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ABRASION FOR THIN FILM RESISTANCE CONTROL

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FIG. 1

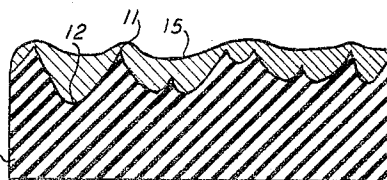


FIG. 2

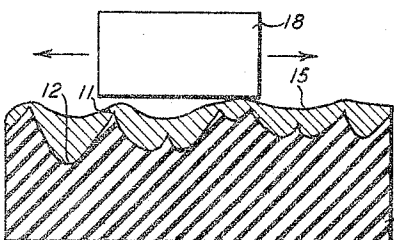


FIG. 3

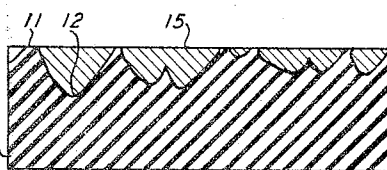


FIG. 4

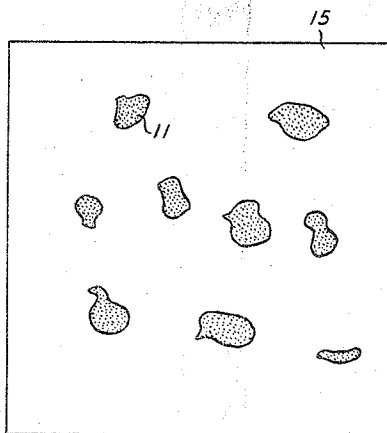


FIG. 5

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ABRASION FOR THIN FILM RESISTANCE CONTROL**Casimir J. Mytych, Rochester, N.Y., assignor to Xerox Corporation, Rochester, N.Y., a corporation of New York****Filed Oct. 1, 1962, Ser. No. 227,334**
6 Claims. (Cl. 117-212)

This invention relates to miniature electrical circuit components and particularly to thin film resistors.

The complexity of modern electronic equipment has created a demand for more reliable miniature circuit components and in response to this demand various technological approaches have been developed. The approach to which this invention is directly related is that of thin film technology as applied to the formation of resistors by coating a dielectric substrate with a material possessing the desired electrical properties. Thus, a thin film resistor produced in this manner may take the form of a tiny wafer comprising ceramic or glass coated with a material such as nickel-chromium alloy.

For a given film thickness the electrical resistance of a thin film resistor is proportional to the length-to-width ratio of the electrical path provided by the resistive material. In thin film work it is convenient to consider the resistance provided by a square unit of a coated wafer and assign to this an ohm-square value. From this value the length-to-width ratio of the electrical path needed to provide the desired resistance may be easily calculated. For example, to form a 400-ohm resistor on a substrate containing a resistive film of thickness corresponding to 100 ohm-square it would be necessary that the electrical path of the resistive material have a 4-to-1 length-to-width ratio.

It is also known that the resistance of a material varies with changes in temperature. The fractional change in resistance (commonly expressed in parts per million per degree centigrade) is referred to as the temperature coefficient of resistance, which for convenience is designated TCR. Most metals are said to exhibit a positive TCR. That is, their electrical resistance increases with increasing temperature. Although the TCR of most metals may generally be considered a constant within reasonably small ranges of temperature change, the TCR of a thin film coated on a substrate exhibits greater variation and is a function of film thickness. As a film is made thinner its TCR decreases and eventually becomes negative. Thus the film thickness at which the TCR changes from positive to negative corresponds to zero TCR. In the interests of operating stability, it is generally desirable that the resistor be formed with a thickness approaching zero TCR, especially in those applications requiring high value components.

Unfortunately, the ohm-square value corresponding to this optimum thickness is relatively low, approximately 100-300 for commonly used resistive materials. This poses a problem with respect to high value resistors since the electrical length-to-width ratio must be varied accordingly. For instance, a 100,000-ohm resistor made from a 100 ohm-square wafer would require an electrical path with a length 1,000 times its width. A well-known method of accomplishing this comprises selective removal of the resistive film from a coated wafer in a series of closely spaced parallel adjustment lines resulting in a long narrow electrical path. Present methods for making these adjustment lines are time consuming and expensive and impose severe practical limitations on the upper limit of resistance obtainable.

In order to obtain miniature resistors of relatively high values by present methods, such as electro-etch or chemical-etch, it is necessary to produce resistors having extremely fine, closely spaced adjustment lines. It has

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been reported that by means of the electro-etch process the highest value resistor successfully fabricated on a wafer .3 inch x .3 inch is 40,000 ohms. Through the use of photoresist, resistors of 100,000 ohms can be produced on the same size wafer. Stability, however, is still a problem, since none of these methods affect the TCR of the resistor. Also, appreciably higher resistance values are frequently required in electronic circuitry. It follows that a simple method for producing a stable high-value resistor independent of the length-to-width ratio is desirable and useful.

The present invention provides a simple method for producing a high yield resistor exhibiting improved stability with respect to temperature changes from a wafer comprising a dielectric substrate coated with resistive material. This is accomplished according to the present invention by appropriately treating the surface of the layer of resistive material after it has been deposited on the dielectric substrate. The present method permits the use of thicker films and does not require the use of uniformly finished substrates. As a matter of fact, as will be explained below, substrate roughness is used to an advantage.

Accordingly, it is an object of the present invention to provide a practical method for producing high value resistors with improved temperature coefficient characteristics.

It is a further object of this invention to simplify thin film resistor design by eliminating dependence upon the electrical length-to-width ratio.

It is a further object of this invention to provide a method for the fabrication of resistors in the megohm range in relatively small areas.

It is a still further object of this invention to provide a method for forming resistors using resistive films of lower ohm-square values and with decreased dependence on film uniformity.

These and other objectives and advantages of the present invention will become apparent to those skilled in the art from the description and accompanying drawings in which:

FIGURE 1 illustrates a substrate suitable for use in the present invention;

FIGURE 2 illustrates a wafer comprising a dielectric substrate coated with resistive material;

FIGURE 3 illustrates abrasion of the wafer;

FIGURE 4 illustrates a thin film resistor as formed according to the instant invention; and,

FIGURE 5 shows an additional view of a resistor formed according to the instant invention.

FIGURE 1 shows a cross-section view of substrate 10 of any suitable dielectric material such as ceramics, glass, plastic, inorganic refractory material, or the like. Substrate 10 need not have a highly finished surface since roughness is a desired characteristic for use in the present invention. In effect, substrate 10 comprises formations of micro hills 11 and valleys 12. For purposes of illustration these are shown as grossly exaggerated in FIGURE 1. Although the degree and uniformity of roughness of the surface of substrate 10 is not critical a 5-15 micro inch surface finish is preferable.

FIGURE 2 shows a cross-sectional view of substrate 10 after resistive layer 15 has been applied. A suitable application method for purposes of this invention may be vacuum evaporation although other well-known methods for applying a thin film may be used. Layer 15 may comprise any of a large number of resistive materials well-known in the thin film art, such as chromium, tin oxide, nickel-chromium alloys, nickel-chromium-silicon oxide, and the like. As shown in FIGURE 2, the resistive material has a tendency to fill in the valleys, hence the thickness of layer 15 will be non-uniform. Those portions of layer 15 corresponding to the micro peaks of sub-

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strate 10 will tend to be raised with respect to those portions corresponding to the valleys. This phenomenon is used to advantage in the present invention and the only requirement is that the over-all TCR characteristic of layer 15 be negative at this stage of the instant process. Since, as explained above, TCR depends upon film thickness it is believed that the portions of layer 15 corresponding to the micro peaks exhibit a more highly negative TCR than those corresponding to the valleys. Accordingly, it is presently believed that removal of these highly negative portions of layer 15 will have a two-fold effect: the over-all TCR of the layer will be made less negative and the resistance of the layer will be increased. Whether or not this belief is accurate, it has been found that abrading or removal as now to be described accomplishes this effect.

A preferred method for selective removal of portions of layer 15 is shown in FIGURE 3. Abrader 18 is placed on the surface of layer 15 and moved back and forth. This abrading action will remove resistive material principally from the raised portions corresponding to the micro peaks and as a result the desired changes with respect to increased resistance and improved TCR characteristics will be achieved.

FIGURE 4 and FIGURE 5 both illustrate a thin film resistor formed according to the present invention. After resistive material of layer 15 has been selectively removed, areas corresponding to micro-peaks 11 constitute areas of theoretically infinite resistance. The perforate layer formed by the selective removal of resistive material is more clearly seen in FIGURE 5. Thicker deposits of resistive material exhibiting a less negative, or positive, TCR remain in the valleys 12.

Production of extremely high value resistors at low cost is made possible by the described method. It is only necessary to apply the abrading step to a layer 15 of resistive material having an over-all negative TCR. The abrading action is continued until the desired resistance is obtained, as indicated by a monitoring ohm-meter, and this action improves the TCR characteristic. Without any alteration of the electrical length-to-width ratio, it has been possible by the present invention to change a 5,000 ohm resistor fabricated from a chromium film of 4,000 ohm-square to a value of 10 megohms. As described, the present method dispenses with critical dependence upon film uniformity, substrate surface finish, and electrical length-to-width ratio.

The method according to the instant invention is both economical and simple to carry out. A suitable and preferred abrasive material for abrader 18 comprises an ordinary rubber eraser. Other commonly available material, such as tissue and cloth, have also been successfully employed as abrasives to increase the resistance of layer 15. As already stated the surface finish of substrate 10 has been found not to be critical. However, it was found that greater pressure had to be applied to films deposited on ceramic substrates having a 5 micro inch surface finish than on films deposited on rougher surfaces of from 12-15 micro inch finishes. Chemical means also may be employed for selective removal of portions of layer 15. For example, a cotton swab may be dipped in hydrochloric acid and then rubbed across the surface of layer 15 to remove resistive material principally from the raised portions. If desired, the coated wafer may instead be immersed in a solvent or corrosive that will chemically attack the resistive material.

Without intending to limit the present invention, a preferred embodiment is set forth in terms of specific materials and procedures for purposes of complete disclosure. A ceramic strip of a material comprising about 99% alumina and about 1% magnesium and capable of withstanding temperatures above 1000° C. was used for the dielectric substrate. One such material was purchased from American Lava Company, Chattanooga, Tennessee, and was sold under the trade name Alsimag 614. Other materials were also used and are available from other sources.

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Generally such a substrate should have an ability to withstand high temperatures if used in a vacuum coating system but all such substrates should have the surface characteristics previously discussed. The substrate was heated to a temperature at 350° C. in a vacuum evaporation chamber with a tungsten boat containing chromium powder. The chamber was evacuated to a vacuum of 5×10^{-5} Torr, and the tungsten boat heated by resistance heating to vaporize the chromium. The substrate was allowed to remain in the chromium vapor stream for approximately 1-5 minutes, the time being highly non-critical. Heating was then discontinued and the chamber was allowed to cool to approximately 100° C. at which point air was admitted. The coated substrate was then allowed to cool to room temperature. The electrical resistance of the chromium layer was measured by an ohmmeter. While it was still connected to the monitoring ohm-meter, the chromium layer was then abraded by rubbing its outer surface with an ordinary pencil eraser. As the abrading action continued, it was observed that the electrical resistance increased gradually and steadily. The abrading action was continued until the ohm-meter indicated a predetermined resistance. The temperature coefficient of resistance of the chromium film before abrading was found to be highly negative, and became significantly less negative with the noted increase in resistance.

Resistors in the megohm range have been formed in an area of .015 square inch by the present method. Accordingly the present method is suitable for application in high component density electronic packages. The present method is capable of producing high value resistors from films which are of a more stable nature since all evaporation coatings may be made of thicker films corresponding to low ohm-square values which would otherwise be unsatisfactory. As an additional advantage, this method offers exact control of resistance values heretofore not attainable with other adjustment methods.

Limitation by the specific embodiments of the invention as set forth in this application is not intended. Further, it is intended that the claims apply broadly within the spirit and scope of this invention.

What is claimed is:

1. The method for forming a temperature stable thin film electrical resistor of predetermined resistance, comprising:

(a) depositing a film of resistive material on a dielectric substrate having a surface of minute peaks and valleys, said film having

- (1) a resistance lower than the predetermined resistance,
- (2) an overall negative temperature coefficient of resistance, and,
- (3) a non-uniform thickness, with relatively thinner deposits of resistive material over the minute peaks as compared with deposits of resistive material in the valleys of said dielectric substrate; and

(b) randomly removing some of said thinner deposits from said film,

whereby, the predetermined resistance is achieved and said temperature coefficient of resistance is made less negative.

2. The method for forming a temperature stable thin film electrical resistor of predetermined electrical resistance, comprising:

(a) depositing a thin metallic film on a dielectric substrate having a surface of minute peaks and valleys, said film having

- (1) a resistance lower than the predetermined resistance,
- (2) an overall negative temperature coefficient of resistance, and
- (3) a non-uniform thickness, with relatively thinner and relatively thicker deposits of film corresponding to the minute peaks and valleys of said dielectric substrate, respectively; and

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(b) randomly abrading said film until the predetermined electrical resistance is achieved and the temperature coefficient of resistance of said film is near zero.

3. Method of claim 2 wherein said metallic film is of a material selected from the group consisting of: chromium, tin oxide, nickel-chromium alloys. 5

4. Method of claim 2 wherein said metallic film comprises chromium and said dielectric substrate comprises about 99% of alumina and about 1% magnesium. 10

5. The method of claim 2 wherein said abrading is by means of a rubber eraser.

6. The method for forming a temperature stable thin film microcircuit resistor of predetermined fixed electrical resistance, comprising: 15

(a) heating metallic powder in a vacuum chamber in the presence of a dielectric member having a non-smooth surface of minute peaks and valleys for a time sufficient to deposit on said dielectric member a continuous metallic film of non-uniform thickness, relatively thicker deposits of said film filling said valleys as compared with relatively thinner deposits covering said peaks; and

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(b) abrading said film to remove some of said thinner deposits to achieve the predetermined electrical resistance and reduce the degree to which the resistance of said film varies in response to changes in temperature.

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