R_s Ω/sq. when the thin film is 300 A. thick. The sheet resistivity is 57 Ω/sq. for a 300 A. thick film. This means that a resistor satisfying the invention, i.e., a metal film resistor in which the temperature coefficient of resistance and sheet resistivity and, accordingly, specific resistance are all small, cannot be obtained.

This defect, however, of the increase of the temperature

coefficient of resistance has been eliminated by this invention by forming the second evaporated thin film **3** on the first evaporated thin film **2** as shown in FIG. 1B. This second layer creates the possibility that a conductive gold layer formed on the surface by diffusion and precipitation in the heat treatment is eliminated while the favorable electrcial characteristics of the first evaporated thin film are maintained. A nickel chromium alloy or a metal the temperature coefficient of resistance of which is not very large can be used as the metal for the second thin film. For example, a single metal of chromium, titanium or nickel can be used. After the first and second evaporated thin films have been formed, the two films are heated to stabilize the characteristics. Here the thickness of the second thin film is selected depending upon the material therefor, so that the diffusion of gold may be impeded or prevented during said heat treatment. In evaporating a nickel chromium alloy as the second thin film to a thickness of about several hundreds A., the heating temperature can be selected at 200–300° C. and the heating can continue for a period of time of from several hours to over ten hours. Since the heating period can be varied arbitrarily, the heating temperature range can be further widened to 150–350° C. The second evaporated thin film must be evaporated to a thickness that will not disturb the electrical characteristic of the first evaporated thin film. The thickness can be varied arbitrarily by one skilled in this field depending on the material used.

Curve *b* of FIG. 3 shows the temperature coefficient of resistance of a metal film obtained by evaporating the second evaporated thin film comprising nickel and chromium to a thickness of 200 A. on the first evaporated thin film comprising nickel, chromium and gold. The gold content of said first film is variable. The two thin films are then heated at a temperature of 250° C. for 10 hours.

In FIG. 4, curves *c, d, e* and *f* show the relation between temperature T (° C.) and resistance change $\Delta R/R$ (%) when gold contents are 62%, 75%, 83% and 90%, respectively. These resistance changes are computed based on the resistance values available when the ambient temperature is 30° C. It is seen from the above that in a thin film, the gold content of which is about 80%, the temperature coefficient of resistance is approximately zero and the variation of the resistance to the temperature is a minimum when the temperature is near the room temperature. It must be noted here that the gold content of the first evaporated thin film of the resistor of which the temperature coefficient of resistance is approximately zero, is higher by about 20% than the gold content of the resistor obtained by heating the first evaporated thin film only of which the temperature coefficient of resistance is approximately zero and that the slope of the curve is gentle. When the gold content is 80%, the temperature coefficient of resistance is very small and the sheet resistivity is 30 Ω/sq. These two values well satisfy the object of this invention.

According to this invention, the gold content of the first evaporated thin film is selected between 60% and 95%. As a consequence, the temperature coefficient of resistance is varied approximately between −50 p.p.m./° C. and +100 p.p.m./° C. Also, the sheet resistivity is less than 60 Ω/sq.

Various modified embodiments of this invention can be obtained based on an example of experiment described above by varying the gold content of the first evaporated thin film within a range of 60–95% by varying the metals for constituting the second evaporated thin film within the range of the metals described in this invention and further varying the thicknesses of said thin films.

Next, an embodiment of this invention will be described wherein each of the first and second evaporated thin films comprises a mixture of nickel, chromium and other additive metals such as, for example, aluminum and copper. A first evaporated thin film comprising nickel, chromium, aluminum, copper and gold, of which the gold content is 33% by weight was formed on a ceramic base body by evaporating an evaporation source of gold and another evaporation source of a nickel chromium alloy in which the ratio by weight of nickel to chromium, aluminum and copper is 75:20:2.5:2.5, and the second evaporated thin film comprising nickel, chromium, aluminum and copper was further formed on said first evaporated thin film by evaporating an evaporation source of an alloy in which the ratio by weight of nickel to chromium, aluminum and copper is 75:20:2.5:2.5. The first evaporated thin film of the metal film resistor was evaporated to a thickness of about 300 A. Following the formation of said first film, the second evaporated thin film was evaporated to a thickness of 150 A. After the evaporation was finished, the two films were heated for 10 hours at 250° C. This metal film resistor has a resistance of about 30Ω and a temperature coefficient of resistance of within 10 p.p.m./° C. The resistance change of this resistor in relation to temperature is as shown by curve *e'* in FIG. 4.

We claim:

1. A metal film resistor consisting essentially of a first evaporated thin film of nickel, chromium and gold and an electrically stable second evaporated thin film selected from nickel chromium alloys, chromium, titanium and nickel on said first evaporated thin film to prevent diffusion and precipitation of gold in said first evaporated thin film and protect said first evaporated thin film.

2. The metal film resistor of claim **1**, wherein the first evaporated thin film has a gold content of 60–95% by weight and is evaporated on a base body of nonconductive material from an evaporation source of a nickel chromium alloy and another evaporation source of gold, the evaporation from said two evaporation sources being made simultaneously, and a second evaporated thin film consisting essentially of a nickel chromium alloy.

References Cited

UNITED STATES PATENTS

2,840,468	6/1958	Brenner	75—165
2,935,717	5/1960	Solow	338—308
3,356,982	12/1967	Solow	338—308
3,381,256	4/1968	Schuller et al.	117—217X
3,462,723	8/1969	Phillips	29—195X
3,493,352	2/1970	Wright et al.	29—195X
3,495,959	2/1970	Johnson	29—195

L. DEWAYNE RUTLEDGE, Primary Examiner

E. L. WEISE, Assistant Examiner

U.S. Cl. X.R.

117—217; 338—308