Nov. 5, 1957 L. MOLES 2,812,411

MEANS FOR VAPOR DEPOSITION OF METALS

Filed Sept. 30, 1955

Fig. 1.

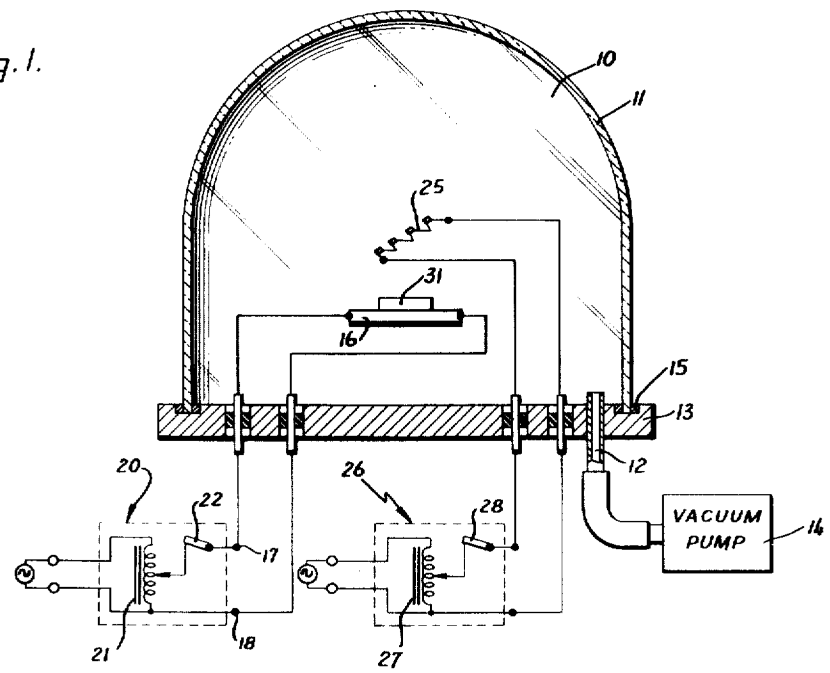
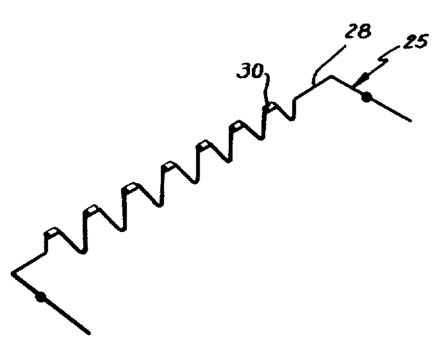


Fig. 2.



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United States Patent Office

2,812,411

Patented Nov. 5, 1957

2,812,411

MEANS FOR VAPOR DEPOSITION OF METALS

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Application September 30, 1955, Serial No. 537,663

7 Claims. (Cl. 219—19)

This invention relates to the vapor deposition of metals and, more particularly, to improved means for depositing a layer of molten metal of substantial thickness upon a surface by evaporation of a metal from a heated filament.

In various applications wherein a layer of molten metal is to be deposited upon a surface by evaporation of the metal from a filament, difficulty is encountered in depositing relatively thick layers by methods heretofore known to the art. For example, in the semiconductor art, in the formation of a fused P-N junction upon the surface of a semiconductor body, an improved method for forming the P-N junction has been disclosed and claimed in copending application Serial No. 490,599 now Patent No. 2,789,068, for "Evaporation-Fused Junction Semiconductor Devices", by Joseph Maserjian, filed February 25, 1955, assigned to the assignee of the present application, which necessitates the deposition of a molten layer of aluminum, for example, upon a semiconductor body. The thickness of the layer of molten metal used in such a process often approaches 5 to 10 mils, which is greatly in excess of the thickness of vapor-deposited films heretofore used in the art. In addition, since the molten film must be of even thickness over a predetermined surface, the methods heretofore known to the art for depositing metal by the evaporation of the metal from a heated filament have not proven satisfactory.

Accordingly, it is an object of the present invention to provide an improved means for depositing layers of molten metal of substantial thickness upon a surface.

It is another object of the present invention to provide a means for vapor depositing a layer of molten metal in substantial thickness upon a surface in which the thickness of the deposited metal is uniform over the surface.

It is a further object of the present invention to provide an improved filament from which molten metal may be deposited by evaporation in conjunction with methods heretofore known to the art.

It is a further object of the present invention to provide a means for evaporating molten metal which allows an accurately predetermined amount of molten metal to be deposited uniformly upon a surface.

Still a further object of the present invention is to provide an improved means for producing broad area P-N junctions in semiconductor bodies by insuring the even deposit, by evaporation, of a substantial mass of solvent metal upon the surface of the semiconductor body.

In accordance with the present invention a filament is provided for use in conjunction with vapor deposition apparatus of the type heretofore known to the art in which the filament comprises a resistance heating element formed from a continuous length of wire upon which barriers having a cross sectional area greater than that of the wire are periodically positioned.

The novel features which are believed to be characteristic of the invention, both as to its organization and method of operation, together with further objects and advantages thereof, will be better understood from the following description considered in connection with the

accompanying drawing, in which an embodiment of the invention is illustrated by way of example. It is to be expressly understood, however, that the drawing is for the purpose of illustration and description only and is not intended as a definition of the limits of the invention.

Fig. 1 is a schematic diagram, partly in section, of one form of apparatus for depositing molten metal in substantial thickness upon a surface by evaporation of the metal from a filament constructed in accordance with the present invention; and

Fig. 2 is a view in elevation of a filament constructed in accordance iwth the present invention to be used in the evaporation of molten metal.

Referring now to the drawing wherein like reference characters designate like or corresponding parts throughout the views, there is shown in Fig. 1 one form of apparatus for depositing molten metal upon the surface of a semiconductor body which is illustrative of the applicability of the present invention. For example, in forming a P-N junction upon a silicon semiconductor body in accordance with the method disclosed and claimed in Maserjian, supra, a silicon body is preheated to a temperature above the eutectic temperature of silicon and aluminum, and a molten layer of aluminum is deposited upon the silicon surface to a substantial thickness. The heating of the body and the evaporation of the metal upon the surface thereof is performed in an inert atmosphere or in a vacuum.

Referring now to Fig. 1, the apparatus for carrying out such a process is shown and comprises a vacuum chamber **10** defined by a bell jar **11** and a base **13** having an exhaust port **12** therethrough to which a vacuum pump **14** is connected. Positioned within the chamber **10** is a heating platform **16** which may be supported within the chamber by any suitable means, not shown for purposes of clarity. The platform **16** in the apparatus shown is a graphite heating element which is connected outside the chamber **10** to two output terminals **17** and **18**, respectively, of an electrical power source **20**. The electrical power source includes any conventional electrical circuit which is controllable for supplying a predetermined amount of eletrical energy to the graphite heating platform **16**. Power source **20** includes, for example, an autotransformer **21** which is connected across a 110-volt alternating current source, as indicated, and to a switch **22** through which a potential output from the auto transformer **21** may be applied to the heating platform **16**.

Positioned within the bell jar **11** is the resistance heating filament **25**, constructed in accordance with the present invention, connected to a second electrical power source **26** which may again be any conventional electrical circuit which is controllable for supplying a predetermined amount of electrical energy to the resistance heating filament **25**. The second power source **26** also includes an auto transformer **27** which is connected across a 110-volt alternating current source and the output which may be connected to filament **25** through a switch **28**.

The resistance heating filament of the present invention, in its presently preferred embodiment, comprises a tungsten wire **28**, as shown in Fig. 2, which is shaped generally in a saw tooth form lying in a plane parallel to the plane of the surface upon which the molten metal is to be deposited. In this embodiment, the resistance heating filament, although saw toothed, is rounded slightly at the apex of each of the triangles which adjoin to form the saw tooth. A physical barrier **30** is positioned at each of the upper apexes and forms a region of greater diameter than the diameter of the tungsten wire, for purposes which will be described hereinafter. In the presently preferred embodiment, the tungsten wire **28** which is used as the filament is four-strand tungsten having a diameter of the order of 20 mils and the filament is approximately five inches in length. In the presently preferred embodiment, which is illustrated, the physical barrier **30** is formed by wrapping tantalum wire approximately 20 mols in diameter about the tungsten wire of the filament at the spaced apexes to form a barrier having a width of approximately ⅛ inch which is then pressed into good thermal contact with the filament.

Although tantalum wire is used in the presently preferred embodiment, other heat conductive materials, such as tantalum strips or tungsten wire, may be used to form the regions of increased diameter.

In order to further illustrate the utility of the present invention, the operation of the apparatus of Fig. 1 will be further described in conjunction with the formation of a layer of molten aluminum upon a semiconductor body. With the bell jar **11** removed, a semiconductor body **31** is placed upon the graphite heating platform **16**. The resistance heating element **25** is positioned within the evacuated chamber **10** approximately ½ inch above the upper surface of the semiconductor body **31**. A predetermined quantity of aluminum is placed on the filament by winding the filament with aluminum wire or placing aluminum slugs in the form of strips at spaced intervals along the filament.

The bell jar **11** is then placed upon the base **13** where the chamber is sealed by gaskets **15** and the chamber is evacuated. The graphite heating platform is raised to the necessary temperature by means of the source of electric current. After the heating platform has attained the required temperature, current is passed through the filament **25** to raise its surface to a temperature sufficient to melt the aluminum and to cause the aluminum to wet the tungsten wire, thus forming a molten coating of aluminum upon the wire. In practice, using a tungsten filament made from four-strand 20 mil tungsten wire, approximately 20 amperes of current are passed through the tungsten wire until the surface of the tungsten is fully wetted and appears to glow with an orange-red color, indicating a probable surface temperature for the filament of about 900° C. When the tungsten filament appears to be completely wetted and uniformly coated by the aluminum, current in the filament is increased, for example, to 30 amperes. It may then be seen that the filament becomes incandescent to a brilliant white light and within about ten seconds substantially all the aluminum is evaporated from the tungsten filament. The aluminum evaporated from the filament deposits upon the upper surface of the semiconductor body **31** to the required depth, for example, five to ten mils and the apparatus and semiconductor body are cooled to form a P-N junction within the body.

Prior to the present invention, a resistance heating filament of the type heretofore known to the art was used which commonly comprises a saw tooth wire of constant diameter throughout its length. In using such a filament, it was found tht the aluminum when it became molten and began to wet the filament, as described hereinbefore, gravitated to several points of the filament where it collected in globules. The molten aluminum then fell from the filament or was evaporated unevenly due to its uneven distribution along the length of the filament. However, in using a filament constructed in accordance with the present invention, in which the diameter of the wire forming the filament is increased at spaced intervals along the length of the filament, this difficulty is overcome. The increased diameter forms a physical barrier to the coalescence or gravitation of the molten aluminum to any portions of the filament and keeps the aluminum evenly distributed along the length of the filament. In addition to forming a barrier due to the increased diameter, it also presents a barrier due to the increased radiation of heat from the increased diameter which forms, in effect, a portion of lowered temperature which also prevents the flow of molten metal past the area. Thus, the aluminum is evaporated uniformly and deposits evenly upon the surface of the body.

Although a tungsten filament was illustrated in conjunction with an apparatus for evaporating aluminum upon semiconductor bodies, it will be apparent to those skilled in the art that many modifications of the present invention may be utilized. For example, although a saw tooth filament is shown, various forms, such as a filament generally in the shape of a sine-wave, may also be used. Further, although tungsten was used in the illustrative embodiment, other metals or materials which will be wet by aluminum or other metals being evaporated may also be used. In addition, although tantalum wire is wound about alternate apexes of the filament in this illustrative embodiment, the increased diameter of the filament may be obtained by other means, such as for example, wrapping the apexes of the filament with tungsten wire or strips, or using beads of heat conducting material which are formed about the wire portion of the filament.

Although physical barriers at alternate apexes of the filament have been described, the number may be decreased and the optimum number for a given application may be determined by routine experiment of one skilled in the art. On a five-inch filament, for example, excellent results have been achieved by using three regularly spaced barriers.

Thus, the present invention provides an improved resistance heating filament for use in the evaporation and vapor deposition of metals upon a surface which accomplishes a more uniform, and more accurately controlled, layer of substantial thickness of molten metal upon the surface.

What is claimed is:

1. In an apparatus for the vapor deposition of molten metal in substantial thickness upon a surface wherein the molten metal is evaporated from a resistance heating filament by the application of electric current to the filament upon which has been placed the metal to be evaporated, the resistance heating filament comprising: a continuous length of wire, said wire having a substantially constant cross sectional area, and physical barriers of heat conductive material spaced at intervals along the length of said filament and in surrounding relationship therewith, said physical barriers having a melting temperature substantially greater than the vaporizing temperature of said molten metal and a greater cross-sectional area than that of said wire.

2. In an apparatus for the vapor deposition of molten metal in substantial thickness upon a surface wherein the molten metal is evaporated from a resistance heating filament by the application of electric current to the filament upon which has been placed the metal to be evaporated, the resistance heating filament comprising: a length of wire of substantially constant diameter, said wire being formed in a planar configuration, and a plurality of physical barriers spaced at periodic intervals along the length of said wire and in surrounding relationship therewith, said barriers being formed from heat conductive material having a melting temperature substantially greater than the vaporizing temperature of said molten metal and having a cross-sectional area greater than the cross-sectional area of said wire.

3. In an apparatus for the vapor deposition of molten metal in substantial thickness upon a surface wherein the molten metal is evaporated from a resistance heating filament by the application of electric current to the filament upon which has been placed the metal to be evaporated, the resistance heating filament comprising: a continuous length of tungsten wire in a planar configuration and a plurality of physical barriers spaced at periodic intervals along the length of said wire and in surrounding relationship therewith, said barriers being formed from heat conductive material having a melting temperature substantially greater than the vaporizing temperature of said

molten metal and having a cross-sectional area greater than the cross-sectional area of said wire.

4. In an apparatus for the vapor deposition of molten metal in substantial thickness upon a surface wherein the molten metal is evaporated from a resistance heating filament by the application of electric current to the filament upon which has been placed the metal to be evaporated, the resistance heating filament comprising: a continuous length of tungsten wire in a planar configuration, and a plurality of physical barriers periodically spaced along said wire and in surrounding relationship therewith, said physical barriers being heat conductive wire having a melting temperature substantially greater than the vaporizing temperature of said molten metal wound about said filament wire and in thermal contact therewith.

5. In an apparatus for the vapor deposition of molten metal in substantial thickness upon a surface wherein the molten metal is evaporated from a resistance heating filament by the application of electric current to the filament upon which has been placed the metal to be evaporated, the resistance heating filament comprising: a continuous length of tungsten wire in a planar configuration, and a plurality of physical barriers periodically spaced along said wire, said physical barriers being tantalum wire wound about said filament wire and in thermal contact therewith.

6. In an apparatus for the vapor deposition of molten metal in substantial thickness upon a surface of a semiconductor body wherein the molten metal is evaporated from a resistance heating filament by the application of

electric current to the filament upon which has been placed the metal to be evaporated, the resistance heating filament comprising: a continuous length of wire in a substantially saw tooth planar configuration, and a plurality of physical barriers having a melting temperature substantially greater than the vaporizing temperature of said molten metal in surrounding relationship with said wire at alternate apices of said saw tooth wire.

7. In an apparatus for the vapor deposition of molten metal in substantial thickness upon a surface of a semiconductor body wherein the molten metal is evaporated from a resistance heating filament by one application of electric current to the filament upon which has been placed the metal to be evaporated, the resistance heating filament comprising: a continuous length of tungsten wire having a substantially saw tooth planar configuration, and a plurality of physical barirers of tantalum wire wound about said tungsten wire at alternate apices of said saw tooth configuration.

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