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PATENT SPECIFICATION

DRAWINGS ATTACHED

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COMPLETE SPECIFICATION

Semiconductor Device and Method of Producing Same

We, TEXAS INSTRUMENTS INCORPORATED, 13500 N. Central Expressway, Dallas, Texas, United States of America, a corporation organized and existing under the Laws of the State of Delaware, 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 a semiconductor device and method of producing same.

The present invention is a semiconductor device comprising a semiconductor crystal having at least one junction therein, at least two leads directly bonded to the surface of the crystal, one of the two leads being bonded on one side of said junction and the second of the two leads being bonded on the other side of said junction, an oxide film covering said junction and a high melting point glass bonded to said crystal over its surface not having the leads connected thereto and to a portion of each of said leads adjacent the surface of the crystal thereby encapsulating said crystal and said portions of said leads.

The present invention is also a method of producing a semiconductor device including the steps of providing a semiconductor crystal with at least one P-N junction therein, bonding at least two lead wires directly to the surface of the crystal so that a first lead wire is directly bonded to the crystal on one side of said junction and a second lead wire is directly bonded to the crystal on the other side of said junction, and having an enlarged cross-section at its point of contact with the semiconductor crystal, surrounding said crystal and a portion of each lead wire with a high temperature melting glass, and heating the glass-surrounded crystal to a temperature in the range sufficient to fuse the glass to cause the glass to be bonded to the crystal and to the portions of the lead wires adjacent and contacting the crystal in a manner to completely encapsulate the crystal.

Embodiments of the invention will be described, by way of example, with reference to the accompanying drawing, in which:—

Fig. 1 is a sectional view of a glass encapsulated semiconductor crystal diode according to one embodiment of this invention;

Fig. 2 is a sectional view of a glass encapsulated mesa type semiconductor according to the invention; and

Fig. 3 is an elevational view which is representative of the complete outline of either Fig. 1 or Fig. 2.

More specifically, a slice of silicon or germanium crystal having a diffused P-N junction is plated on each exposed surface with nickel and gold or platinum using conventional techniques. The slice is cut into dice of about 0.016 inch in diameter. A dice is then etched, cleaned and dried to produce a semiconductor diode crystal element according to conventional methods. It should be noted that though the discussion relates to a diode, the procedure would operate equally well for triodes, tetrodes, etc. The semiconductor element is then assembled to two lead wires and heated to 350°C. for a period of 5 to 10 minutes at a pressure of 30,000 PSI at the semiconductor element-lead wire interface. The lead wires can be almost any Ni-Fe alloy. The lead wires may be platinum or silver plated to prevent any oxide being liberated during fabrication, thereby preventing contamination of the junction. This effects a thermo-compression bond. A high temperature melting glass sleeve or body such as Corning 0120 lead glass with 630°C. softening point is then assembled to the leads and positioned over

[Price 4s. 6d.]

the semiconductor crystal element ("Corning" is a Registered Trade Mark). The assembly is heated in dry air or in an inert atmosphere to 720°C. for about 6 minutes to fuse the glass to the leads and the semiconductor element. This heating effectuates a bond of the glass to the crystal and both lead wires. It should be noted that the temperature at which the bond of the glass to the crystal is effectuated can be anywhere in the range of 720°C. to 1000°C. with the time required for this procedure decreasing from about six minutes at 720°C. to about 30 seconds at 1000°C.

The bonding of the glass and the electrical lead wires can be done in one operation by holding the lead wires and glass in one jig and heating to the correct temperature for the correct period of time.

Referring now to Fig. 1 there is shown a typical end product of the above procedure. Crystal 1 is shown bonded to lead wires 2 and 3 by a thermo-compression bond. High temperature melting glass 4, preferably Corning 0120 lead glass is shown bonded to both crystal 1 and leads 2 and 3.

Referring now to Fig. 2, there is disclosed a mesa type diode 6 encapsulated in glass 4^1. The region 5 is an oxide film previously formed on the crystal by an oxidation process. The oxide may be left on the diode to protect the junction of the device except where the mesa top joins lead 3^1. It should be noted that the main purpose of encapsulating a crystal in glass is to protect the junctions from an ambient atmosphere having detrimental effects on the junctions. In Fig. 2 such protection is not necessary if the oxide is left on. This would be an economical and rapid method of encapsulating the device. However, even greater protection will be provided by further enclosing this device in glass. The oxide film may remain on the diode and the entire unit then encapsulated in glass. The diode can be oxidized by several methods which are well known in the art, such as heating to approximately 800°C. in an oxidizing atmosphere. Diode 6 of Fig. 2 may be bonded to lead wires 2^1 and 3^1 by a thermo-compressive bond in the same manner as described relative to Fig. 1.

It should be noted that the coefficient of expansion of the glass and the lead wires are matched and that the slight difference in expansion coefficients of the glass and silicon is of no consequence due to the small sizes involved. The leads 2 and 2^1 are enlarged at their ends that come into direct contact with their respective crystals 1 and 6, in the manner shown in Figs. 1 and 2.

Referring again to Fig. 1 it is noted that in the specific embodiment set forth the diameter of wafer 1 is 0.016 inch, the largest cross-sectional diameter across the glass encapsulating the wafer is 0.040 inch and the diameter of the lead wires is 0.010 inch. With Ni-Fe alloy leads of 0.010 inch diameter, the standard "bend" test can be performed without breaking the leads. The standard bend test consists of bending the lead at a 90° angle and then making a reverse bend of 180°. The ratio of the cross-sectional diameter of the glass to the diameter of the wafer to the diameter of the lead is therefore about 4 to about 1.6 to about 1.

Referring again to Fig. 2 it is noted that in this embodiment the diameter of the bottom portion of the mesa type wafer 6 is 0.016 inch. The diameter of the top portion or mesa of the wafer is 0.007 inch. The total wafer thickness is about .005 inch. The lead wires are 0.010 inch in diameter. The length of the glass member encapsulating the diode is 0.060 inches. The same bend test can be performed as indicated supra.

WHAT WE CLAIM IS:—

1. A semiconductor device comprising a semiconductor crystal having at least one junction therein, at least two leads directly bonded to the surface of the crystal, one of the two leads being bonded on one side of said junction and the second of the two leads being bonded on the other side of said junction an oxide film covering said junction, and a high melting point glass bonded to said crystal over its surface not having the leads connected thereto and to a portion of each of said leads adjacent the surface of the crystal thereby encapsulating said crystal and said portions of said leads.

2. A semiconductor device according to claim 1, wherein the leads are connected to said crystal by a thermo-compression bond.

3. A seminconductor device according to claim 1 or 2, wherein each lead has a diameter of approximately 0.010 inches.

4. A semiconductor device according to any of claims 1 to 3, wherein the crystal is of circular section and the ratio of the diameter of said crystal to the diameter of said leads is approximately 1.6 to 1.

5. A semiconductor device according to claim 4 wherein the encapsulating glass is of circular section and the ratio of the largest cross-sectional diameter of said glass encapsulation to the diameter of said crystal is approximately 4 to 1.6.

6. A semiconductor device according to any preceding claims, wherein at least one of the leads includes an enlarged area where it is bonded to the semiconductor crystal.

7. A method of producing a semiconductor device including the steps of providing a semiconductor crystal with at least one P-N junction therein, bonding at least two lead wires directly to the surface of the crystal so that a first lead wire is directly bonded to the crystal on one side of said junction

the semiconductor crystal element ("Corning" is a Registered Trade Mark). The assembly is heated in dry air or in an inert atmosphere to 720°C. for about 6 minutes to fuse the glass to the leads and the semiconductor element. This heating effectuates a bond of the glass to the crystal and both lead wires. It should be noted that the temperature at which the bond of the glass to the crystal is effectuated can be anywhere in the range of 720°C. to 1000°C. with the time required for this procedure decreasing from about six minutes at 720°C. to about 30 seconds at 1000°C.

The bonding of the glass and the electrical lead wires can be done in one operation by holding the lead wires and glass in one jig and heating to the correct temperature for the correct period of time.

Referring now to Fig. 1 there is shown a typical end product of the above procedure. Crystal 1 is shown bonded to lead wires 2 and 3 by a thermo-compression bond. High temperature melting glass 4, preferably Corning 0120 lead glass is shown bonded to both crystal 1 and leads 2 and 3.

Referring now to Fig. 2, there is disclosed a mesa type diode 6 encapsulated in glass 4^1. The region 5 is an oxide film previously formed on the crystal by an oxidation process. The oxide may be left on the diode to protect the junction of the device except where the mesa top joins lead 3^1. It should be noted that the main purpose of encapsulating a crystal in glass is to protect the junctions from an ambient atmosphere having detrimental effects on the junctions. In Fig. 2 such protection is not necessary if the oxide is left on. This would be an economical and rapid method of encapsulating the device. However, even greater protection will be provided by further enclosing this device in glass. The oxide film may remain on the diode and the entire unit then encapsulated in glass. The diode can be oxidized by several methods which are well known in the art, such as heating to approximately 800°C. in an oxidizing atmosphere. Diode 6 of Fig. 2 may be bonded to lead wires 2^1 and 3^1 by a thermo-compressive bond in the same manner as described relative to Fig. 1.

It should be noted that the coefficient of expansion of the glass and the lead wires are matched and that the slight difference in expansion coefficients of the glass and silicon is of no consequence due to the small sizes involved. The leads 2 and 2^1 are enlarged at their ends that come into direct contact with their respective crystals 1 and 6, in the manner shown in Figs. 1 and 2.

Referring again to Fig. 1 it is noted that in the specific embodiment set forth the diameter of wafer 1 is 0.016 inch, the largest cross-sectional diameter across the glass encapsulating the wafer is 0.040 inch and the diameter of the lead wires is 0.010 inch. With Ni-Fe alloy leads of 0.010 inch diameter, the standard "bend" test can be performed without breaking the leads. The standard bend test consists of bending the lead at a 90° angle and then making a reverse bend of 180°. The ratio of the cross-sectional diameter of the glass to the diameter of the wafer to the diameter of the lead is therefore about 4 to about 1.6 to about 1.

Referring again to Fig. 2 it is noted that in this embodiment the diameter of the bottom portion of the mesa type wafer 6 is 0.016 inch. The diameter of the top portion or mesa of the wafer is 0.007 inch. The total wafer thickness is about .005 inch. The lead wires are 0.010 inch in diameter. The length of the glass member encapsulating the diode is 0.060 inches. The same bend test can be performed as indicated supra.

WHAT WE CLAIM IS:—

1. A semiconductor device comprising a semiconductor crystal having at least one junction therein, at least two leads directly bonded to the surface of the crystal, one of the two leads being bonded on one side of said junction and the second of the two leads being bonded on the other side of said junction an oxide film covering said junction, and a high melting point glass bonded to said crystal over its surface not having the leads connected thereto and to a portion of each of said leads adjacent the surface of the crystal thereby encapsulating said crystal and said portions of said leads.

2. A semiconductor device according to claim 1, wherein the leads are connected to said crystal by a thermo-compression bond.

3. A seminconductor device according to claim 1 or 2, wherein each lead has a diameter of approximately 0.010 inches.

4. A semiconductor device according to any of claims 1 to 3, wherein the crystal is of circular section and the ratio of the diameter of said crystal to the diameter of said leads is approximately 1.6 to 1.

5. A semiconductor device according to claim 4 wherein the encapsulating glass is of circular section and the ratio of the largest cross-sectional diameter of said glass encapsulation to the diameter of said crystal is approximately 4 to 1.6.

6. A semiconductor device according to any preceding claims, wherein at least one of the leads includes an enlarged area where it is bonded to the semiconductor crystal.

7. A method of producing a semiconductor device including the steps of providing a semiconductor crystal with at least one P-N junction therein, bonding at least two lead wires directly to the surface of the crystal so that a first lead wire is directly bonded to the crystal on one side of said junction

and a second lead wire is directly bonded to the crystal on the other side of said junction, and having an enlarged cross-section at its point of contact with the semiconductor crystal, surrounding said crystal and a portion of each lead wire with a high temperature melting glass, and heating the glass-surrounded crystal to a temperature in the range sufficient to fuse the glass to cause the glass to be bonded to the crystal and to the portions of the lead wires adjacent and contacting the crystal in a manner to completely encapsulate the crystal.

8. A method according to claim 6, wherein the lead wires are bonded to the crystal by applying a pressure of substantially 30,000 PSI at the crystal lead wire interfaces and heating to about 350° centigrade.

9. A semiconductor device substantially as hereinbefore described with reference to and as illustrated in Figs. 1 and 3 of the accompanying drawing.

10. A semiconductor device substantially as hereinbefore described with reference to and as illustrated in Figs. 2 and 3 of the accompanying drawing.

11. A method of producing a semiconductor device substantially as hereinbefore described with reference to the accompanying drawing.

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