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PATENT SPECIFICATION

DRAWINGS ATTACHED

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COMPLETE SPECIFICATION

Composite Header for a Semiconductor Device

We, TEXAS INSTRUMENTS INCORPORATED, a Corporation organised according to the laws of the State of Delaware, United States of America, of 13500 North Central Expressway, Dallas, Texas, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to headers for semiconductor devices.

Mounting supports such as headers for semiconductor devices are, for the most part, constructed from metals and then coated with a layer of some metal, for example gold, to prevent contamination of the device. The fabrication of metal headers and the gold plating adds to the cost of these headers.

It is an object of the invention to provide a semiconductor device header of reduced cost compared with known headers.

According to one aspect of the invention there is provided a header for a semiconductor device including a plurality of alternate layers of glass and ceramic material which are fused together, and a plurality of lead wires extending through the layers and held in place by fusing glass in the layers to the wires.

According to another aspect of the invention there is provided a method for making a header structure for a semiconductor device comprising the steps of:

a. placing alternate layers of granulated glass and a granulated ceramic material into a mould;

b. comprising said alternate layers of granulated materials to form a composite body having holes extending through said layers of glass and ceramic material;

c. heating said body to fuse the compressed glass granules to each other and to said ceramic granules;

d. inserting lead wires into said holes ex-

tending through said glass and said ceramic layers; and

e. heating said body and said lead wires to fuse said glass to said lead wires.

By way of example certain embodiments of the invention will now be described with reference to the accompanying drawings in which like reference numerals designate like parts throughout the figures thereof, and in which:

FIGURE 1 is a pictorial drawing of an example of a glass-ceramic header embodying the invention with leads extending therefrom;

FIGURE 2 is a cross-section of the header in FIGURE 1 taken across section lines 2—2 with the addition of a semiconductor device mounted thereon and enclosed by an epoxy material represented by dashed lines;

FIGURE 3 is a second embodiment of the invention showing a metallic eyelet having flanges thereon and a can shown in dashed lines enclosing the top of said header;

FIGURE 4 is a block flow diagram of the basic process for producing the header illustrated in FIGURE 1;

FIGURE 5 is a pictorial view of a glass-ceramic wafer produced by the process of the invention.

FIGURE 6a is a top view of a third embodiment of the invention showing a glass-ceramic header with recessed portions;

FIGURE 6b is a sectional view of the glass-ceramic header along the line A—A of FIGURE 6a;

FIGURE 7a is a top view of a conventional metal-glass integrated circuit header;

FIGURE 7b is a sectional view of the metal-glass integrated circuit header along the line B—B of FIGURE 7a;

FIGURE 8a is a pictorial view, partly in section, of a fourth embodiment of the invention showing a glass-ceramic integrated circuit header;

FIGURES 8b—8d are sectional views of

[Price 4s. 6d.]

the glass-ceramic integrated circuit illustrated in FIGURE 8a using different encapsulation techniques.

Referring now to the drawings, there is shown in FIGURE 1 a composite header made of a layer of glass 3 interposed between and fused to two ceramic layers 2 and 4. Extending through and sealed to the glass and ceramic layer are the leads 5, 6, and 7. Each of the leads 5, 6 and 7 has a round, flat portion 5a, 6a and 7a, respectively, which is an integral part of the lead. These flat portions help hold the lead wires in place and provide mounting surfaces and/or connection points for any device mounted on the header.

Figure 2 is basically a section taken through section line 2—2 of FIGURE 1 showing the cross-section of the ceramic-glass wafer and the leads which extend through openings 10 in the composite wafer. In addition, a semiconductor device is shown mounted on lead 6 and regions of the device connected to the lead wires 5 and 7 at 5a and 7a, respectively. To seal the device upon the top of the header, an epoxy material, represented by dotted line 11, may be coated over the semiconductor device and the wires connected thereto.

The center layer 3 of the composite header is a glass which may be from one of the amorphous silicates, borates, phosphates or several other suitable materials, and the outer layers 2 and 4 are a ceramic material. In the process of making the header, the glass layer 3 flows into the openings 10 about the lead wires extending through the openings 10 and seals the lead wires within the openings. It should be noted that the glass in the hole 10 does not extend completely through the ceramic wafer. Therefore, a bending of the lead wires does not cause a cracking of the glass.

If it is desired that a metallic can be used to enclose the header, a metallic eyelet such as the eyelet 17 shown in FIGURE 3, may be placed around the composite header and fused thereto by the glass during the process of manufacturing as shown at 16. The header can 14 has a flange 15 which mates with the flange 12 of the metallic eyelet 17. These two flanges may be sealed together for example, by welding, thereby hermetically sealing the header. The header shown in FIGURES 2 and 3 results in a reduction of the metal surfaces to be gold plated, for example, in the header shown in FIGURE 2 only the top portions 5a, 6a and 7a of leads 5, 6 and 7 need be plated, resulting in a cost saving in the gold plating alone. In FIGURE 3 there is no top surface to the eyelet 17 as there normally is in a metallic header thereby this area need not be plated.

FIGURE 4 is a flow diagram of the basic steps to take in making the composite header. Block a of FIGURE 4 represents the placing of the ceramic and glass in a mold to be pressed. Block b specifies that the glass and

ceramic is to be compressed at about 5000 psi to mold the glass and ceramic powders into a disc similar to that shown in FIGURE 5. The application of pressure to the glass and ceramic material compresses it so that it will hold together until it is sintered. In Block c the pressed disc is sintered to fuse the glass and the glass-ceramic mixture together. After the disc has been sintered, lead wires are inserted into the holes 10. The disc with the lead wires therein is again fired (Block e) to fuse the leads to the glass within the holes.

A more detailed description of the process used in making the glass and ceramic disc is as follows: Specific materials are used in the following example for purposes of explanation only. Other suitable materials as listed hereafter may be used and the invention is not limited to those specifically described below. First, a mixture of powdered glass and a temporary binder is made by mixing together 100 parts by weight of powder glass approximately 280 mesh, 2 parts by weight polyethylene glycol polymer and 15 parts by weight water. A suitable glass is Corning 7052. In the event that the leads are to be made of a nickel-iron-cobalt alloy such as for example, KOVAR (Registered Trade Mark), sometimes referred to as F-15 alloy, it would be desirable for the glass to have a coefficient of expansion of about $40 \text{ to } 50 \times 10^{-7}$ per °C. The above mixture is thoroughly mixed and granulated by forcing it through a 28 mesh screen. Other methods for making granulations are also suitable, for example, using a spray dryer, hammer mills, etc. The granules are then dried in an oven at about 100°C for about 30 minutes or until the material flows freely without clogging.

The preparation of the ceramic material is as follows: Mix 50 parts by weight of the same type of glass powder used above with 50 parts by weight of a refractory oxide such as aluminum oxide, zirconium oxide, or any other suitable refractory oxide. The two are mixed together, for example in a pebble mill, for about 30 minutes. The ceramic mixture is then granulated as was the glass and dried until it flows freely without clogging.

After the ceramic material and glass have been prepared portions of each material are placed in a press. A first layer of ceramic is covered with a layer of glass and then a second layer of ceramic is applied over the glass. The glass layer is made approximately twice as thick as the ceramic layer. The layered powder material is then subjected to a pressure between 500—20,000 pounds per square inch or preferably between 500 and 5000 pounds per square inch. The material is pressed into discs as illustrated in FIGURE 5. The holes 10 are formed in the disc by having pins of a suitable diameter within the die so that the powder is pressed about the pins. Any number of pins may be used to

provide the number of holes desired within the disc.

After the material has been pressed, the temporary binder will hold the disc together so that it may be removed and handled without the powdery material crumbling apart. The pressed discs are then sintered in an air atmosphere to burn off the temporary binder material and fuse the glass particles together according to the following schedule:

5—20 minutes at 300°C
5—20 minutes at 650°C
5—20 minutes at 750°C

The time of sintering is not critical and anywhere within the time range indicated, for example about 15 minutes will sufficiently sinter the glass and the glass within the ceramic mixture to hold the disc together. The sintering renders the glass impervious without losing its shape, and shrinkage will be only about 5%. Other mixtures will require a higher or lower firing temperature depending upon the softening point of the glass used. It should be noted that if other glasses or other refractory oxides are used, the proportions must be adjusted so that the ceramic layers have a softening point about 250°C higher than the glass.

After sintering, lead wires are then inserted into the holes 10 and placed in a suitable jig made of graphite or equally suitable material. The jigs should have provisions for a small weight to provide about 1 pound per square inch of pressure to the top of the header to keep the wires down and exert some pressure between the layers. Caution should be taken since too much weight will force the glass out from between the ceramic layers at the sides of the disc. Only sufficient pressure is needed to keep the leads in place and to force a small amount of glass about the wires as illustrated at 9 in FIGURE 2. There may be a slight bowing of the side of the glass disc as indicated at 8 in FIGURE 2. After the lead wires have been inserted and the pressure applied, the discs and leads are fired in a neutral atmosphere at about 1000°C for no less than 10 minutes and then cooled while still in the neutral atmosphere.

The process for making the flanged header as illustrated in FIGURE 3 is the same as making the headers illustrated in FIGURE 2 except that after the headers have been fired for the second time the top is removed from the graphite jigs and a metal eyelet is placed around the glass ceramic disc. After the metal eyelet has been placed around the disc the lid is put back on and the weight is placed on. However, this time the weight is approximately doubled, for example about 2 pounds per square inch over the top of the disc. The disc eyelet combination is then refired in the neutral atmosphere at the same temperatures and for

the same time as before. By doubling the weight extra pressure is exerted on the glass layer between the two ceramic layers forcing the glass against the eyelet 17 as shown in FIGURE 3, to cause the glass to contact the eyelet at 16. The glass fuses to the eyelet thereby holding the eyelet in place and forming a hermetic seal therewith.

After the eyelet is attached to the disc, a semiconductor device may be mounted thereon in the same manner as that shown in FIGURE 2. Can 14, shown in FIGURE 3, is then placed over the header, and the flanges 12 and 15 attached together by any convenient method, for example by welding.

Table 1 is a listing of specific materials that may be used in the composite headers. Dumet is a copper clad F-15 alloy and Alloy #52 is a nickel-iron-chrome alloy. The Corning glass No. 7052 is a Boro-silicate glass and the No. 9010 is a Soda-lime glass.

To reduce the cost of the glass-ceramic header, the plated area of the leads is minimized by selectively plating only the portions of the leads that will be enclosed with the active device following encapsulation. However, due to the formation of bubbles on the surface of the ceramic during the plating process which prevents plating small metal areas nearer than .005" to the ceramic surface, the surface of the lead that will act as the bonding area for the semiconductor device must extend above the surface of the ceramic by at least .005". Standard mass production lead bonding techniques require that the ends of the lead wires must be higher than the .010" semiconductor wafer by at least .005" to prevent short circuiting the lead wires to the semiconductor wafer. Therefore, in conventional low profile packages the leads will extend to a greater height above the ceramic substrate than is desired.

In FIGURES 6a and 6b are illustrated a glass-ceramic header with recessed portions 23 on opposite faces and diametrically opposite each other. By the use of recessed portion to mount the semiconductor device, the total package height can be kept to a minimum. The opposed recessed portions allow automatic insertion of the leads for either surface of the glass-ceramic header can be utilized without surface orientation. The nailhead lead 24 is positioned in one of the recesses 23 which allows the attachment of the semiconductor wafer to the nailhead lead surface 25 within the recess 23 (semiconductor wafer not shown). The semiconductor wafer's top surface will be below the top surface of the leads 26.

When the standard metal-glass integrated circuit header 27, as illustrated in FIGURES 7a and 7b, is manufactured, the leads 28 must be accurately formed by stamping or etching a lead frame to enable the individual leads to be accurately aligned in the narrow openings of the metal case 29. Due to the accuracy

required in forming the lead frame the leads 28 are very expensive. In addition, many headers are rejected due to shorting between leads 28 and the metal case 29 and loss of hermeticity of the leads' glass-to-metal seal.

Both of the above mentioned reasons for the relative high cost of a metal-glass integrated circuit header are eliminated by use of the glass-ceramic header 30 as shown in FIGURE 8a. The expensive leads shown in FIGURE 7a are eliminated. Individual leads 31 can be used in a glass-ceramic header for the ceramic 32, an electrical insulator, positions the leads itself. The leads 31 can be loaded and positioned automatically at a further saving of cost over the hand positioned lead frame containing the leads 28 shown in FIGURES 7a. (Lead frame not shown).

In the glass-ceramic header shown in FIGURE 8a, the leads 31 are round as opposed to the rectangular leads used in the conventional metal-glass integrated circuit header (see FIGURE 7a). By being round the leads 31 can be purchased as standard size lead wire which reduces the cost of the leads. The leads 31 extend from the sides of the header 30 but extend vertically through the header 30 to utilize the glass layer 33 to form the glass-to-metal seal necessary for lead hermeticity. The leads 31a extend from the floor 34 of the header 30 to a sufficient height so that later wire connections from the leads 31a can be made down to the top of the device (shown in FIGURES 8b, 8c and 8d) positioned on the floor 34 of the header 30. The header 30 is built up in the areas 35 where the leads 31a emerge within the header 30 for mechanical support of the leads 31a.

After the device is bonded to the floor 34

of the header 30 and the connecting wires 36 are bonded to the top of the leads 31a and the surface of the device 37, the header 30 can be enclosed by the use of a metal lid 38 as shown in FIGURE 8b. The metal lid may be fused to the header 30 by the use of a low temperature glass 39 which forms a hermetic seal.

In FIGURE 8c is illustrated a low cost package utilizing an epoxy or similar type plastics filler 40 to encapsulate the glass-ceramic header 30. Although the epoxy filled header 30 is not as hermetic as the package shown in FIGURE 8b, the epoxy 40 gives sufficient protection for most commercial applications.

Another method of encapsulation using a low temperature sealing glass is shown in FIGURE 8d. A ceramic lid 41 is fused to the header 30 by the use of the glass 42. By the use of this method, the only conducting parts of the package are the active device itself and the leads 31 and this method finds application where high packing densities are involved with the inherent short circuiting problem.

In addition to the methods of encapsulation shown, a metal rim can be fused to the header by glassing or brazing to the header. A metal lid can then be either brazed or welded to the metal rim. The glass-ceramic header lends itself quite readily to all standard methods of encapsulation known in the art.

Although the invention has been described with respect to a specific preferred embodiment, it will be apparent that changes and modifications are possible without departing from the scope of the invention as defined in the appended claims.

TABLE 1

Ceramic Layer	Glass Layer	Flange	Lead Wires	Sintering Temperature	Fusing Temperature	Approximate Coefficient of Expansion
40% Al_2O_3	Corning	Kovar	Kovar	750°C in Air	1000°C in N_2	46×10^{-7} per °C
60% No. 7052	7052	(F15 Alloy)				
60% SiO_2	Corning	1010 Steel	Dumet	650°C in Air	900°C in N_2	90×10^{-7} per °C
40% 7052	9010					
Typical Composition of Kovar Sealing Glasses						
Typical Composition of Dumet or #52 Alloy Sealing Glass						
SiO_2 —	64%	K_2O	1. Soda-Lime Glass			
B_2O_3 —	20%	N_2O	2. Lead Glass			
Al_2O_3 —	7%	Li_2O	SiO_2 —	74%	SiO_2 —	64%
BaO —	3%		Na_2O —	16%	PbO —	21%
			CaO —	5%	Na_2O —	8%
			MgO —	4%	K_2O —	6%
			Al_2O_3 —	1%	Al_2O_3 —	1%
Approximate Coefficient of Expansion — 46×10^{-7} per °C. Approximate Coefficient of Expansion — 90×10^{-7} per °C.						

All percentages by weight.

WHAT WE CLAIM IS:—

1. A header for a semiconductor including a plurality of alternate layers of glass and ceramic material which are fused together, and a plurality of lead wires extending through the layers and held in place by fusing glass in the layers to the wires.
2. A header according to claim 1, in which the outer layers are both of the ceramic material.
3. A header according to claim 1 or 2, wherein one of said lead wires has an enlarged portion for mounting a semiconductor device thereon.
4. A header according to claim 1, 2 or 3 including a metallic eyelet surrounding said glass and ceramic layers, said eyelet being held in place by and bonded to glass in the layers.
5. A header according to claim 4, wherein said eyelet has an outwardly extending flange around its circumference.
6. A method for making a header structure for a semiconductor device comprising the steps of:
 - a. placing alternate layers of granulated glass and a granulated ceramic material into a mould;
 - b. compressing said alternative layers of granulated materials to form a composite body having holes extending through said layers of glass and ceramic material;
 - c. heating said body to fuse the compressed glass granules to each other and to said ceramic granules;
 - d. inserting lead wires into said holes extending through said glass and said ceramic layers; and
 - e. heating said body and said lead wires to fuse said glass to said lead wires.
7. A method according to claim 6, wherein the material for the layers of granulated glass is produced by mixing a glass powder with a temporary binder and granulating the mixture and wherein the material for the layer of ceramic material is produced by mixing a ceramic powder comprised of a glass powder mixed with a refractory oxide and granulating said mixture.
8. A method of making a header structure for a semiconductor device comprising the steps of:
 - a. mixing a powder of glass with a binder by weight glass to 2 parts by weight binder material, and 15 parts by weight water, and granulating said glass mixture to 28 mesh;
 - b. preparing a powder of a ceramic material by combining 50 parts by weight of a powdered glass and 50 parts by weight of a refractory oxide and granulating the mixture to 28 mesh;
 - c. placing alternate layers of the ceramic material and the glass powder in a mould so that the first and last layers are of the ceramic material;
 - d. compressing said alternate layers of material under pressure between 500 and 5000 pounds per square inch to form said material into a composite body having alternate layers of glass and ceramic material and having holes extending through the layers;
 - e. firing said compressed body in an atmosphere of air for 5 to 20 minutes at 300°C. followed by 5 to 20 minutes at 650°C. and for 5 to 20 minutes at 750°C; and
 - f. inserting lead wires in the holes in said composite body and heating said body and lead wires to fuse the glass to said lead wires to hold said lead wires in place.
9. A method according to claim 8, including the additional steps of:
 - a. placing a flanged metal eyelet around the composite body;
 - b. applying substantially 2 pounds of pressure per square inch to said body to hold the lead wires in place and exert pressure on the layers of said body and firing in a neutral atmosphere at substantially 1000°C. for at least 10 minutes to fuse the glass of the glass layer to said flanged metal eyelet.
10. A header for a semiconductor device substantially as herein described with reference to Figures 1 and 2, Figure 3, Figures 6a and 6b or Figure 8a of the drawings.
11. A method of making a header for a semiconductor device substantially as herein described with reference to Figure 4 of the drawings.
12. A semiconductor device with a header according to any of claims 1 to 5 or 10.
13. An integrated circuit device with a header according to any of claims 1 to 5 or 10.

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