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[56]

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[54] **DOUBLE-SINTERED GOLD-NICKEL ELECTRICAL CONTACT FOR COMPRESSION-BONDED ELECTRICAL DEVICES**
23 Claims, 8 Drawing Figs.

[52] U.S. Cl..... **317/234,**
317/235; 29/582; 117/217
 [51] Int. Cl..... **H011 1/02,**
H011 1/12, H021 11/00
 [50] Field of Search..... **317/234/6,**
234/4, 234/5.2, 234/5.3

ABSTRACT: An electrical contact is first plated with a layer of nickel on at least its contact surface which is then metallurgically bonded to the contact by a heat-treating process. The nickel-plated contact is then plated with gold on at least the nickel-covered contact surface. The gold is metallurgically diffused into, and alloyed with the nickel by a heat-treating process.

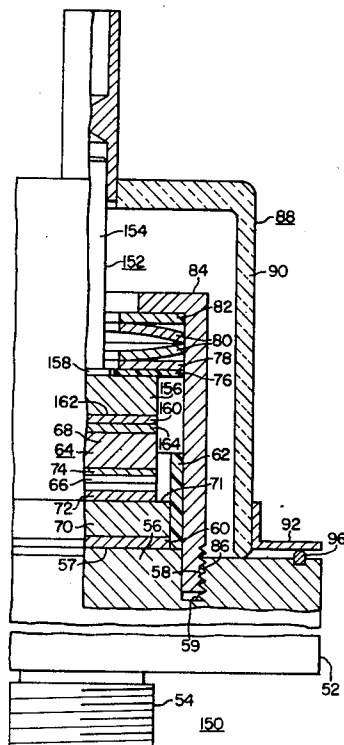


FIG. 1.

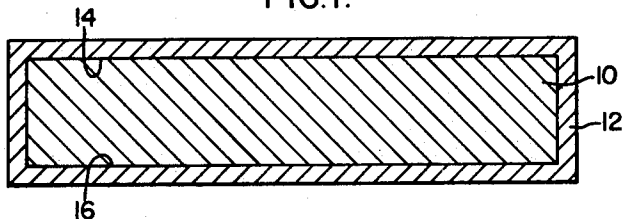


FIG. 2.

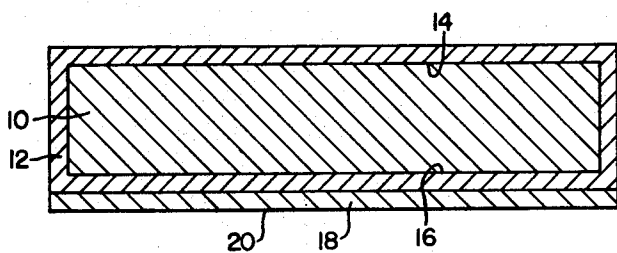


FIG. 3.

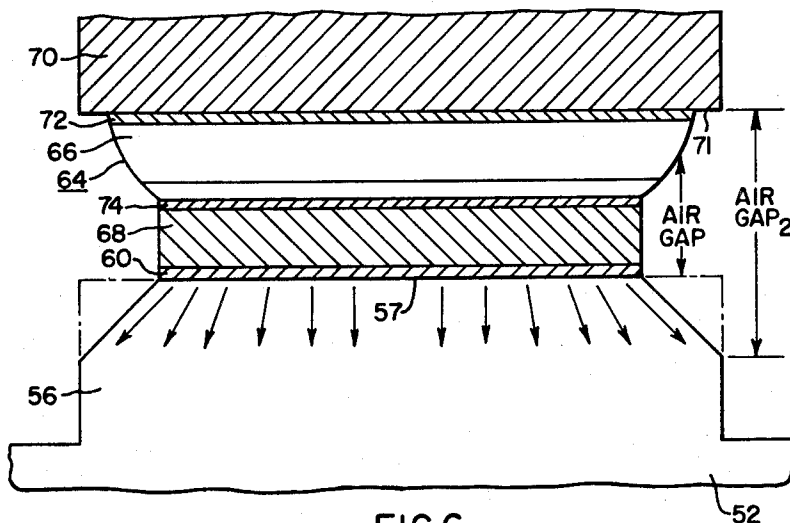
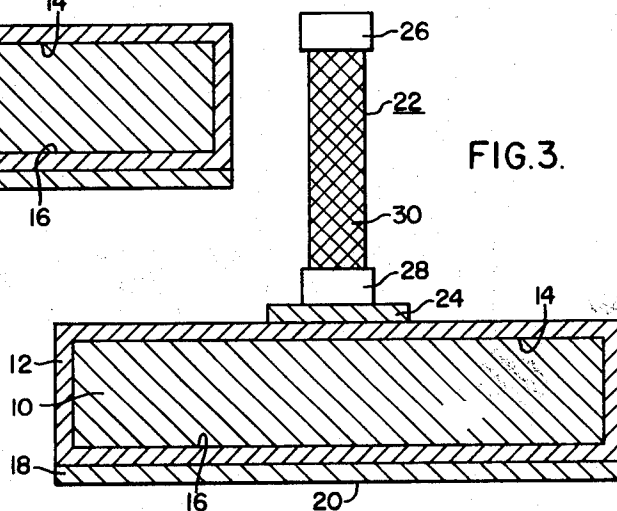


FIG. 6.

WITNESSES

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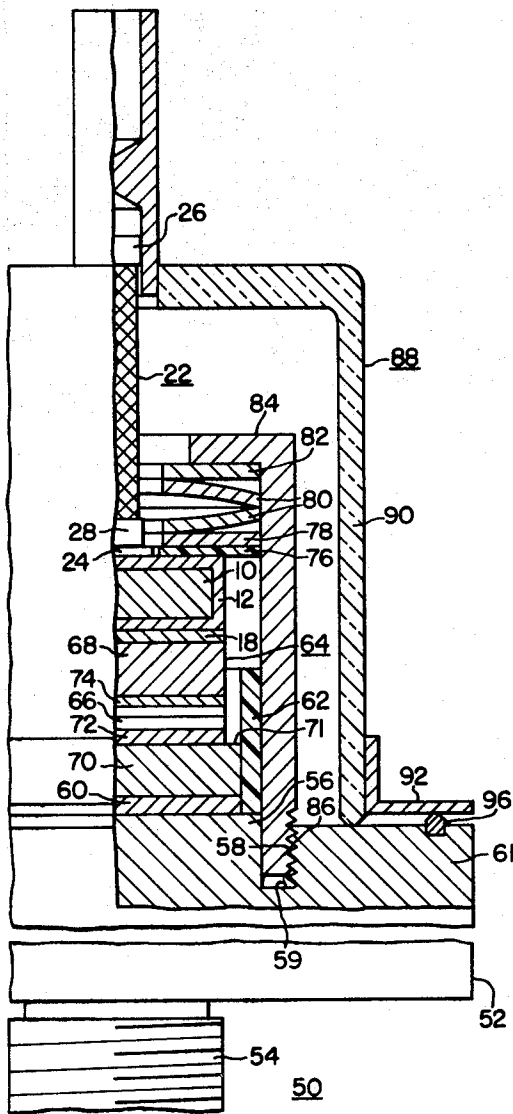


FIG. 4.

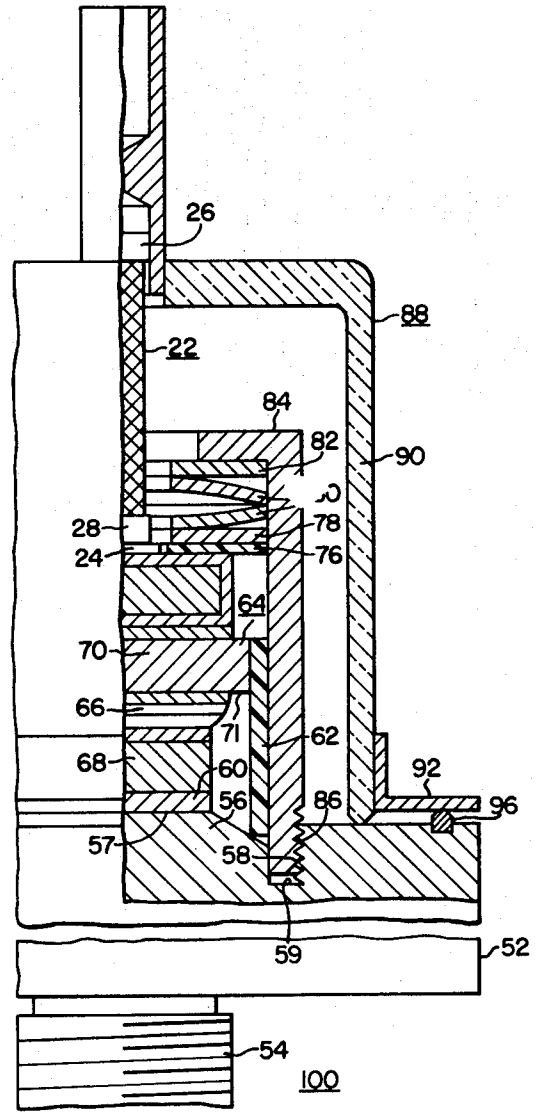


FIG. 5.

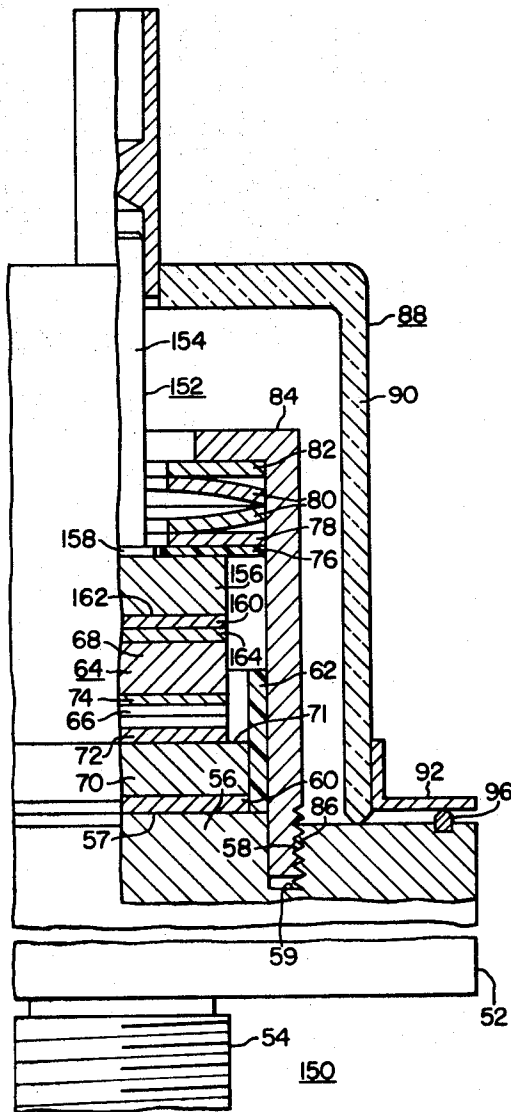


FIG. 7.

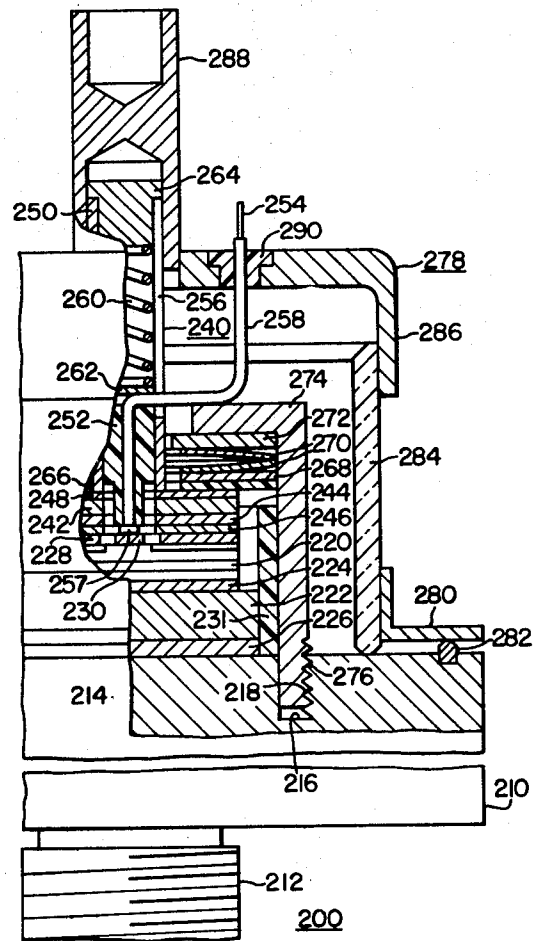


FIG. 8.

DOUBLE-SINTERED GOLD-NICKEL ELECTRICAL CONTACT FOR COMPRESSION-BONDED ELECTRICAL DEVICES

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to semiconductor devices having a pressure electrical contact.

2. Description of the Prior Art

Heretofore, electrical devices having pressure electrical contacts contained therein have encountered difficulties with nickel-gold, silver-antimony, leadfoil electrical contacts. During power, or duty, cycling of the electrical devices embodying the nickel-gold plated electrical contacts, the forward voltage drop of the device was abnormally increased and complete failure of the devices even occurred.

SUMMARY OF THE INVENTION

In accordance with the teachings of this invention there is provided an electrical contact comprised of a body of electrically and thermally conductive material having at least two major opposed surfaces, one of which is an electrical contact surface; a layer of nickel disposed on at least the electrical contact surface and metallurgically bonded to the body; and a layer of gold disposed on, and metallurgically bonded to, at least the layer of nickel.

An object of this invention is to provide a gold-nickel-plated electrical contact suitable for use in electrical devices having pressure electrical contact assemblies embodied therein.

Another object of this invention is to provide a process for making gold-nickel-plated electrical contacts for pressure electrical contact assemblies.

Another object of this invention is to provide a support member for an electrical device in which the air gap between two components, each of which are at different electrical potentials, is maximized without any appreciable loss of the total thermal dissipation capability by the support member.

DRAWINGS

In order to more fully understand the nature and objects of this invention, reference should be had to the following drawings in which:

FIG. 1 is a cross-sectional view of an electrical contact being processed in accordance with the teachings of this invention;

FIG. 2 is a cross-sectional view of an electrical contact made in accordance with the teachings of this invention;

FIG. 3 is a view, partly in cross section, of an electrical contact assembly made in accordance with the teachings of this invention;

FIGS. 4 and 5 are views, partly in cross section, of electrical devices made in accordance with the teachings of this invention;

FIG. 6 is an enlarged cross-sectional view of a portion of the electrical device of FIG. 5; and

FIGS. 7 and 8 are views, partly in cross section, of electrical devices made in accordance with the teachings of this invention.

DESCRIPTION OF THE INVENTION

With reference to FIG. 1, there is shown a body 10 of electrically and thermally conductive material upon which is disposed a layer 12 of nickel. The body 10 is comprised of a material selected from molybdenum, tantalum, tungsten, copper, nickel, Kovar and base alloys of molybdenum, tantalum, tungsten, and copper.

In order to more adequately describe this invention, and for no other purpose, the body 10 will be described as being comprised of molybdenum.

The layer 12 of nickel is, initially, from 0.0002 inch to 0.0003 inch in thickness. The layer 12 of nickel may be

disposed on the body 10 by any suitable means known to those skilled in the art such, for example, as by electroplating. Although the layer 12 need be only disposed on the opposed major surfaces 14 and 16 of the body 10, it is found more convenient and economical to plate the entire body 10.

The nickel-plated body 10 is then disposed in a controlled atmosphere furnace and heated to a temperature of from 800° C. $\pm$ 15° C. to 850° C. $\pm$ 15° C. for a period of approximately 10 minutes. The plated body 10 is furnace cooled to 605° C. $\pm$ 15° C. for a period of approximately 5 minutes and then cooled to room temperature. This heat treatment diffuses nickel into the molybdenum to form a good metallurgical bond between the metals.

Referring now to FIG. 2, a layer 18 of gold is disposed on at least that portion of the nickel layer 12 disposed on one of the major opposed surfaces 14 and 16. The layer of gold is from 0.000050 inch to 0.000200 inch in thickness and may be disposed on the portion of the layer 12 by any suitable means known to those skilled in the art such, for example, as by electroplating. The entire nickel-plated body 10 may also be entirely plated with gold depending upon the economics and feasibility presented by the plating process employed.

The gold-plated body 10 is placed in a controlled atmosphere furnace and heated to a temperature of from 800° C. $\pm$ 15° C. to 850° C. $\pm$ 15° C. for a period of approximately 10 minutes. The gold-plated body 10 is then furnace cooled to 605° C. $\pm$ 15° C. in a period of approximately 5 minutes and then cooled to room temperature. This heat treatment diffuses the nickel and gold metals into one another to form a metallurgical bond with each other.

A suitable heat treatment process for both the nickel layer 12 and the gold layer 18, is to place the plated body 10 in suitable fixtures which pass through a furnace approximately 8 feet in length on a moving belt traveling at a rate of 7.5 inches per minute. A heat treatment after gold plating results in substantially all of the gold color disappearing and being replaced by a surface 20 having a grayish color over substantially all of the surface 20.

With reference to FIG. 3 there is shown an electrical lead assembly 22 comprised of an electrical conductor 30 affixed to the plated body 10 by a layer 24 of a suitable brazing material such, for example, as solder alloys of silver and gold as base materials. The contact assembly 22 is comprised of electrically conductive end caps 26 and 28 affixed to opposite ends of a braided electrical conductor 30. The electrical lead assembly 22 may be joined to the plated body 10 at the same time the nickel-plated body 10 with the electroplated gold layer 18 is heat treated.

With reference to FIG. 4 there is shown an electrical device 50 which embodies the nickel-fold-plated molybdenum body 10.

The device 50 is comprised of a massive metal member 52, which member 52 may be made of a thermally and electrically conductive metal such, for example, as copper, brass, aluminum, aluminum alloys, and steel alloys. A threaded stud portion 54 is integral with, or affixed to, the member 52 for assembling the device 50 into electrical apparatus. The upper side of the member 52 is provided with a pedestal portion 56.

A metal layer 60 is disposed on the pedestal 56 and is centered thereon by a tubular electrically insulating member 62 disposed also on the pedestal 56 and about the outer periphery of the layer 60. The layer 60 comprises a suitable electrically and thermally conductive metal such, for example, as silver. The layer 60 may also be disposed on the pedestal 56 by other such suitable means as, for example, plating. A suitable material for the tubular member 62 is polytetrafluoroethylene.

A semiconductor fusion assembly 64 is disposed on the metal layer 60 within the tubular member 62. The fusion assembly 64 comprises a body 66 of semiconductor material disposed between, and affixed to, electrically and thermally conductive metal contacts 68 and 70.

The body 66 is comprised of a semiconductor material such, for example, as silicon, silicon carbide, germanium, com-

pounds of Group III and Group V elements, and compounds of Group II and Group VI elements. The contacts 68 and 70 are each comprised of a metal selected from the group consisting of molybdenum, tungsten, tantalum, combinations and base alloys thereof. An alloy of from 12 percent to 17 percent weight silver and the remainder tungsten is particularly suitable for making the contact 70. In order to more adequately describe the invention and for no other purpose, the body 66 will be described as being made of silicon having at least two regions of opposite type semiconductivity and a PN junction formed by the interface of each pair of regions of opposite type semiconductivity. Additionally the contacts 68 and 70 will be described as being made of molybdenum.

The contact 70 is joined to the body 66 of silicon by a solder layer 72 of a suitable material such, for example, as a silver-lead-antimony alloy. The contact 68 is joined to the body 66 of silicon by a solder layer 74 of a suitable material such, for example, as an alloy of aluminum and silicon.

The double-plated body 10 with its attached lead assembly 22 is disposed on the contact 68. An apertured electrically insulating washerlike member comprised is disposed about the lead assembly 22 and on the plated body 10. A first apertured metal thrust washer 78 is disposed about the lead assembly 22 and on the insulating member 76. At least one convex apertured spring member 80 is disposed about the lead assembly 22 on the thrust washer 78. A second apertured metal thrust member 82 is disposed on the at least one convex spring member 80.

A cup-shaped member 84 having external threads at 86 is placed over the electrical lead assembly 22 and the external threads 86 are screwed down onto the threaded portion 58 of a slot 59 located between the pedestal 56 and the outer peripheral portion 61 of the member 52 until a desired predetermined force is applied to the plated contact body 10. This predetermined force resiliently urges the plated body 10, the fusion assembly 64, and the pedestal 56 of the member 52 into a pressure electrical and thermal-conductive relationship with each other.

The device 50 is completed by hermetically encapsulating the fusion assembly 64 within a header assembly 88. The header assembly 88 is comprised of ceramic insulator 90 jointed to an outwardly extending metal flanged portion 92. The flanged portion 94 is welded to a weld ring 96 affixed to the massive metal member 52. A hollow stem member 98 affixed to the ceramic insulator 90 is fitted over the lead 22 and is electrically connected thereto by compressing or rolling a part of the stem 98 about the end cap 26.

Referring now to FIG. 5, there is shown an electrical device 100 which is an alternate embodiment of the electrical device 50 of FIG. 4. All the components are the same except for the orientation of the fusion assembly 64 and the shape of the pedestal 58 of the support member 52.

In the electrical device 100, the fusion assembly 64 is reversed to provide a reverse polarity rectifier assembly. In the fusion assembly 64 the semiconductor element 66 and the contact 68 are smaller in width than the width of the contact 70. In low voltage rectifiers the vertical distance, or air gap, between the top surface 71 of the contact 70 and the top surface 57 of the pedestal 56 of the support member 52. As the potential difference between the contacts 68 and 70 increases, the greater the air gap between the two surfaces 57 and 71 must become to prevent arc-over from occurring between them. The upper surface 57 of the pedestal 56 is at the same potential as the contact 68. Therefore, when the potential difference is in the neighborhood of 2,000 volts or better, the more likely it becomes that arcing will occur between the two surfaces 71 and 57. Therefore, the pedestal 56 has the preferred shape as shown in FIG. 5. This preferred shape does not detract from the thermal conductive ability of the support member 52.

With reference now to FIG. 6 there is shown the fusion assembly 64 disposed on the pedestal 56 modified for use in the reversed polarity electrical device 100. The heat generated by

operation of the semiconductor element 66 has to be dissipated by the support member 52. The lower portion of the member 52 is at a lower temperature than the upper portion including the pedestal portion 56. Therefore, the heat travels away from the surface 57 to the bottom surface of the member 52. Little, or substantially no heat, is dissipated by the portion of the pedestal 56 shown in the phantom view, nor is any significant amount of heat thermally dissipated through the same region.

Therefore, it has been determined that starting at the interface of the top surface 57 of the pedestal 56 with the outer periphery of the contact 68, one may chamfer the upper peripheral side surface of the pedestal 56 at an angle of about 45° to provide an included angle of approximately 135° between the top surface 57, the peripheral side surface of the body 66 and the chamfered peripheral side surface. This chamfering increases the air gap between the surface 71 of the contact 70 and any exposed surface of the pedestal 56 to various lengths between air gap₁ and air gap₂ thereby providing a means to reduce the susceptibility to arcing between the surfaces as the reverse polarity electrical device 100 operates in the vicinity of about 2000 volts and above.

Referring now to FIG. 7, there is shown an electrical device 150 which is an alternate embodiment of the electrical device 50 of FIG. 4. The electrical device 150 is comprised of exactly the same components as those comprising the device 50 except that the electrical lead assembly 22 has been replaced by a new contact assembly 152.

The electrical contact assembly 152 is comprised of a solid electrical conductor 154 comprised of a suitable electrically conductive material such, for example, as copper, brazed to an electrically conductive member 156. The member 156 is comprised of a material such, for example, as copper, brazed by a suitable layer 158 of brazing material such, for example as a silver base solder alloy to the conductor 154. The assembly 152 may also be formed as one integral contact from one piece of starting material.

The contact member has a layer 160 of sintered nickel disposed on at least the contact surface 162. A layer 164 of sintered gold is disposed on the layer 160 of sintered nickel. The layers 160 and 164 of nickel and gold respectively are of the same thicknesses as those on the body 10, FIGS. 1 and 2, and are deposited and heat treated in the same manner as hereinbefore described.

Power cycling of the device showed no detrimental loss of forward voltage drop or of any undesirable effects of the rubbing of the plated contact surface 162 of the contact assembly 152 on the surface of the contact 68.

Referring now to FIG. 8, there is shown an electrical device 200 embodying a double sintered nickel-gold-plated electrical contact made in accordance with this invention.

The device 200 comprises a massive metal support member 210, which member 210 may be made of copper, brass, aluminum or any other suitable electrically and thermally conductive material. The member 210 has at its lower end a screw-threaded portion 212 for assembling the device into electrical apparatus. The upper side of the member 210 is provided with a pedestal 214 and a closed slot 216 about the lower portion of the pedestal 214. The outer wall surface of the slot 216 has threads 218.

A semiconductor element 220 has a support plate 222 comprised of a material selected from the group consisting of tungsten, tantalum, and base alloys thereof soldered thereto by a layer 224 of aluminum. The semiconductor element 220 is formed with the desired junction therein by any of the methods well known in the art. The semiconductor element 220 may be of the PNP, NPN, PNPN, or any other desired type having three or more electrical contacts. The support plate 222 is placed on top of the pedestal 214 and a layer 226 of silver or gold positioned between the plate 222 and the top of the pedestal 214.

The element 220 is shown as a four-region device. A contact layer 228 of a gold alloy is provided by suitable means

known to those skilled in the art on the upper surface of the element 220 to provide a cathode contact to the element 220. A center gate, or control electrode contact, 230 is also provided on the upper surface of the element 230. An electrically insulating tubular member 231 centers the element 230 and the plate 222 on the pedestal 214.

Electrical contact is made to the cathode contact 228 and the gate contact 230 by a cathode-gate assembly 240. The cathode-gate assembly 240 is comprised of a molybdenum washer 242 having layers 244 and 246 of sintered nickel and gold platings made in accordance with the teachings of this invention formed thereon. The molybdenum washer 242 is in turn brazed to a copper washer 248 which, in turn, is brazed to a hollow electrical connector 250 extending upwardly from the copper washer 248. An electrically insulating plug 252 is slidably mounted inside the hollow connector 250.

A gate or control lead 254 extends downwardly through a slot 256 in the sidewall of the hollow connector 250 and down through the center of the slidable electrically insulating plug 252 and terminates in a button-shaped contact member 256. Gate lead electrical insulation 258 is placed over the gate lead 254 and the lower end of the insulation 258 is sealed in the plug 252.

A resilient force is maintained on the button shaped contact 256 by means of a coil spring 260 which is positioned inside the hollow conductor 250. A mica washer 262 is positioned between the gate lead electrical insulation 258 and the spring 260 to protect the insulation 258 against wear and damage by the spring 260. The spring 260 is retained in compression by a plug 264 which fits tightly into the upper end of the hollow conductor 250. The spring 260 maintains a constant force of from 3 to 5 pounds on the button-shaped contact member 256.

An electrical insulating washer 266 comprised of such, for example, as mica is placed on top of the copper washer 248 and a metal washer 268 is disposed on the insulating washer 266. At least one convex spring washer 270 is disposed upon the metal washer 268 and a second metal washer 272 is placed on the uppermost convex spring washer 270.

A cup-shaped member 274 having external threads at 276 is placed over the hollow conductor 250 and screwed down onto the threads 218 until a desired predetermined force is applied to the cathode contact 228 and the anode contact 222.

The entire assembly is hermetically sealed within a header assembly 278. The header assembly is comprised of an annular flange member 280 welded to a weld ring 282 joined to the member 210. A ceramic creep insulator 284 is joined to the flange member 280. A metal cap member 286 is joined to the creep insulator 284. A hollow electrically conductive stem member 288 hermetically sealed within the cap member 286 fits over the hollow conductor 250 and is electrically connected to the hollow conductor 250 by rolling or compression or crimping in some known manner. The stem member 288 provides a means for attaching a cathode lead to the device 200.

The gate lead 254 after passing through the slot 256 in the side of the hollow connector 250 is hermetically sealed within the metal cap member 286 by means of an electrical insulator 290.

The following is an example of the teachings of this invention:

Sixty-one rectifier devices, the same as that shown in FIG. 4, were fabricated and assembled in accordance with the teachings of this invention.

The body 10 of each device was made of molybdenum and was nickel plated all around, the plating thickness being approximately 0.0003 inch in thickness. The nickel was electroplated on the molybdenum body.

The nickel-plated bodies were fixtured and placed on a moving belt which passed through a heat treating furnace. The furnace is approximately 9 feet in length and had three temperature zones of equal length. The first temperature zone had a temperature of $800^{\circ}\text{C.} \pm 15^{\circ}\text{C.}$ the second zone was 800°C.

$\pm 15^{\circ}\text{C.}$, and the third zone was $605^{\circ}\text{C.} \pm 15^{\circ}\text{C.}$ The furnace atmosphere was hydrogen gas flowing at a rate of 70 standard cubic feet per hour.

The furnace had an enclosed preheat portion which was approximately 3 feet in length and a flow of nitrogen at 60 standard cubic feet per hour provided a curtain between the ambient atmosphere and the furnace atmosphere. An enclosed furnace cooling portion at the end of the heat-treat furnace provided a furnace cooling length of travel of approximately 3 feet. Again nitrogen gas, flowing at a rate of 70 standard cubic feet per hour, provided a curtain between the hydrogen atmosphere of the furnace and the ambient atmosphere. The speed of the furnace belt was 7 1/2 inches per minute.

After heat treatment to the nickel-plated bodies, all the bodies were gold plated by an electroplating process. The plated gold thickness was approximately 70×10^{-6} inch. A braided electrical lead and a brazing preform of silver alloy was fixtured onto a surface of each plated body. The gold-nickel-plated bodies with the leads and preforms were then heat treated in the same manner as the aforementioned heat treatment process of the nickel-plated bodies. Upon removal from the furnace, the electrical lead was brazed to the gold-nickel-plated body.

The electrode 68 was made of molybdenum. The backup electrode 70 was comprised of an alloy of from 15 percent by weight silver and the remainder was tungsten.

Each assembled electrical device was power cycled 5,000 times. The pulse was 235 amperes at 25°C. for a duration of 10 milliseconds. At the end of the power cycling, the average forward voltage drop was no greater than 4 percent. A visual examination of contact surfaces of the bodies 10 showed no evidence of galling or fusion of any portion of the surfaces with contiguous contact surfaces of the electrical components in physical contact with them.

While the invention has been described with particular reference to specific embodiments and examples of the invention, it will be understood, or course, that modifications, substitutions and the like may be made therein without departing from its scope.

I claim:

1. An electrical contact comprising:
 - a body of electrically and thermally conductive material having at least two major opposed surfaces;
 - a layer of nickel disposed on at least one surface and metallurgically bonded to said body, said layer of nickel as applied being initially from 0.0002 inch to 0.0003 inch in thickness; said body and said layer of nickel heated to an elevated temperature 850°C. to 850°C. for a sufficient time to metallurgically bond the nickel to the body; and
 - a layer of gold disposed on, and metallurgically bonded to, at least said layer of nickel, said layer of gold as applied being initially from 0.000050 inch to 0.000200 inch in thickness said body, said metallurgically bonded nickel, and said gold heated to an elevated temperature of approximately 800°C. — 850°C. for a sufficient time to sinter them whereby to metallurgically bond the gold to the metallurgically bonded nickel layer.
2. The electrical device of claim 1 in which said electrically and thermally conductive material is one selected from the group consisting of molybdenum, tungsten, tantalum, copper, aluminum, and combinations and base alloys thereof.
3. The electrical contact of claim 1 in which an electrical lead is electrically connected to said body.
4. The electrical contact of claim 3 in which said electrical lead is an integral part of said electrical contact.
5. The electrical contact of claim 3 in which said body is comprised of molybdenum, and said electrical lead is comprised of braided copper wire.
6. The electrical contact of claim 4 in which said body and said electrical lead is comprised of a copper-based alloy.
7. An electrical device comprised of:
 - a. an electrically and thermally conductive support member;

b. a semiconductor element disposed on said support member, said element having at least two regions of alternate type semiconductivity and at least one PN junction formed at the interface of said two regions of different type semiconductivity and at least a first electrical contact electrically affixed to at least one region of semiconductivity, and a second electrical contact electrically connected to the other region of semiconductivity; and

c. a third electrical contact disposed on, and electrically connected to one of said first and said second electrical contacts, said electrical contact being comprised of a body of electrically and thermally conductive material having at least two major opposed surfaces, one of the at least two major opposed surfaces being an electrical contact surface, a layer of nickel disposed on at least that portion of said body disposed on at least said contact surface and metallurgically bonded to said body, the layer of nickel of said third electrical contact being initially from 0.0002 inch to 0.0003 inch in thickness said body and said layer of nickel heated to an elevated temperature of approximately 800° C. to 850° C. for a sufficient time to sinter them whereby to metallurgically bond the gold to the metallurgically bonded nickel layer, and a layer of gold disposed on and metallurgically bonded to said layer of nickel said layer of gold being initially from 0.000050 inch to 0.000200 inch in thickness said layers having been sintered together.

8. The electrical device of claim 7 in which said electrically and thermally conductive material is one selected from the group consisting of molybdenum, tungsten, tantalum, copper, aluminum and combinations and base alloys thereof.

9. The electrical device of claim 7 in which an electrical lead is electrically connected to said body of said third electrical contact.

10. The electrical device of claim 9 in which said electrical lead is an integral part of said third electrical contact.

11. The electrical device of claim 10 in which said body and said electrical lead of said third electrical contact are integral with one another and are each comprised of a copper based alloy.

12. The electrical device of claim 8 in which each of said first and said second electrical contacts each are comprised of a metal selected from a group consisting of molybdenum, tungsten, tantalum and combinations and base alloys thereof.

13. The electrical device of claim 12 in which:

said first electrical contact consists of an alloy of from 12 to 17 percent by weight silver and the remainder is tungsten; and

said second and said third electrical contacts are each consisted of molybdenum.

14. The electrical device of claim 13 in which a hermetic enclosure seals therein said semiconductor element.

15. The electrical device of claim 7 in which said support member has an upwardly extending pedestal, said pedestal having a peripheral side surface, at least a portion of which is beveled and forms an included angle of approximately 135° with the top surface of said pedestal.

16. The electrical device of claim 15 in which:

said first electrical contact is comprised of an alloy of 12 to 17 percent by weight silver and the remainder is tungsten; and

said second electrical contact is comprised of molybdenum.

17. The electrical device of claim 15 in which the top surface of said pedestal has at least the physical dimensions as the bottom surface of said first electrical contact.

18. The electrical device of claim 7 in which:

said semiconductor element has at least three regions of alternate type semiconductivity;

a fourth electrical contact electrically connected to a third region of semiconductivity of said element;

an electrical lead electrically connected to said fourth electrical contact; and

said force means acts on said fourth electrical contact.

19. In a process for making an electrical contact, the steps comprising:

a. disposing a layer of nickel of a thickness of from 0.0002 to 0.0003 inch on at least the electrical contact surfaces of a body of electrically and thermally conductive material;

b. heating said body and said layer of nickel to an elevated temperature of approximately 800° C. to 850° C. for a sufficient time to metallurgically bond the nickel to the body;

c. disposing a layer of gold of a thickness of from 0.00005 to 0.0002 inch on at least the layer of metallurgically bonded nickel; and

d. heating said body, said metallurgically bonded nickel, and said gold to an elevated temperature of approximately 800° C. to 850° C. for a sufficient time to sinter them whereby to metallurgically bond the gold to the metallurgically bonded nickel layer.

20. The process of claim 19 in which each of said heating steps is practiced at an elevated temperature of at least 800° C. $\pm 15^\circ$ C.

21. The process of claim 19 in which each of said heating steps is practiced by heating said contact to a temperature of 800° C. $\pm 15^\circ$ C. for a period of approximately 6½ minutes.

22. The process of claim 21 in which said contacts are preheated during each heating step to a temperature of 800° C. $\pm 15^\circ$ C. in approximately 5 minutes; and said contacts are furnace cooled during each heating step to 605° C. $\pm 15^\circ$ C. in approximately 5 minutes.

23. The process of claim 22 in which the furnace atmosphere is hydrogen.