April 15, 1969 D. G. SCHIMMEL 3,439,306

SELF-SUPPORTING RESISTANCE FILM

Original Filed May 6, 1963

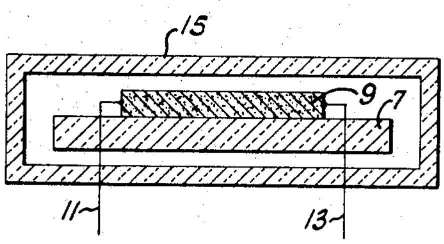

Fig. 1

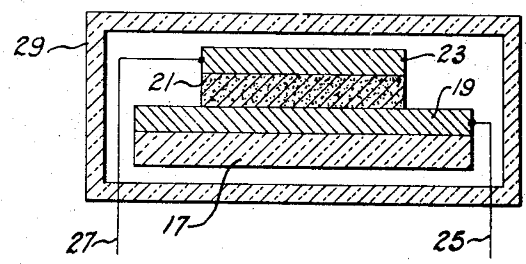

Fig. 2

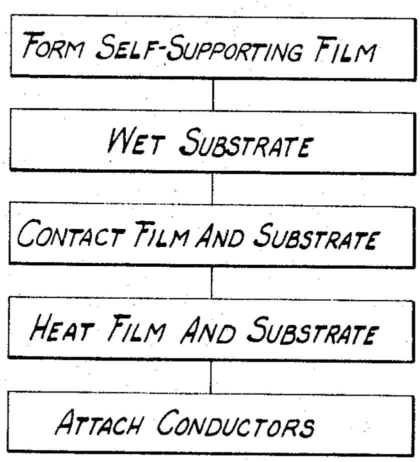

Fig. 3

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United States Patent Office

3,439,306
Patented Apr. 15, 1969

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3,439,306

SELF-SUPPORTING RESISTANCE FILM

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Continuation of application Ser. No. 278,084, May 6, 1963. This application June 5, 1967, Ser. No. 645,541
Int. Cl. H01c 3/00
U.S. Cl. 338—212 4 Claims

ABSTRACT OF THE DISCLOSURE

A self-supporting resistance film is provided in which the binder is of an organic material capable of being softened by an organic solvent and the resistance characteristic is attained by uniformly dispersing resistance particles in contacting relationship throughout the binder, the film being applied to any contoured surface configuration by wetting the binder with the solvent and while the film is still wet, contacting the film with the surface.

This is a continuation of application Ser. No. 278,084 filed May 6, 1963, now abandoned.

This invention relates to resistors and a process for the fabrication thereof and more particularly to linear and nonlinear resistors and a process for manufacture thereof from a self-supporting film containing a resistive material.

Generally, known resistors consist of a layer of linear or nonlinear resistive material having a pair of conductors attached thereto for electrically connecting the resistive material to external elements. The resistive material layer is usually supported by a substrate whereon it is sprayed, painted, vacuum deposited, deposited from the vapor phase by thermal methods, or applied in some such manner in an amount sufficient to provide a desired resistance value intermediate the attached electrical conductors.

Although the above mentioned resistors and processes of fabrication are commonly encountered, it has been found that the finished product as well as the processes of fabrication leave much to be desired. For instance, it is well known that a uniform and consistent thickness and density is difficult to control in a spraying or painting process. Further, when this uniformity must be maintained in a repetitive operation where interruptions are all too frequent, consistency becomes more important and more difficult. Additionally, vacuum deposition and similar "batch" processes are expensive as well as time consuming and are not particularly adapted to consistency nor to automation.

Therefore, it is an object of this invention to provide a resistor having improved uniformity.

Another object of this invention is to reduce the resistive material variations intermediate the attached electrical conductors.

Still another object of this invention is to improve the resistive material thickness and density consistency in a resistor manufacturing process.

A further object of this invention is to reduce the ratio of resistor cost to resistor value variation in a resistor fabrication process.

A still further object of this invention is to improve the ratio of resistor fabrication time to resistor value variation.

Briefly, these objects are fulfilled in one aspect of the invention by the provision of a resistive layer formed from resistive material homogeneously dispersed in a self-supporting film which is disposed intermediate a pair of electrical conductors. In the resistor fabrication process, the resistance material is suspended in a self-supporting film having a volatile organic binder and a binder plasticizer.

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The film is adhered to a substrate by wetting the substrate with a solvent for the film and then contacting the film and substrate. Thereafter, heat is applied in an amount dependent upon the resistive material in the film and the results desired. Subsequently, a pair of electrical conductors are attached to the resistive layer for external connection thereto and the resistive layer may be encapsulated as a protective measure.

For a better understanding of the present invention, together with other and further objects, advantages, and capabilities thereof, reference is made to the following disclosure and appended claims in connection with the accompanying drawings in which:

FIG. 1 is an elevated view of one embodiment of the invention;

FIG. 2 is an elevated view of another embodiment of the invention; and

FIG. 3 is a flow chart illustrating a process for fabricating resistors.

Referring to FIG. 1 of the drawings, there is illustrated a linear-type resistor having a substrate **7** whereon is attached a linear resistance material layer **9**. A pair of conductors **11** and **13** are attached to the resistive material layer **9** to provide external electrical connection thereto. The substrate **7** and resistive material layer **9** may be encapsulated in a housing **15** which protects the resistive material layer **9** from atmospheric and abrasive damage.

FIG. 2 illustrates a nonlinear type resistor having a substrate **17** whereon is attached a metallized layer **19**. A nonlinear resistive material layer **21** is attached to the metallized layer **19** and subsequently an electrically conductive layer **23** is deposited thereon. The electrically conductive layers **19** and **23** form the electrodes of the resistor, and conductors **25** and **27** may be attached thereto for external electrical connections. Additionally, the substrate **17**, electrically conductive layers **19** and **23**, and nonlinear resistive material layer **21** may be encapsulated in a housing **29** to prevent atmospheric and abrasive damage to the nonlinear resistive material layer **21**.

FIG. 3 illustrates a process for fabricating resistors from a self-supporting film containing resistive material. A substrate is wetted with a solvent for the binder in the film, and the film and wetted substrate are brought into contact. Upon contact, the solvent softens the film and the film adopts the contour of the substrate and adheres thereto. Heat is then applied to the film in an amount dependent upon the resistive material in the film and the organic constituent volatilization required to provide a resistive material layer. Subsequently, conductors may be attached to the layer to permit external electrical connection and the substrate and resistive material layer may be encapsulated to provide protection thereof.

In preparing a self-supporting resistive film adapted to the formation of a resistive material layer, a lacquer suspension comprising an organic binder and a binder plasticizer is dissolved in a mixture of organic solvents. For example, the following lacquer suspension has yielded excellent self-supporting resistor films upon addition of a resistive material thereto:

	Grams
Ethylene carbonate	100.00
Toluene (400 ml.)	346.40
Synasol (100 ml.)	79.00
Butyl carbitol (15 ml.)	14.34
Ethyl cellulose N–300	30 00

The ethyl cellulose N–300 binder in the above formulation has an ethoxyl content of between 47.5 and 49.0 percent by weight and a viscosity of approximately 300 centipoises in a 5.0 percent solution of 80:20 toluene to synasol, with the butyl carbitol being defined in Merck's Index, Sixth Edition, as diethylene glycol monogutyl ether.

The ethyl cellulose N-300 binder is but one of many applicable organic binders such as nylon, methyl methacrylate, polyvinyl alcohol, methyl cellulose, nitrocellulose, and styrene-vinyl copolymers.

Further, the binder selected must be compatible with the solvents and both must be volatile. Additionally, the binder content is dependent upon the desired density of the resultant film and preferably should be in the range of 3.0 to 30.0 percent by weight of solids.

A temporary plasticizer such as butyl carbitol in the range of approximately 0.5 to 15.0 percent and preferably 2.5 percent based on the weight of the suspension is particularly adapted to the presented formulation. Moreover, the variety of plasticizing agents for ethyl cellulose binders is unusually large and includes most known classes of flexible agents for coatings and plastics. Further, plasticizers of a more permanent nature such as castor oil, butyl stearate, and dibutyl phthalate may be used although the more temporary plasticizers are preferred. Additionally, the amount of plasticizer is, of course, dependent upon the density and flexibility desired in a resultant self-supporting resistor film which may be fabricated from the above mentioned lacquer suspension when a resistive material is added thereto.

The ethylene carbonate, which may be in the range of approximately 1.0 to 30.0 percent and in the preferred formulation 17.6 percent by weight of the total suspension, acts not only as a temporary plasticizer but aids in controlling the film density by producing voids in the film as the other solvents are vaporized therefrom.

A mixture of organic solvents such as the above listed toluene and synasol having different temperatures and rates of evaporation provides many advantages over a single solvent. For instance, the solubility of the binder is improved, the viscosity of the suspension is more easily duplicated, and the swelling of the cellulose is better controlled. Further, the use of a nonpolar solvent such as toluene, which is the last to leave the film, imparts strength to the film for subsequent handling thereof without fear of rupture. Although an 80:20 ratio of toluene to synasol is preferred, ratios up to and including 10:90 toluene to synasol may be used without significant change in suspension viscosity. Moreover, numerous solvents may be used in the above mentioned formulation including methanol, benzene, methyl formato, heptane, acetone, and even water in a binder such as hydroxyethyl cellulose.

The preparation of the lacquer suspension is unsophisticated and straight-forward. The above mentioned ingredients are measured and dispensed directly into a ball-mill jar and rolled for approximately 16 hours. Thus, all solids are thoroughly dissolved and a uniformly blended lacquer suspension is provided.

Following, a resistive material is added to the above lacquer suspension. This resistive material may be in particle form or as a suspension containing resistive material particles. Further, the resistive material additive may be in any of a large number of such materials as well as a combination thereof. For instance, such commonly used linear resistive materials as graphite, lampblack, fine metal particles, and metallic oxides are appropriate and applicable. Additionally, nonlinear resistive materials, materials which do not follow Ohm's Law, such as silicon carbide, cadmium sulfide, stannous oxide, and numerous other nonlinear materials and combinations thereof have been found suitable for use with the above mentioned lacquer to provide a self-supporting resistive film.

Regarding the proportions of resistive material additive in the suspension, obviously the type of material as well as the resistance value desired are determining factors. For instance, suspensions having a nonlinear resistive material in the range of about 25 to 75 percent by weight of the total suspension and self-supporting nonlinear resistive films having approximately 50 to 99 percent by weight of resistive material have been found appropriate. Moreover, suspensions having a linear resistance material in the range of about 0.05 to 15.0 percent by weight of the total suspension and films having about 0.5 to 25 percent by weight of linear resistive material have been found suitable. Additionally, linear resistive self-supporting films having a thickness in the range of 0.0003 to 0.005 inch and a density of about 0.3 to 0.7 gms./cm.^{3} provide resistors having desired characteristics.

The above mentioned lacquer suspension and resistance material additive may be formulated in a manner previously disclosed in Patent No. 3,017,281, "Formulation for Casting Pigmented Film," issued to Lambert and McKeirnan, and then cast on a casting wheel according the teaching of Crosby and Stoll in Patent No. 2,965,927. Further, these processes have been found to be well suited to the production of a pliable self-supporting film having a uniformly smooth surface, very minute variations in density and thickness, and a consistency and repeatability throughout which, as far as is known, had been previously unobtainable.

Having provided a self-supporting film containing the desired resistive material, a substrate material is selected whereon the film is to be disposed. Any of the materials commonly used as substrates are applicable depending upon use and temperature to which it will be exposed. For example, glass, plastic, ceramic, and numerous other such materials are suitable. Additionally, the substrate may be metallized to provide an electrode having intimate contact with the resistive layer to be disposed thereon. Again, numerous metals and alloys are suitable such as copper, gold, aluminum, molybdenum, and others depending upon the conductivity, affinity for attachment to the substrate, tempertaure characteristics, and use.

Following, the selected substrate or metallized surface of the substrate is wetted with a solvent for the film. The solvent may be any one or combination of solvents for the film as previously mentioned. Further, the process of wetting the surface may be any of numerous ordinary techniques such as spraying, painting, swabbing with a solvent-soaked sponge, and many others.

Following, the film is brought into contact with the solvent wetted substrate. Thereupon, the solvent progressively dissolves some of the binder in the film and softens the film. Further, the surface tension of the solvent causes the softened film to adopt the contour of the substrate. Additionally, the solvent evaporates and the film is adhered to the wetted surface thereby permitting transport of the substrate and film without fear of rupture or loosening of the film.

Regarding the above mentioned self-supporting film adhered to a substrate, the film may be, but not necessarily need be, cut to a desired configuration to provide a desired resistance value. Further, the technique for cutting the film may be any of a number of such processes depending on the particular circumstances. For instance, if the desired film pattern is not too intricate, the film may be cut and the resultant pattern adhered to the substrate as described above. Alternately, the film may be adhered to the substrate and a metal pattern placed thereover whereupon the undesired film portions may be removed by a process such as sandblasting. Moreover, the film may be attached to the substrate and a photoetching process employed. Anyone or all of these processes are suitable although not a requirement of the presented process.

Thereafter, the substrate and adhered film are heated to a temperature and for a time which is dependent upon the resistive material additive in the film as well as the ultimate desired result. For example, in the formation of a linear resistor, a linear resistive material such as graphite particles may be homogeneously dispersed in a binder and a plasticizer for the binder to provide a self-supporting film. Subsequently, this film may be heated to a temperature in the range of about 650° C. to 950° C. whereupon the organic constituents are volatilized from the film and the remaining graphite particles in contiguous relationship form a layer having a linear resistive characteristic.

Alternately, in the formation of a nonlinear resistor, a nonlinear resistive material such as stannous oxide particles may be homogeneously dispersed in a binder and a plasticizer for the binder to provide a self-supporting film. Subsequently, the film is heated to a temperature in the range of about 125° C. to 250° C. to insure volatilization of all solvents and improved adherence of the film to the substrate. Thus, the film having contiguous particles of nonlinear resistive material suspended therein provides a layer having a nonlinear resistive characteristic.

Subsequently, a pair of conductors are attached to the resistive layer as illustrated in FIGS. 1 and 2 to provide electrical connection of the layer to external elements. This conductor attachment may be any of a great number of processes such as brazing the layer to pins as illustrated in FIG. 1 or adhering the resistive film layer to a metallized ceramic and depositing a surface layer **23** thereon as illustrated in FIG. 2. Additionally, the substrate and attached resistive material may be encapsulated in any of a number of ways whereby the resistive material layer is protected from atmospheric and abrasive damage.

Nonlinear resistor

In fabricating a nonlinear resistor, a nonlinear resistive material was added to the previously described lacquer suspension. For example, 15 gms. of stannous oxide was added to 15 gms. of the above mentioned lacquer and rolled in a glass bottle until homogeneous dispersion was obtained. Thereupon, the following suspension resulted:

	Grams
Ethylene carbonate	1.32
Toluene	12.03
Synasol	1.05
Butyl carbitol	0.20
Ethy cellulose N–300	0.39
Stannous oxide	15.00

This suspension was then cast into a film in a manner previously described and provided a self-supporting film having a density of about 3.24 gms./cm.^{3} and a thickness of approximately 0.0027 inch. Further, the film contained stannous oxide in an amount of approximately 97.47 percent of the total film weight.

Following, a glass substrate was metallized with a layer of copper which acts as one electrode for the resistor. This copper layer was then wetted with synasol, a solvent for the above mentioned resistive material self-supporting film, by swabbing the surface with a soaked sponge.

Thereafter, the film and solvent wetted surface were contacted whereupon the solvent softened the film and the surface tension caused the film to adopt the contour of the metallized surface. Moreover, the film adhered to the surface and the solvent or at least a major portion thereof evaporated.

Subsequently, the film was heated to a temperature of approximately 170° C. in air for a period of about five minutes to insure removal of all of the solvent from the film and the surface. Moreover, the heat improved the adhesion and contact between the film and the metallized layer.

Afterwards, a metallized layer of aluminum was vacuum deposited onto the resistive film layer to provide a second electrode for the resistor. Thereafter, the resistor was encapsulated in a glass envelope which was then evacuated to provide atmospheric and abrasive protection of the resistive film.

Linear Resistor

In the fabrication of a linear resistor, graphite in the form of Aquadag 154A which consists of 90 percent isopropyl alcohol and 10 percent graphite and is made by Atcheson Colloid Corporation of Port Huron, Mich., is added to the previously described lacquer suspension. For example, 7.2 grams of Aquadag 154A was added to 150 grams of lacquer and rolled in a glass bottle until homogeneous dispersion was obtained. Thereupon the following suspension resulted:

	Grams
Ethylene carbonate	26.33
Toluene	91.19
Synasol	20.79
Butyl carbitol	3.77
Ethyl cellulose N–300	7.91
Isopropyl alcohol	6.48
Graphite	0.72

This suspension was then cast as described above and provided a self-supporting film having a density of about 0.52 gm./cm.^{3} and a thickness of approximately 0.0003 inch. Moreover, the graphite contained in the film was about 8.34 percent of the total film weight, and the film after heat treatment, had a resistance of 2165 ohms/sq.

Additionally, a ceramic was selected as a substrate and wetted with a solvent for the film by swabbing the ceramic surface with a solvent soaked sponge. Furthermore, the film was cut to a configuration adapted to provide the desired resistance value.

Following, the film was brought into contact with the solvent wetted ceramic surface and the solvent caused the film to soften. Further, the surface tension of the solvent forced the pliable film to adopt the contour of the ceramic surface whereon it adhered. Additionally, a major portion of the solvent evaporated leaving a substantially dry and transportable film adhered to the ceramic surface.

Thereafter, the ceramic and adhered film were heated in wet dissociated ammonia for about three minutes at a temperature of approximately 800° C. Thereupon, the organic constituents were volatilized from the film leaving a graphite resistance layer affixed to the ceramic substrate. Additionally, the resistive layer was brazed to a pair of electrical conductors with a titanium hydride flux which was heated to about 800° C. in a pure hydrogen atmosphere.

Subsequently, the resistive layer and substrate were encapsulated in a glass bulb and the atmosphere evacuated therefrom to provide atmospheric and abrasive protection for the resistive layer.

Thus, there has been provided both linear and nonlinear resistors whereon the resistive layer has a density, thickness, and consistency which, as far as is known, has been previously unobtainable. Further, the process of fabricating resistors from a self-supporting film having resistive materials contained therein not only reduces the cost and time required for fabrication but provides a reliability and repeatability well adapted to automated processes. Moreover, the process provides reproducible results wherein variations in resistive values are minimized when compared with previous known techniques.

While there has been shown and described what are at present considered the preferred embodiments of the present invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention as defined by the appended claims.

I claim:

1. An electrical resistor material comprising a flexible self-supporting film of resistance material particles homogeneously dispersed in an organic binder, the binder being selected from the group consisting of ethyl cellulose, methyl methacrylate, polyvinyl alcohol, methyl cellulose and nitrocellulose, said film having a substantially uniform thickness and density and being heat transformable to a substantially uniformly thick and uniformly dense layer of contacting resistance material particles.

2. The electrical resistor material of claim 1 wherein said organic binder is ethyl cellulose.

3. An electrical resistor material comprising a flexible self-supporting film of linear resistance material particles homogeneously dispersed in a thermoplastic organic binder, said film having a substantially uniform thickness of about 0.0003 inch to 0.005 inch and uniform density in the range of about 0.3 to 0.7 gm. per cubic centimeter and includes resistance particles in the range of about 0.5 to 25% by weight of said film, said film being heat transformable to a substantially uniformly thick and uniformly dense layer of contiguous contacting resistance material particles.

4. An electrical resistor material comprising a flexible self-supporting film of linear resistance material particles homogeneously dispersed in a thermoplastic organic binder, said film having a substantially uniform thickness of about 0.0003 inch and uniform density of about 0.52 gm. per cubic centimeter and includes graphite particles in the amount of about 8.3% by weight of said film, said film being heat transformable to a substantially uniformly thick and uniformly dense layer of contiguous contacting resistance material particles.

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U.S. Cl. X.R.

106—193; 117—226; 219—549; 252—511; 260—037; 338—308