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1

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THIN FILM RESISTORS AND METHODS OF MAKING THEREOF

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This invention relates to thin film resistors. More particularly, this invention relates to an electrical resistor element in thin films comprising a vapor-deposited metal and a poly(p-xylylene).

Heretofore, resistors employed in electric circuitry have been limited to certain current-conducting high resistance elements, compounds, compositions and alloys. Carbon has most widely been employed for such applications but alloys of certain metals, as well as other compounds and compositions have found applications in electric circuitry. With the advent of miniaturized and microminiaturized electric circuitry, however, there is need for reducing the effective size of certain elements, particularly the resistors, capacitors and other bulky elements of amplification, rectification and attenuation circuits. Presently available materials of construction are not suitable for constructing microminiaturized resistors. In fact in many amplification, attenuation and rectification circuits, the resistors and capacitors have proven to be the bulkiest of the components, even greater in size by many times than the transistors and diodes employed therein.

According to the present invention, it has now been discovered that thin film resistors can now be prepared by forming an intimate dispersion of vapor-deposited conductive metal and a normally solid poly(p-xylylene). These compositions, as hereinafter more fully described, provide unique resistors having a temperature coefficient of resistance at least equivalent to that of carbon resistors but which can be prepared in thicknesses ranging from 50 A. thick on other insulative supports or substrates to self-supporting films having any desired thickness. As such, the thickness of the resistor per se is not critical. The most useful and practical benefits of this invention are served with such thin films in microminiaturized circuits which could not heretofore be made.

As another aspect of this invention, there is provided a method for the formation of resistor elements having any selected or desired resistance which comprises the steps of simultaneously depositing under reduced pressure a mixture of a vaporized normally conductive metal and a vaporous p-xylylene diradical in such ratios that the solid deposited matrix constitutes from about 25 to 75 percent by weight metal, the balance being a linear solid poly(p-xylylene). The particular vaporous diradical employed is not critical and can be substituted in any of the free valence positions with any inert substituents as hereinafter more specifically set forth. The vaporous mixture of metal and reactive diradicals readily condenses on any surface maintained below the ceiling condensation temperature of the diradical to yield an intimate mixture of metal and solid linear poly(p-xylylene). The condensation and instantaneous polymerization of the diradicals physically entraps the metal in atomic or nearly atomic dispersion, to form a film comprising a dispersion matrix which exhibits resistance to electric current flow, the resistance depending primarily on the amount of metal in the dispersion, as well as upon the thickness and size of the film.

2

Generally the metal should be present in the dispersion in an amount of at least 25 percent by weight, otherwise the resistance of the element is so high as to be almost an insulator. Also, it is desirable that there be present in the dispersion at least 25 percent by weight poly(p-xylylene) in order to adequately bond and entrap the metal and give sufficient strength to the resistor to enable it to be resistant to rubbing and abrasion. If it is desired to deposit the resistor dispersion on a temporary substrate from which the resistor film can be ultimately lifted off to form a self-supporting film, polymer concentration should be about 40 percent or more by weight.

Best results have been found in those materials having between about 30 percent to 60 percent by weight metal, the balance being the polymer.

It is not critical in this invention which particular metal is employed other than it should be an electrically conductive metal, and preferably is one easily evaporated and readily depositable by vacuum techniques. Those metals most readily deposited by vacuum evaporation normally have a vapor deposition rate of about 5×10^{-6} grams per second per $cm.^2$ of surface at 1 micron pressure (absolute), and thus are most readily employable in this invention. Illustrative of such metals that lend themselves readily adaptable to the making of resistors are metals such as aluminum, gold, silver, copper, magnesium, zinc, tin, lead, chromium, cobalt, titanium vanadium manganese iron, nickel, platinum, tungsten, tantalum and other like metals. Any of such metals are electrically conductive for use in the resistors of this invention.

While any of such materials can be used, it is generally preferred that the metal be an excellent natural conductor in the solid state, i.e. have a resistivity less than 100μ ohm centimeters, and more preferably less than 10μ ohm centimeters such as for example silver, gold, copper, aluminum, and lead because less metal is required to give the desired conductance to the resistor. However, in most instances, the amount of metal needed is of minor importance as long as the matrix dispersion possesses the desired degree of resistance and other physical properties required of it for its intended end uses.

The physical appearance of the matrix dispersion of metal and polymer varies considerably and quite often, is different than that expected from the metal. Matrices of aluminum, zinc, lead, cadmium and lithium for example are black and smokey in appearance. Copper and germanium matrices on the other hand are clear and deep yellow whereas selenium and silver matrices are clear and red, blue or brown. These colors of course vary significantly depending on the amount of metal present, with the more intense and darker colors secured as the amount of metal in the polymer increases. At metal contents of about 50 percent by weight, most of the matrices appear black and smokey.

The resistance features of these matrices is believed due in part to the atomic or nearly atomic metal intimately dispersed in the polymer. It is only through the practice of the method described herein that such intimate dispersions can be secured. Attempts to employ finely ground metals and other conducting compositions have failed completely to provide thin resistors comparable to those secured herein. Principally, this is due to the unique manner by which these are made and to the unique properties imparted by the polymer phase.