May 8, 1956 P. R. MARVIN 2,744,987

ELECTRICAL RESISTANCE HEATING ELEMENTS

Filed March 18, 1954

FIG-1

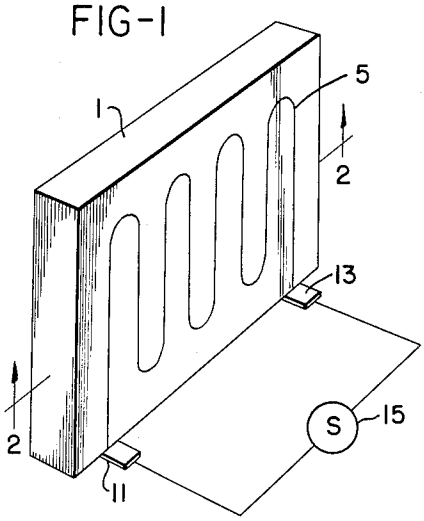


FIG-2

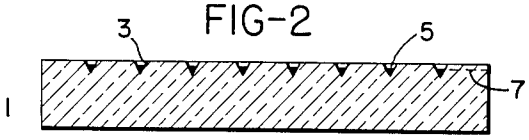
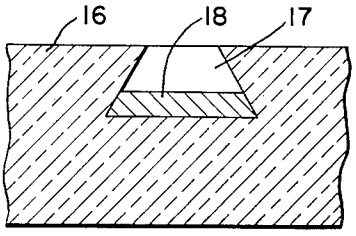


FIG-3



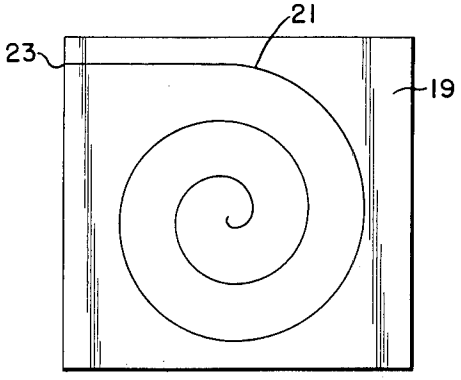


FIG-4

FIG-4A

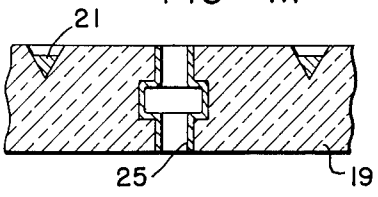
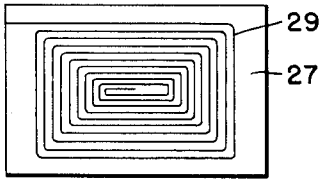


FIG-5



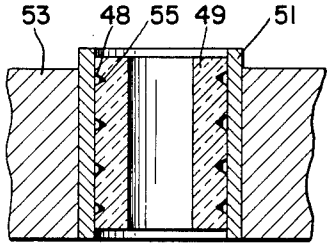


FIG-7

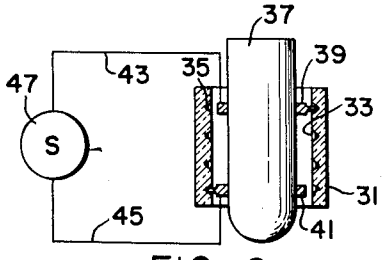


FIG-6

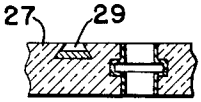


FIG-5A

INVENTOR.
PHILIP R. MARVIN
BY Toulmin & Toulmin
ATTORNEYS

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ELECTRICAL RESISTANCE HEATING ELEMENTS

Philip R. Marvin, Dayton, Ohio, assignor to The Commonwealth Engineering Company of Ohio, Dayton, Ohio, a corporation of Ohio

Application March 18, 1954, Serial No. 417,641

5 Claims. (Cl. 201—63)

This invention relates to electrical resistance heating elements.

The invention particularly contemplates the provision of novel electrical heating elements in which the resistor component is securely anchored to an insulating body.

It is an important object of this invention to provide an electrical heating element in which the resistor component is protected from mechanical damage.

A further object of the invention is the provision of a novel heating element which may be of a predetermined shape to accurately conform to the contour of an object to be heated.

These and other allied objects of the invention are attained, generally speaking, by forming a depression in an insulating body and depositing a coating of metal in the depression.

The metal constituting the electrical resistor component in the practice of the invention is deposited from a gaseous heat decomposable metal bearing compound upon contact thereof with a body of insulating material which is itself heated to achieve the thermal decomposition of the gas. The metal is deposited directly into the depressions of the insulating body in the preferred practice of the invention and the metal deposit is restricted suitably by masking the remainder of the insulating body.

The body of insulating material is preferably a ceramic, but may be of glass or other resistant material, the particular insulating material usually being selected with a view to the ultimate use and cost.

Similarly, the metal is selected on the basis of conditions of operation as well as cost and the metal may be, for example, iron, nickel, chromium, copper or a suitable alloy such as nickel-chromium. The metal is itself deposited in extremely thin films, usually on the order of less than 2 mils and preferably less than 0.5 of a mil. Such films are of a stability and order of magnitude with respect to resistance characteristics that they are of very considerable utility in electrical resistance heating arrangements.

In addition to the thinness of deposit attained in plating from the gaseous stage, this method also provides an extremely uniform film thickness and thus localized hot spots in resistor elements are avoided.

The depression in the insulating body may be formed in any suitable manner as by pressure, etching, cutting or molding, and may be formed in any of a number of contours as more particularly noted hereinafter.

The resistance values of the elements are attainable over wide ranges as the metal itself, the cross-sectional area of the groove, shape of the groove and extent to which the metal fills the groove may be accurately controlled.

The invention will be more fully understood by reference to the following detailed description and accompanying drawing wherein:

Figure 1 is a schematic view of a heating element having associated therewith equipment to effect electrical flow in the element;

Figure 2 is a view taken on line 2—2 of Figure 1 illustrating in cross-section the novel heating element;

Figure 3 is a cross-sectional enlarged view of another embodiment of the invention;

Figures 4 and 4–A illustrate in plan and enlarged section, respectively, a further embodiment of the inventive concept;

Figures 5 and 5–A illustrate another embodiment of the inventive concept;

Figure 6 is a view partially in section illustrating a cylindrical heating element adapted to heat the contents of a test tube; and

Figure 7 is a view partially in section indicating the use of a cylindrical heating element in accordance with the precepts of the invention, the heating element being on the outer surface of the cylinder.

Referring to the drawings there is shown at **1** in Figures 1 and 2 a ceramic wafer which is provided with a shallow groove **3** in V-shape form cut into the surface thereof, and the groove as shown is partially filled with metal forming resistor **5**. The height of the metal extends to the dotted line indicated by the numeral **7**.

The metal resistor extends in the groove fully around the contour thereof to the edge thereof where opposite ends of the metal resistor, separated by the insulating ceramic, contact leads **11**, **13**, respectively, extending from a suitable course of voltage indicated at **15**.

The length of the groove, the nature of the metal therein, the cross-sectional configuration and the thickness of the metal are the principal factors determining the characteristics of the particular heating element and each may be selected to achieve a particularly desired result. For example, while the cross section of the groove in Figure 2 is indicated to be triangular, the cross section might equally well be curvilinear, or may, as indicated in Figure 3 in enlarged view, be trapezoidal as indicated by the numeral **17**.

As will be noted the insulating glass body **16** is so formed with the depression **17** that the metal **18** in the base of the depression is locked from movement in both the transverse and vertical directions and the film of metal is protected from mechanical damage since it is positioned well within the recess of the heating element. Thus the contour of the ceramic piece as well as the adhesion of the plated metal itself for the ceramic contribute to anchoring of the metal film.

Figures 4 and 4–A illustrate another embodiment and as shown in Figure 4 the ceramic member **19** has in a surface groove thereof a deposit of metal **21** in spiral form. One end **23** of the spiral terminates at an edge of the ceramic member, while the other end of the spiral terminates centrally of the member; as shown in Figure 4–A this latter end **25** extends through a central aperture of the ceramic piece to provide a contact flush with the base of the member **19** as shown. The metal **25** may only coat the walls of the central aperture as shown which provides a convenient opening for receipt of a conductive lead, or the aperture may be small and completely filled with metal and adapted to engage a flat electrical contact.

Figure 5 illustrates yet another embodiment and it is to be particularly noted from this figure that the ceramic piece **27** has a large multitude of grooves **29** spaced very close together which permit the attainment of extremely high heating temperatures over a small surface area. The opposite ends of the metal in the groove **29** are provided as described in connection with Figure 4; and as may be noted from Figure 5A, the central aperture of the piece may have a widened portion to assist in receiving and retaining an electrical contact member (not shown).

There is shown in Figure 6 a cylindrical ceramic member **31** having spiralled on the interior surface thereof

grooves 33 which are partially filled with a resistor forming metal 35. The piece 31 closely surrounds test tube 37 and itself provided with thin metallic collars 39, 41 which contact, respectively, the opposed ends of the spiral and are provided with projections to extend slightly into the grooves to contact the metal of the spiral. The collars 39, 41 have secured thereto leads 43, 45 which extend from a suitable generating source of electrical current indicated at 47. The arrangement described permits the controlled heating of material within the test tube 37 in a facile manner.

As shown in Figure 7 grooves 48 may be spiralled on the outer surface of a cylinder 49 and the cylinder enclosed within a container 51 to effect heating of material 53 surrounding the container; the material 53 while indicated in the figure to be of metal may also be a liquid it being only necessary to suitably seal the liquid from the resistor by a close fitting of container 51 with or without additional sealing means such as gaskets. The resistor metal 55 is protected from abrasion, etc. against the wall of the container 51 by reason of its position within only the lower portion of the groove.

The ends of the cylinder in this case may be notched longitudinally (not shown) to provide for the passage of leads to a source of voltage, the leads passing through end sealing means of the container where such are employed.

In the formation of the metal resistors the ultimate purpose for which the resistor element is to be employed governs the selection of the insulating material, the metal of the resistor, and the physical characteristics of the metal such as cross-sectional area, cross-sectional shape and length. Copper, for example, while low in resistance in comparison with chromium when plated in thin films has a sufficiently high resistance for many applications. Similarly ceramics in general are preferred to ordinary glass or even Pyrex as experiments indicate that the temperature coefficient of resistance is not quite as satisfactory with glass

In the practice of the process of invention the grooved insulating material is suitably masked off to leave only the areas showing which it is desired to plate; the insulating material is then heated preferably under vacuum conditions to slightly above the decomposition temperature of the metal bearing compound and is contacted with a flow of gas of the latter.

Since deposition will occur on the insulating material if unmasked it is necessary to extend the masking material to all portions on which plating is not desired; for masking portions of the grooves a thin coating of a high melting point wax or an organic protective coating is preferred to tape which is sometimes difficult to accurately position. With the organic coating the groove may be partially coated or the whole groove coated and the excess then removed to form the surface for receipt of the metal.

With respect to the deposition it is to be noted that if it is desired to secure a particular configuration of the metal that the metal deposition may be effected to a partial extent, and then the article with the deposited metal thereon may be removed from the plating apparatus; thereafter a portion of the deposited metal may be coated as with a wax, and the material again subjected to a plating operation to secure the particularly desired configuration or metal cross section.

With thin ceramic wafers the depth of the groove is very slight and the metal will deposit within the groove in substantially the manner shown in the figures; with some shallow grooves it will not generally be desirable or necessary to effect two plating operations. However as the thickness of the material and groove depth increases a dual plating may be desirable to secure particular configurations, and such is within the contemplation of the invention.

The gas flow is continued to a sufficient length of time to achieve the required metal deposit, the element removed from the vacuum and heat and the masking stripped away.

Chromium metal deposited from chromium hexacarbonyl on grooved ceramics is particularly useful as the temperature coefficient of resistance of such a combination is extremely low, about 0.01 of 1% over a temperature range of −55° C. to 105° C. However, the following compounds have characteristics which render them useful as gas plating agents, and particular plating materials may be useful in given circumstances, depending upon the results desired. In each case the gas composition is of such a nature that its deposition rate may be readily controlled to plate thin films of high electrical resistance. While in the table preferred pressures are indicated for specific deposition, together with the usual temperature depositions of the compound, both pressure and temperature may be altered to suit particular plating conditions:

Plating Material	System Pressure, mm. of Hg	Temperature Range of Base Material in Degrees Fahrenheit
$Ni(CO)_4$	0. 5–1. 0	350–750
$Cr(CO)_6$	0. 5–1. 8	375–750
$Mo(CO)_6$	0. 5–1. 8	750–650
$W(CO)_6$	0. 5–1. 8	625–775
$Cu(C_5H_7O_2)_2$	0. 5–1. 8	400–750

Normally the deposition when effected under the conditions set forth would provide the metal in very fine form and the plated object will have a completely finished smooth surface. Plated objects may of course be worked to remove any irregularities which may occur due to abnormal plating conditions. The finished product will have an overall resistance which depends upon the cross-sectional configuration and length of the plating material as well as the nature of the metal plated, and it may be generally stated that the resistance value may vary from 100 ohms per inch length to 100,000 ohms per inch length.

The insulating bodies of the elements may be of any suitable thickness and may in fact be substantially wafer-like, as set out in my co-pending application, Serial No. 417,042, filed March 18, 1954.

It will be understood that this invention is susceptible to modification in order to adopt it to different usages and conditions and accordingly, it is desired to comprehend such modifications within this invention as may fall within the scope of the appended claims.

I claim:

1. An electrical resistor comprising a base of electrical insulating material having a spiral groove therein, the base also having an opening therethrough transversely to the groove coinciding with one end of the groove, and a film of metal in the groove and also in the opening on the sides thereof.

2. An electrical resistor comprising a base of electrical insulating material having a spiral groove therein, the base also having an opening therethrough transversely to the groove coinciding with one end of the groove, and a film of metal in the groove and also in the opening on the sides thereof, the metal in the groove terminating below the upper surface of the base.

3. An electrical resistor comprising a base of electrical insulating material having a spiral groove therein one end of which terminates at an edge of the insulating material and the other end of which terminates at a substantially central aperture through the material, the aperture extending through the base transversely to the groove and metal in the groove and opening extending from the said edge to a lower side of the opening.

4. An electrical resistor comprising a base of electrical insulating material having a spiral groove therein, the base also having an opening therethrough coinciding with one end of the groove, the opening extending through the

base transversely to the groove, and a film of metal in the groove and also in the opening on the sides thereof, the opening being formed to receive a contact member securely therein.

5. An electrical resistor comprising a base of electrical insulating material having a spiral groove therein, the base also having an opening therethrough coinciding with one end of the groove, the opening extending transversely to the base, a film of metal in the groove and also in the

opening on the sides thereof, the opening having a widened portion for the reception of an electrical contact member therein.

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