MULTIPLE ELECTRICAL CONTACT ASSEMBLY FOR COMPRESSION BONDED ELECTRICAL DEVICES

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ABSTRACT OF THE DISCLOSURE

An electrical contact assembly comprises at least two electrical contacts, one inserted within, and interlocked with, the other; the electrical contacts are joined together, and are electrically insulated from each other, by suitable electrical insulating materials. The electrical contact surfaces may then be lapped after joining to produce contact surfaces in essentially the same plane.

This invention relates to a new structure for a multiple electrical contact suitable for use in compression bonded semiconductor devices.

Heretofore multiple electrical contacts manufactured for employment with compression bonded semiconductor devices required careful processing. In order to compensate for manufacturing tolerances, the contact surface of each electrical contact had to be made relatively smaller in area than the metalized area affixed to a semiconductor element with which the contact made electrical contact. The metalized surface areas on the element made allowances for non-centering of the contact, allowable tolerances and eccentricities inherent in the components.

In addition, to achieve the best results obtainable from pressure contacts, the contact pressure should be uniform over all contact surfaces. Stress concentrations resulting in excessive pressure in one or more areas may deleteriously affect the electrical characteristics of, or fracture, the semiconductor wafer, thereby destroying its usefulness.

An object of this invention is to provide a unitary multiple electrical contact assembly suitable for use in compression bonded semiconductor devices in which the contact assembly comprises at least two electrically and thermally conductive interlocking electrical contact elements joined together by an electrically insulating material disposed between, and adhering to, selected opposed surfaces of each contact element.

Other objects of the invention will, in part, be obvious and will, in part, appear hereinafter.

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

FIGURE 1 is a top view of an electrical contact element made in accordance with the teachings of this invention;

FIG. 2 is a top view of another electrical contact element made in accordance with the teachings of this invention;

FIG. 3 is a side view, partly in cross-section, of the element shown in FIG. 1 taken along the line III—III;

FIG. 4 is a side view, partly in cross-section, of the element shown in FIG. 2 taken along the line IV—IV;

FIG. 5 is a side view, partly in cross-section, of a multiple electrical contact assembly made in accordance with the teachings of this invention;

FIG. 6 is a side view, partly in cross-section of a portion of a compression bonded electrical device employing the multiple electrical contact assembly of FIG. 5; and

FIG. 7 is a side view, partly in cross-section of a compression bonded electrical device embodying the structural portion shown in FIG. 6.

In accordance with the present invention and in attainment of the foregoing objects, there is provided a multiple electrical contact assembly comprising at least two electrically and thermally conductive interlocking electrical contact elements and a layer of electrically insulating material disposed between, and adhering to, selected opposed surfaces of the contact elements and joining the interlocking contact elements together.

The electrical contacts may be designed to have all the load bearing surface, as well as the contact bearing surface, of each element lying in approximately the same plane. Alternately, to meet specific design requirements, one, and even all, of the contact surfaces and bearing surfaces may lie in different planes.

The physical shape of the contact elements can be varied to meet design requirements. Shapes such, for example, as ovals, rectangles and squares as well as circular can be used in fabricating an interlocking multiple contact assembly.

The method of interlocking the elements together is as varied as the physical shapes desired. The elements may be intermeshed within one another, much like two combs stuck together with their teeth intermeshed, or joined together like two jigsaw pieces. Other possible structures include encompassing all of one portion of a contact element within at least a portion of another contact element as well as intermeshing other portions of each of the elements simultaneously.

For purposes of illustrating and describing the electrical contacts and the multiple electrical contact assembly of this invention, and for no other purpose, the contacts will be illustrated and described as being varying sizes of circular disks with all contact surfaces lying in the same plane.

With reference to FIGS. 1 and 3, there is shown a first electrical contact 10 made in accordance with the teachings of this invention.

The contact 10 comprises a good electrically and thermally conductive metal selected from the group consisting of molybdenum, tungsten, tantalum, copper and base alloys thereof. An iron-nickel-cobalt-manganese alloy, such as one sold under the trademark of "Kovar" is also satisfactory.

The metal selected should have a coefficient of expansion compatible with the coefficient of expansion of the semiconductor material in contact with the metal. This contact 10 may be produced by any suitable manufacturing method known to those skilled in the art such, for example, as by milling, turning, electrical spark discharge machining, stamping and investment casting.

The contact 10 has a top, or load bearing surface 12 and a bottom surface 14. The surfaces 12 and 14 are substantially parallel to one another. A peripheral flange 16 is disposed about the outer periphery of the contact 10 and integral with the top surface 12.

The contact 10 has an aperture 18 disposed within it. The aperture 18 is approximately semicircular in shape and leaves a peripheral portion of the contact 10, including the shoulder 16.

A first annular recess 20 is disposed in the bottom surface 14 of the contact 10. The intersection of the recess 20 with the aperture 18 leaves only approximately a semi-circular portion of the recess 20 remaining. The portion of the bottom surface 14 disposed between the outer peripheral edge immediately adjacent to the bottom surface 14 and the outer peripheral wall of the recess 20
functions as a first annular electrical contact surface 22, and is continuous around the periphery. A second annular recess 24 is disposed within the bottom surface 14. The recess 24 is intercepted by the aperture 18 resulting in the remaining portion of the recess 24 being approximately semicircular. The portion of the surface 14 between the inner peripheral wall of the recess 20 and the outer peripheral wall of the recess 24 functions as a second electrical contact surface 26.

A third electrical contact surface 28 is shaped approximately like a semicircular disk. It is a portion of the surface 24 disposed between the inner peripheral wall of the recess 24 and the inner peripheral wall of the aperture 18. With reference to FIGS. 2 and 4, there is shown a second electrical contact 30 made in accordance with the teachings of this invention.

The contact 30 comprises a good electrically and thermally non-conductive metal selected from the group consisting of molybdenum, tungsten, tantalum, copper and base alloys thereof. An iron-nickel-cobalt-manganese alloy such as that sold under the trademark "Kovar" may also be used. The contact 30, although not required, is preferably made of the same material as the contact 10 in order that the electrical contact assembly utilizing the contacts 10 and 30 will have a uniform thermal and electrical conductivity throughout the assembly. The metal selected should have a coefficient of expansion compatible with the coefficient of expansion of the semiconductor material in contact with the metal.

The contact 30 may be produced by any suitable manufacturing method known to those skilled in the art. Such known manufacturing methods include milling, turning, electrical spark discharge machining, stamping, die casting and investment casting.

The contact 30 has an outer peripheral edge 31, a top surface 32 and a bottom surface 34. The surfaces 32 and 34 are substantially parallel to one another. The thickness of the contact 30 as measured between the surfaces 32 and 34, is the same as the thickness of the contact 10 as measured between the surfaces 12 and 14.

A first recess 36 is disposed in the bottom surface 34 of the contact 30. The recess 36 is wider than the width of the contact surface 26. The portion of the bottom surface 34 disposed between the outer peripheral edge of the contact 30 and the outer peripheral wall of the recess 36 functions as a first annular electrical contact surface 38. The width of the contact surface 38 is less than the width of the recess 20 of the contact 10.

A centrally disposed cup-shaped depression 42 is formed in the bottom surface 34 of the contact 30. The portion of the surface 34 disposed between the inner peripheral wall of the recess 36 and the outer peripheral wall of the depression 42 functions as a second annular electrical contact surface 44. The width of the surface 44 is less than the width of the recess 24.

A remaining portion 46 left after the removal of part of the contact 30 including a part of the surface 32 is approximately semicircular in shape. The portion 46 has a remaining outer peripheral side edge which is an integral part of edge 31 and a second side edge 47. The width of the portion 46 is less than the width of the aperture 18.

The removal of the portion of the contact 30 converts a portion of the annular recess 36 to a semicircular aperture as shown in FIG. 4. The surfaces 48 and 50 lie in the same plane, the plane being substantially parallel to both the top surface 32 and the bottom surface 34.

The thickness of that portion of the contact between the surfaces 48 and 50 and the bottom surface 34 is less than the depth of either the recess 20 or the recess 24 of the contact 10.

Electrical conductors 52 and 54, each comprising a good electrically conductive material, such, for example, as copper, are each affixed by suitable means, for example, each lead being disposed in the respective contacts 10 and 30 through the respective top surfaces 12 and 32. The conductors 52 and 54 each may be joined to the respective contacts 10 and 30 by such suitable means as casting in place, soldering or brazing.

With reference to FIG. 5, there is shown the electrical contacts 10 and 30 joined together to form a multiple electrical contact assembly 60.

In the process of joining the contacts 10 and 30 together, a coating 68 of electrically insulating material is first disposed on portions of the contact 30 including at least the outer peripheral edge 31, the second side edge 47, the surfaces 48 and 50 and portions of the inner peripheral walls of the recess 36 and the depression 42 which project into the recesses 20 and 24. Suitable examples of such electrically non-conducting or electrically insulating materials are electrically insulating varnishes, shells and resins such, for example, as a methyl-phenylsilicone varnish.

The coating 68 although not required provides assurance that there will be no electrical conductivity between opposing surfaces of the contact 10 and 30. The coating 68 is applied before the two contacts 10 and 30 are joined together.

The coated contact 30 and the contact 10 are each disposed in a suitable mold fixture. The contacts 30 and 10 are properly oriented and situated in place. A suitable bonding material 70, such, for example, as an electrically non-conducting epoxy resin, is then poured into the mold and permitted to flow in and about specific surface areas of the contacts 30 and 10. The material 70 is then cured. Upon curing the material 70 bonds the oriented contacts 30 and 10 together into the unitary multiple contact assembly 60.

To assure that the surfaces 32 and 12 lie in one plane, as well as the surfaces 22, 38, 26, 44 and 28 lie in one plane, all the surfaces 32, 12, 22, 38, 44, 26 and 28 have a surface finishing operation performed on them. This operation assures one that the resulting two planes are each substantially parallel to one another.

It is very desirable to have the planes substantially parallel to each other in order to minimize any undue stress concentrations from occurring in compression bonded electrical devices. It is desirable to have the contact surfaces in each major surface face in the same plane as to assure a good electrical and thermal conductivity relationship with a mating body of semiconductor material and to minimize undue local stressing in either the assembly 60 or in the mating body of semiconductor material.

With reference to FIG. 6 there is shown a portion of a compression bonded electrical device utilizing the multiple electrical contact assembly 60 of FIG. 5. The multiple electrical contact assembly 60 is disposed on a semiconductor-contact assembly 104 which in turn is disposed in an electrically and thermally conductive support member 82. The support member 82 is comprised of a peripheral flange 84 and an upwardly-extending pedestal portion 86. The upwardly-extending pedestal portion 86 has an uppermost mounting surface 88. The peripheral flange 84 has a top surface 90 and the upwardly-extending pedestal portion 86 has a peripheral side surface 92.

The support member 82 is made of a metal selected from the group consisting of copper, silver, aluminum, base alloys thereof and ferrous base alloys. Copper and brass, a base alloy of copper, have been found particularly satisfactory for this purpose.

A non-reactive, malleable, electrically and thermally conductive layer 122 is disposed on the uppermost mounting surface 88 of the support member 82. The layer 122 comprises a metal selected from the group consisting of gold, silver, tin, indium, lead and aluminum. The layer 122 compensates for any surface irregularities which may occur on the surface 88. The layer 122 may be dis-
posed upon the surface 88 by any suitable means known to those skilled in the art, such for example, as electrodeposition means, or a pressed disk of a suitable metal affixed to the surface 88 and then contoured to specific requirements.

Another suitable method of disposing an equivalent non-reactive, malleable, electrically and thermally conductive structure in lieu of the layer 122 is to coat the surface 88 with a suitable material to promote electrical and thermal conductivity by such suitable means such, for example, as electrodeposition. A metal member comprising a metal selected from the group consisting of gold, silver, tin, indium, lead and aluminum is then disposed between, and in contact with, the coated surface 88 and the semiconductor contact assembly 104 without employing a bonding material to form a permanent joint between the components.

The semiconductor-contact assembly 104 is disposed on the layer 122. The assembly 104 comprises a semiconductor element 106 and an electrical contact 108.

The element 106 comprises a body of a semiconductor material selected from the group consisting of germanium, silicon, silicon carbide, compounds of Group III and Group V elements and compounds of Group II and Group IV elements.

The element 106 has two regions 105 and 107 of first type conductivity, a region 109 of second type conductivity, a semiconductor transition region 111 found at the interface between regions 107 and 109 and a semiconductor transition region 113 found at the interface between regions 105 and 109.

Annular contacts 115 and 117 and a circular contact 119 are each affixed to a separate portion of the region 107 of semiconductivity. Annular contacts 121 and 123 are each affixed to a separate portion of the region 109 of semiconductivity.

The electrical contact 108 comprises a metal, such for example, as molybdenum, tungsten, tantalum and combinations and base alloys thereof. The contact 108 may be gold-plated. The contact 108 is a firm supporting structure for the semiconductor element 106. The contact 108 has electrical and thermal conductivity properties as well as thermal expansion characteristics very similar to the same properties and characteristics of the semiconductor element 106.

Although not required, the semiconductor element 106 is preferably joined to the first electrical contact 108 by a suitable prior joining operation. The joining of the semiconductor element 106 to the contact 108 may utilize a layer 120 of any suitable "hard" or "soft" solder known to those skilled in the art. Although an ohmic type solder may be used the material comprising the layer 120 is a suitable N-type metal or a P-type metal for forming the suitable required electrical junction with the body of semiconductor material comprising the element 106.

The solder layer 120 comprises a suitable solder, such for example, as an alloy of gold-anilmony, or aluminum having a melting point about 350° C. and having a greater strength and hardness than the more common alloys of lead and tin, known to those skilled in the art as a "hard" solder. A solder having a melting point below about 350° C., and known to those skilled in the art as a "soft" solder, may also be used. Such "soft" solders are usually, but need not be, lead-tin alloy solders.

It will be understood, of course, that the particular type of solder will depend on the anticipated operating temperature range of the finished electrical device.

Disposed on the semiconductor element 106 is the multiple electrical contact assembly 60. The contact assembly 60 is oriented so that contact surface 22 of the assembly 60 is in electrical and thermal contact with the electrical contact 115 of the element 106. Simultaneously in a similar manner contact surface 38 and contact 121, contact surface 26 and contact 117, contact surface 44 and contact 123 and contact surface 28 and contact 119 are all electrically and thermally connected to each other.

A thin coating of an electrically conductive metal, such as silver, tin and by base alloys thereof if may be disposed on any or all of the contact surfaces 22, 26, 28, 38 and 44 and contacts 115, 117, 119, 121 and 123. The metal coating reduces the contact resistance between mating contact surfaces of the element 106 and the contact assembly 60.

It is important that the surfaces between the electrical contact 108 and the layer 122, as well as the surfaces between the contact assembly 60 and the semiconductor element 106 be flat and planar so that no uneven pressures develop when compressed together.

An apertured electrically insulating washer 62 is disposed about the electrical conductors 52 and 54 and upon the contact assembly 60. The insulating washer 62 comprises a material selected from the group consisting of ceramic, mica, glass, quartz and fluorocarbon.

An apertured steel thrust washer 64 is disposed about the electrical conductors 52 and 54 upon apertured insulating washer 62. An apertured steel spring washer 66 is then disposed about the electrical conductors 52 and 54 upon the top surface of the apertured thrust washer 64.

The washer 66 electrically insulates the contact assembly 60 from the thrust washer 64. The spring washer 66, acting on the thrust washer 64, which in turn acts on the contact assembly 60, urges the contact assembly 60, the semiconductor-contact assembly 104 and the support member 82 into a good electrical and thermal conductivity relationship with each other.

With reference to FIG. 7, there is shown a complete compression bonded electrical device embodying the components illustrated in FIG. 6.

An upwardly-extending hollow cylindrical member 94 is affixed to the support member 82. The inner periphery of the member 94 conforms to the peripheral surface 92 of the pedestal portion 86. The member 94 is affixed to the support member 86 by any suitable means known to those skilled in the art, such for example, as by disposing a suitable braze material 96 between the top surface 90 and the side surface 92 of the support member 82 and a portion of the inner periphery and all of the bottom of the cylindrical member 94.

An annular groove 98, formed in the wall of the inner periphery of the cylindrical member 94, is located remote from the end joined to the support member 82. An upwardly-extending integral flange 100 is formed about the upper end of the inner periphery. An annular integral weld flange 102 is formed in the upper surface of the member 94.

The cylindrical member 94 is preferably made of a ferrous base material although other suitable materials, particularly metals, may be employed.

Orientation of the multiple electrical contact assembly 60 with the semiconductor-contact assembly 104 to maintain a constant alignment of all respective contact surfaces is achieved through use of an apertured molecular sieve 124.

The outer periphery of the molecular sieve 124 conforms to the inner periphery of the member 94. The inner periphery of the sieve 124 conforms to the side surface of the non-reactive malleable, electrically and thermally conductive semiconductor layer 122. Disposed on the outer peripheral portion of the surface 88 of the pedestal portion 86 of the member 82, the sieve 124 functions as a moisture gettering device and facilitates assembly operation by self-centering device components.

A second apertured steel spring washer 67, the same as the washer 66, as shown in FIG. 6, is disposed about the electrical conductors 52 and 54 upon the apertured steel spring washer 66.

An apertured steel thrust washer 126, similar to the washer 64 is disposed on the spring washer 67. An apertured expandable metal retaining ring 128, similar to a
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snap ring, is disposed about the electrical conductor 52 and 54 within, and is retained by, the groove 98 formed in the inner periphery of the upwardly-extending cylindrical member 94. The ring 128 cooperating with the cylindrical member 94 and acting on the thrust washer 126 resiliently urges the spring washers 66 and 67 to transmit a compression force to the thrust washer 64 and thence through the electrically insulating washer 62 to force the contact assembly 60, the semiconductor element 106, the electrical contact 103 and the uppermost mounting surface 85 of the upwardly-extending pedestal portion 86 of the support member 82 into a firm, intimate, electrically and thermally conductive relationship with each other.

More than one of the apertured spring washers 66 and 67 of the same, or different thickness, may be required to cooperate with the retaining ring 98 and the cylindrical member 94 to create the necessary compressional force required for a reliable operating device 80.

The device 80 is completed by providing a hermetic enclosure for the semiconductor element 106. This hermetic enclosure is formed by affixing an apertured header assembly 130 to the member 94. The header assembly 130 comprises an outwardly-extended flanged member 132 affixed to an apertured insulating seal member 134.

The header assembly 130 is joined to the member 94 by welding the outwardly-extended flanged member 132 to the annular weld ring 102. The integral flange 100 acts as a guide for positioning the header assembly 130 during assembly and joining operations.

An electrical contact and thermal dissipating stud 136 is either affixed or is integral with the support member 82. The stud 136 is used to connect the support member 82 to an electrical conductor and heat sink.

The design and fabrication of the contact assembly 60 results in an optimum uniform pressure being distributed throughout said assembly 60 in the device 80. The resulting design also permits contact surfaces to be more concentric with each other and to have the maximum available contact surface area for the best electrical and thermal conductivity relationships possible. The ability to produce a more closely tolerated multiple electrical contact assembly 60, therefore, reduces the total required eccentricity of required associated contact surfaces of the semiconductor element 106 thereby increasing the reliability and efficiency of the device 80.

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

1. A multiple electrical contact assembly comprised of
(a) a first electrically and thermally conductive contact comprising
    a top surface, a bottom surface, walls defining an aperture extending from said top surface to said bottom surface, other walls defining a plurality of recesses in said bottom surface of said first contact, said recesses having a depth less than the thickness of said first contact;
    (2) a second electrically and thermally conductive contact comprising
        a first portion and a second portion, the first portion of the second contact having the same thickness as said first contact and being disposed within, and spaced from the walls of, the aperture of said first contact, the second portion being integral with said first portion, said second portion having a thickness less than that of said first portion and a bottom surface comprising only in part the bottom surface of the second contact, walls defining a plurality of apertures extending entirely through the thickness of said second portion, said second portion being disposed within, and spaced apart from, the walls defining said plurality of recesses of said first contact.
means for applying a constant force to the multiple electrical contact assembly to maintain the body of semiconductor material and the multiple electrical contact assembly in an electrically and thermally conductive relationship.

10. The electrical device of claim 9 in which the top surface of each of said first and said second contacts is a one load bearing surface, the load bearing surface and the electrical contact surface of each contact being opposed surfaces substantially parallel to each other, and each of said surfaces of one contact lying the same plane as the respective surface of the other contact.

11. The electrical device of claim 9 in which there is a layer of low resistance contact metal disposed on at least one electrical contact surface of one electrical contact, said metal is at least one material selected from the group consisting of gold, tin, silver and base alloys thereof disposed on a portion of each element.

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