A heating element appropriate for use with printed circuits and which is itself a printed circuit comprises a filament consisting of a mixture of aluminum and aluminum oxide, the resistivity of the heating element formed of the filament being adjustable by varying the thickness of the filament. The filament is supported on a ceramic coating on a metal substrate.

11 Claims, 3 Drawing Figures
BACKGROUND OF THE INVENTION

Where miniature heating elements are desired, the length of the heating element is necessarily limited. It has been difficult hitherto to provide miniature heating elements of adequate resistivity, particularly where they must be operated on voltages as high as 220 or even higher. Furthermore, it has been difficult to provide for both close control of the resistivity of such elements and adequate support to eliminate the problem of breakage inherent in the small size of the elements.

SUMMARY OF THE INVENTION

A metal substrate, preferably iron with a carbon content of less than 0.04% is coated with successive thin layers of a ceramic and fired, the objective of using a plurality of ceramic layers being to avoid pin holes which are continuous from the surface of the ceramic to the substrate. The coating is then sprayed with a mixture of aluminum and aluminum oxide using a spray gun to spray molten aluminum globules in an oxidizing atmosphere. The layer of mixed aluminum and aluminum oxide which results is screen-printed with a resist and etched to produce a filament consisting of a mixture of aluminum and aluminum oxide having a high resistivity. Zinc or copper may also similarly be sprayed.

Accordingly, an object of the present invention is to provide an improved process for the manufacture of small heating elements in the form of a printed circuit.

Another object of the present invention is to provide an improved process for the manufacture of a heating element consisting of aluminum and aluminum oxide or zinc or copper and their oxides.

A further object of the present invention is to provide a method for the production of a heating element consisting of aluminum and aluminum oxide on a ceramic base supported on a metal substrate. Zinc and copper in combination with their oxides will also serve.

An important object of the present invention is to provide an improved miniature heating element suitable for use with voltages as high as 220 volts or higher.

A significant object of the present invention is to provide an improved miniature heating element wherein the resistance of the heating element can be controlled by the quantity of mixed aluminum and aluminum oxide or zinc and copper with their oxides deposited on a base.

Yet another object of the present invention is a miniature heating element comprising a mixture of aluminum and aluminum oxide or of zinc and zinc oxide or of copper and copper oxide as the conductive element, the mixture being adherent to a coating of ceramic on a metal substrate.

Still other objects and advantages of the invention will in part be obvious and will in part appear from the specification.

The invention accordingly comprises the several steps and the relation of one or more of such steps with respect to each of the others, and the composition possessing the features, properties, and the relation of constituents, which are exemplified in the following detailed disclosure, and the scope of the invention will be indicated in the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

For a fuller understanding of the invention, reference is had to the following description taken in connection with the accompanying drawings, in which:

FIG. 1 is a schematic sectional view of a ceramic-coated metal plate in accordance with the prior art showing flaws or pinholes reaching from the surface of the ceramic coating to the metallic substrate;

FIG. 2 is a ceramic-coated metal plate in accordance with the present invention; and

FIG. 3 is a sectional view in perspective of a fragment of a heating element in accordance with the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

In the preparation of miniature heating elements by printed circuit techniques, it is desirable to have a metallic substrate for purposes of rigidity. This substrate must then be coated with an insulator, preferably a ceramic. Such a ceramic-coated metallic substrate is shown in FIG. 1 where the ceramic coating 2 is applied on the metallic substrate 1 in accordance with the prior art as a single layer on each side of the metallic substrate 1. As indicated schematically, ceramic coatings generally have flaws in the form of minute holes indicated by the indentations given the reference numeral 2a in FIG. 1. If a heating element were imposed on a perforate layer 2 such as is shown in FIG. 1, the heating element would make contact with the metal substrate 1 at several points, thus, effectively shorting out the heating element.

To avoid the difficulty which would result from using the technique represented by the section shown in FIG. 1, a ceramic coating generally represented by the reference numeral 8 is applied to the metal substrate 1 as shown in FIG. 2. The ceramic coating 8 consists of a plurality of layers, in this case 3 layers, having the reference numerals 3, 4 and 5. As is indicated schematically, layer 3 has pinholes 3a, layer 4 has pinholes 4a and layer 5 has pinholes 5a. However, the probability of pinholes in each successive layer being coincident is extremely small so that the danger of a short or multiple shorts between the heating elements to be superimposed upon the ceramic coating 8 is extremely small. Furthermore, although not so indicated in FIG. 2 each layer is fired and cooled prior to application of the next layer. Consequently each successive layer tends to fill in the pinholes in the previous layer thereby substantially eliminating the possibility of a short between the heating element and the substrate 1.

Although the substrate 1 may be of any metal which can be fired to a high enough temperature so that the ceramic will vitrify, a preferred substrate is iron having a carbon content no greater than 0.04%. A suitable thickness for the substrate is 1 millimeter although this can be varied in accordance with the degree of rigidity needed and the weight which can be tolerated. The advantage of iron of the composition specified is that no significant structural changes will take place during and after the vitrifying treatment.

Subsequent to completion of the operation of coating the metal substrate, it is desirable that the system stand for several days so that any improper operation in preparing the coated substrate will become evident in the form of cracks or scaling. After passing inspection with regard of the integrity of the coating on the metal sub-
strate, the piece is carefully cleaned and degreased before application of the resistive element. Any residue of oil or perspiration from the fingers will impair the adhesion of the resistive element to the ceramic coating.

Subsequent to cleaning the piece to be coated, the temperature of the support is raised to just below that at which softening of the ceramic coating occurs or the ceramic coating becomes pasty. The support, in this condition provides the best adhesion for the resistive element to be applied by spraying. The piece is then sprayed with aluminum, copper or zinc particles projected from a metal-spray gun. The operation is carried out in an oxidizing atmosphere such as air so that the spheroids of metal produced become oxidized on the surfaces thereof to form a corresponding metal oxide. The preferred metal is aluminum. The aluminum may be fed to the metal-spray gun in any convenient form such as powder or wire. It is also desirable that the aluminum be of high purity, since with impurities of unknown amount and unknown type present in the aluminum, the resistivity of the deposited heating element will vary in uncontrolled fashion.

As the aluminum is fused in passing through the nozzle of the metal-spray gun it is subjected to an oxidizing flame, and ejected from the gun by air pressure. Conditions should be such that the spheroidal particles have a diameter of about 8 microns though the actual size is not crucial, so long as it is reproducible. During the course of passing through the oxidizing flame and through the air, a thin layer of aluminum oxide is formed on the surface of the particles, the cores of the particles remaining molten until the particles strike against the surface to be metalized. The particles then break and spatter, the molten metal spattering as it strikes the support and solidifying quickly to form a coating with aluminum oxide inclusions. Naturally, the temperature of the support must be below the melting point of the metal sprayed thereon. The metal-spraying process can be repeated, depositing a succession of metal layers containing oxide and allowing the coated substrate to cool after deposition of each layer. The process can be repeated until the metal-metal oxide coating is of the desired thickness.

Continuous exposure of the metal oxide inclusions causes the resistivity of the deposited film. The resistivity of the finished element can be controlled by the quantity of mixed metal and metal oxide deposited on the support. For many uses it has been found convenient to deposit thicknesses as great as 35 microns but, as is obvious, there is actually no practical limit to the thickness of the mixed metal-metal oxide coating which can be applied in this way.

Due to the fact that the resistivity of the coating is so high, and, due to the fact that, in general, the power dissipated is relatively small, such coatings are suitable for use with voltages as high as 220 and even higher. It should be noted that the resistivity of films deposited in this way is so much higher than that of the metal alone that were the metal alone to be deposited under conditions such that oxidation is to be avoided, then it would be necessary to restrict the thickness of the deposit to about 2 microns which would render the element very susceptible to mechanical damage as well as to failure due to the presence of flaws in the coating. Coatings prepared in accordance with the present invention, particularly those of aluminum and aluminum oxide, have a much higher resistivity than that of the metal alone so that it is convenient to prepare relatively thick coatings of the combination which are tightly adherent to the support, mechanically strong and which can be adjusted to the desired total resistance after shaping by means of the shaping operation itself, or even by surface grinding.

After depositing the metal-metal oxide coating, it can be silk-screened in the usual way to deposit a resist of any desired shape. After drying of the resist, the resistive element is shaped to the desired form by etching by conventional means. Finally, the resist is removed from the product by vapor-degreasing using perchlorethylene or any similar solvent.

It will thus be seen that the objects set forth above, among those made apparent from the preceding description, are efficiently attained and that, since certain changes may be made in carrying out the above process and in the composition set forth without departing from the spirit and scope of the invention, it is intended that all matter contained in the above description and shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

It is also to be understood that the following claims are intended to cover all of the generic and specific features of the invention herein described, and all statements of the scope of the invention which, as a matter of language, might be said to fall therebetween.

What is claimed is:

1. A process of manufacturing small printed circuits for the generation of heat, comprising the steps of depositing a ceramic dielectric coating on a metal substrate, allowing the ceramic-coated substrate to stand at room temperature for a period long enough for any defects in said ceramic coating to become evident, degreasing said ceramic coating, depositing from a metal-spray gun an adherent conductive coating of a metal chosen from the group consisting of aluminum, zinc and copper mixed with the oxide of said chosen metal on said ceramic coating, said ceramic-coated substrate having been preheated to a temperature sufficient to provide good adhesion thereto of said sprayed conductive coatings, said adherent conductive coating having a resistivity much higher than that of the metal alone as the result of inclusion of the metal oxide therein, depositing a resist on said adherent conductive coating and shaping said conductive coating into a desired form by etching.

2. The process as defined in claim 1, wherein said metallic plate is of iron containing not more than 0.04% C.

3. The process as defined in claim 1, wherein said adherent conductive coating is deposited from a metal-spray gun in the form of molten droplets each coating with a thin film of metal oxide, said coated droplets being formed by spraying pure molten metal droplets through an oxidizing atmosphere onto said coated substrate, said droplets breaking, spattering and solidifying on deposition.

4. The process as defined in claim 3, wherein the forming of said mixed adherent conductive coating layer is subdivided into the steps of depositing a thin film of mixed metal and metal oxide from a metal-spray gun, allowing said film to cool, and depositing at least one more of such films, allowing each film to cool before adding any succeeding film.

5. The process as defined in claim 1, wherein said substrate and degreased ceramic coating, plus one or more films of mixed metal and oxide, is heated to a temperature just below that at which said ceramic coat-
5. The process as defined in claim 1, wherein the thickness of said adherent conductive coating is up to 35 microns, the thickness being selected on the basis of the desired resistivity of said coating.

6. The process as defined in claim 1, whereby said ceramic coating is applied in the form of at least two successive deposits with firing following each deposition, thereby decreasing the probability of a continuous flaw in the ceramic coating reaching from the outer surface to the metal substrate.

7. The process as defined in claim 1, wherein said ceramic coating is applied in the form of at least two successive deposits with firing following each deposition, thereby decreasing the probability of a continuous flaw in the ceramic coating reaching from the outer surface to the metal substrate.

8. The process as defined in claim 1, wherein said metal is aluminum and said metal oxide is aluminum oxide.

9. A small printing circuit suitable for the generation of heat, comprising a metal substrate, a plurality of individually fired ceramic coatings on said metal substrate, said ceramic coatings being free of scaling, cracks and other visible defects, and an adherent, shaped coating of a flame sprayed metal containing inclusions of its oxide in sufficient quantity so that the resistivity of said shaped coating makes said circuit suitable for use at voltages as high as 220 volts, said metal being selected from the group consisting of aluminum, zinc and copper.

10. The process as defined in claim 3 wherein said droplets have a diameter of about 8 microns.

11. A process of manufacturing small printed circuits for the generation of heat, comprising the steps of firing and coating a plurality of ceramic coatings on an iron substrate containing not more than 0.04% of carbon, allowing said coated substrate to stand at room temperature for several days to permit any flaws on said ceramic coatings to become evident, cleaning and degreasing said coated substrate, heating said ceramic-coated substrate to a temperature sufficiently high to provide good adhesion between a sprayed-on metal film and said coated substrate, spraying said heated ceramic-coated substrate with molten droplets of a metal coated with its oxide by means of a metal-spray gun with an oxidizing flame in an oxidizing atmosphere, said metal being selected from the group consisting of aluminum, copper and tin, said droplets on striking said coated substrate spattering and solidifying to form a film including metal oxide dispersed therein, allowing said film to cool to room temperature, repeating the metal-spraying and cooling to form a succession of metal layers until the deposit of metal including metal oxide reaches a desired thickness, and shaping said metal-metal oxide deposit into a desired pattern.