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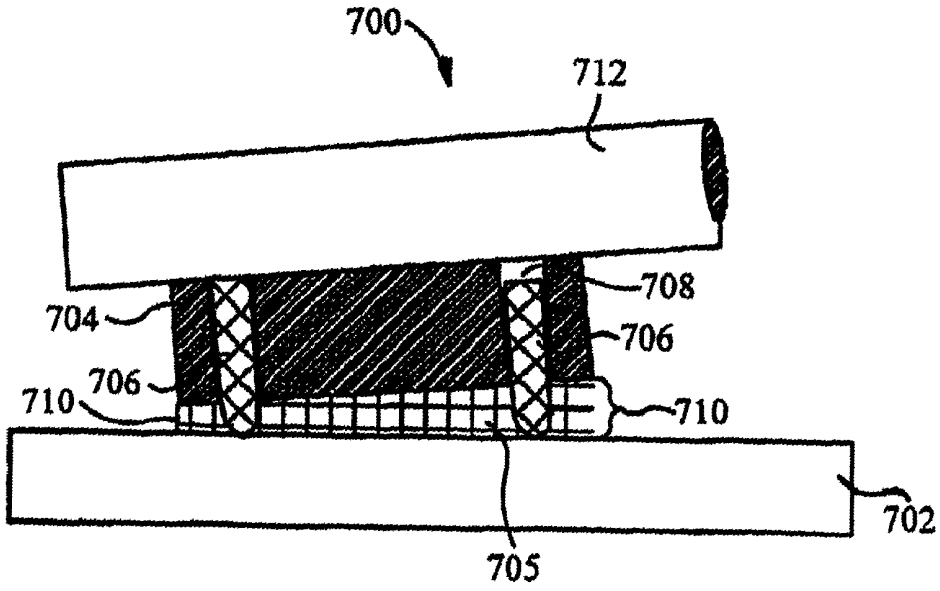
(54) Title: APPARATUS AND PACKAGING METHOD TO ASSEMBLE OPTICAL MODULES TO A COMMON SUBSTRATE WITH ADJUSTABLE PLUGS



(57) Abstract: For any optically interconnected assembly, the packaging tasks include alignment of one or multiple optical devices, and attachement of aligned modules to a common substrate. The concept disclosed here is a packaging method to assemble pre-aligned optical modules on a common structure called motherboard. The apparatus consists of two components: device carrier or motherboard with openings on the sides and adjustable plugs in the form of pins or balls. The method and apparatus utilize plugs as connection bridges between device carriers and motherboard, allowing solid contacts and a rigid aligned sturcture among modules. The direct benefits include relaxation of dimensional tolerances on parts and elimination of the need for high-precision spacers.

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SPECIFICATION

APPARATUS AND PACKAGING METHOD TO ASSEMBLE OPTICAL MODULES TO A COMMON SUBSTRATE WITH ADJUSTABLE PLUGS

1. Field of the Invention.

This invention relates generally to assembly of optical modules. More particularly, it relates to a mechanism for packaging optically interconnected assemblies requiring of structural stability and precision alignment by using adjustable plugs.

2. Background Art.

For most optoelectronic products manufactured today, coupling light into or out of an optical device is accomplished by active alignment of one device with respect to another. The basic process is to move an object in space angularly and laterally to locate a first device [X,Y,Z] and orient [θ_x, θ_y, θ_z] it with respect to a second device. The device can be held either by mechanical clamp or suction generated by vacuum pump. Special toolings are usually made for particular geometry.

To maintain alignment, the first device has to be permanently fixed on a motherboard. The challenge is to find a suitable mounting technique that will allow sufficient angular and lateral offset as the fixture secured to a motherboard. There are usually arbitrary gaps formed between bonding surfaces of the optical device and the motherboard, as depicted in Figure 1 of prior art, due to physical impression of parts. In Fig. 1, a first optical device is aligned respect to a second optical device to couple the light into or out of these optical devices. The gap between surface 1 of the first device and surface 2 of the motherboard is formed. These gaps inhibit the aligned assembly from being assembled with solid contacts.

Figures 2, 3, and 4 demonstrate various prior art assembly concepts to compensate for such angular and lateral deviations. Typical solutions involve the use of thick epoxy and/or solder and precision spacers. Figure 2 shows the gap between two bonding surfaces is filled with epoxy. The problem with this approach is that epoxy shrinks during curing. The resulting dislocation could be significant if the gap is large. This shrinkage is generally predictable and could be accounted for in final assembly. However, this can

make the assembly process complicated and often unreliable. Figure 3 depicts enhanced approach that uses a spacer to reduce the overall gap between the optical device and the motherboard. A layer of epoxy fills the subgap between the optical device and the spacer. The thickness of the spacer has to be precise to properly align the first device with respect to the second. Furthermore, shrinkage of the epoxy during curing is still a problem. Another approach, shown in Figure 4, is to use a solder bump, allowing two surfaces to be bonded with solder reflow at high temperature. Although many advantages of this technology have been realized: high yield, high strength and self-alignment during joining, the initial setup cost is extremely high. Furthermore, the device is not secured to the motherboard during solder reflow and may become misaligned as the solder solidifies. In addition, the solder bump may not be able to withstand large temperature fluctuations due to differences in the coefficients of thermal expansion of the bonding materials. The problem becomes aggravates as the size of solder becomes larger.

There is a need, therefore, for a low cost packaging method to assemble pre-aligned optical modules to a common substrate, by which the optical modules are permanently fixed on the common substrate without dislocation due to temperature variations.

3. Objects and Advantages

Accordingly, it is a primary object of the present invention to provide an actively alignable optoelectronic package having high performance characteristics and low manufacturing cost.

It is a further object of the present invention to reduce the requirement of dimensional tolerances on parts or completely eliminate the need for precision spacers.

It is an additional object of the invention to prevent the shrinkage of epoxy in the gap between the bonding surfaces during temperature variations.

It is another object of the present invention to provide a solution to compensate any arbitrary lateral and angular misfits during final mounting.

It is another object of the present invention to use the plugs as an adjustable spacer between device carriers and motherboard to compensate possible misalignment.

It is an additional object of the present invention to provide solid contacts and create a rigid aligned structure between modules.

4. Summary.

These objects and advantages are attained by apparatus and packaging methods to assemble optical modules to a common substrate with adjustable plugs.

In accordance with a first embodiment of the present invention, the apparatus for attachment and alignment optical devices to a motherboard comprises a device carrier, at least three adjustable plugs, and a filler material. The plugs are configured to fit into openings in the device carrier or the motherboard. A filler material, such as epoxy or solder, fills the space between the device carrier and the motherboard. The device carrier has one or more sides containing the openings. The plugs are typically in the form of the pins or balls with the cross-sections providing maximum contact area such as round or square cross-sections.

The device carrier and the plugs are generally made from materials with low thermal expansion such as aluminum, ceramic, hardened steel, glass, or silicon. These materials will not expand or contract much with the temperature fluctuations, so the overall thermal performance is enhanced. To enhance soldering technique, the plugs could also be plated for soldering or are made from the soldering materials such as tin-lead and gold-tin.

According to a second embodiment of the present invention, a method is set forth for attachment and alignment optical devices to a motherboard to compensate any arbitrary lateral and angular misalignment during the final mounting. In this method, at least three through holes are provided in the device carrier. The plugs are inserted through the holes from the top of the device carrier. The device carrier is aligned spatially and angularly relative to the motherboard. The plugs are tacked to the motherboard and the device carrier to secure the alignment of the device. The filler material fills the gap

between the device carrier and the motherboard. The filler material and the plugs secure the device carrier to the motherboard. The plugs and the holes have cross-sections that provide maximum contact area such as square/square cross-sections or round/round cross-sections. The plugs closely fit into the holes, so the clearance is large enough for plugs to slip through the holes without much insertion force. Through holes are provided in the assembly to confine epoxy or solder at the joints between the device carrier and the plugs and form a channel for plugs to slide up and down during movement of the device carrier relative to the motherboard. In this method, the plugs are used as an adjustable spacer between the device carrier and the motherboard.

Furthermore, according to a third embodiment of the present invention another method for attachment and alignment of optical devices to a motherboard to compensate any arbitrary lateral and angular misalignment during the final mounting. This method is similar to the method in the second embodiment as described above, except the through holes are provided in the motherboard, and the plugs are inserted through the holes from the bottom of the motherboard.

Embodiments of the apparatus and methods for attachment and alignment of optical modules allow sufficient angular and lateral offset as the fixture secured to a motherboard. Furthermore, the methods of the present invention reduce the requirement of dimensional tolerances on parts or completely eliminate the need for precision spacers.

5. Brief Description of the Figures.

Fig. **1** is a schematic diagram illustrating a prior art assembly showing a gap formed between bonding surfaces during mounting an optical device to a motherboard;

Fig. **2** is a schematic diagram illustrating a prior art showing an assembly method wherein the gap between bonding surfaces is filled with epoxy;

Fig. **3** is a schematic diagram of a prior art assembly showing a spacer used to reduce the overall gap between two bonding surfaces;

Fig. **4** is a schematic diagram illustrating a prior art assembly method wherein solder bump is used to bond two surfaces at high temperature;

Fig. **5** is a schematic diagram of an apparatus for attachment and alignment of an optical device to a motherboard with the through holes provided in the device carrier according to a first embodiment of the present invention;

Fig. **6** is a schematic diagram of an apparatus for attachment and alignment of an optical device to a motherboard with the through holes provided in the motherboard according to a second embodiment of the present invention;

Fig. **7** is a cross-sectional schematic diagram showing the use of adjustable plugs as connection bridge between a device carrier and a motherboard according to an embodiment of the present invention;

Fig. **8** is a cross-sectional schematic diagram of the joint structure according to an embodiment of the present invention.

6. Detailed Description.

Although the following detailed description contains many specifics for the purposes of illustration, anyone of ordinary skill in the art will appreciate that many

variations and alterations to the following details are within the scope of the invention. Accordingly, the following preferred embodiment of the invention is set forth without any loss of generality to, and without imposing limitations upon, the claimed invention.

Fig. 5. shows a schematic diagram of an apparatus **500** for attachment and alignment of an optical device to a motherboard **502** according to a first embodiment of the present invention. The apparatus **500** generally comprises a device carrier **504** and adjustable plugs **506** used as a bridge connections between the motherboard **502** and the device carrier **504**. The gap **510** between the device carrier **504** and the motherboard **502** is filled with a filler material such as epoxy or solder.

The device carrier **504** is typically made from a material with a low thermal expansion, which does not expand or contract much with temperature fluctuations, so overall thermal performance is enhanced. This material includes aluminum, ceramic, hardened steel, glass, or silicon. A device, such as a lens array, can be secured in device carrier **504** in a fixed position by any suitable means.

The plugs **506** are typically made from similar materials to those of the device carrier **504** as described above. Furthermore, to offer as an integral part to existing soldering technique, the plugs **506** could also be plated for soldering or are made from the soldering materials such as tin-lead and gold-tin. Generally, three or more plugs **506** are used to align the device carrier **504**.

As shown in Fig. 5, the through holes **508** are provided on the device carrier **504**. The cross-sections of the plugs **506** and through holes **508** are chosen to provide a maximum contact area between them such as square/square or round/round cross-sections. The plugs **506** are inserted into the through holes **508** from the top of the device carrier **504**. The plugs **506** closely fit into the holes **508**, so the clearance is large enough for the plugs **506** to slip through the holes **508** without much insertion force. However the clearance is generally small enough that the plugs **506** are held in place by the force of friction. The clearance between the plugs **506** and the holes **508** can be 50μm or less, depending on the filler materials.

The device carrier **504** is aligned laterally and angularly by using the plugs as an adjustable spacer between the device carrier **504** and the motherboard **502**. The plugs **506** then are tacked to the motherboard **502** to maintain the alignment of the device carrier **504**. The plugs may also be tacked to the device carrier **504**. Any suitable means, such as epoxy, solder, or laser welding, may be used to tack the plugs in place. The filler material, such as epoxy, fills the space **510** between the device carrier **504** and the motherboard **502**. The filler material and the plugs **506** secure the device carrier **504** to the motherboard **502**.

Fig. 6 shows a schematic diagram of an apparatus **600** for attachment and alignment of an optical device to a motherboard **602** according to a second embodiment of the present invention. The apparatus **600** comprises a device carrier **604** and three or more adjustable plugs **606** used as a bridge connection between the motherboard **602** and the device carrier **604**. The gap **610** between the device carrier **604** and the motherboard **602** is filled with a filler material such as epoxy or solder.

The materials for the device carrier **604** and the plugs **606** are similar to the materials of the device carrier **504** and the plugs **506** describe above with respect to Fig. 5.

The method for attachment and alignment of optical devices to the motherboard applying to the apparatus **600** is similar to the method applying for the apparatus **500** as described above. The difference between the two methods is that the through holes **608** are provided on the motherboard **602**, and the plugs **606** are inserted into the holes **608** from the bottom of the motherboard **602**. The plugs **606** are tacked to the device carrier **604** and/or the motherboard **602** to secure the alignment of the device.

A method of utilizing the plugs as a connection bridge between the device carrier and the motherboard described above is shown in cross-sectional diagram **700** in Fig. 7. In Fig. 7, an optical device **712,** which is secured to a device carrier **704**, is connected and aligned relative to a motherboard **702** by plugs **706**. The plugs **706** are inserted into through holes **708**, which are provided in the device carrier **704**. A filler material **705,** such as epoxy or solder, fills a gap **710** between the device carrier **704** and the motherboard **702**. The plugs **706** can slip up and down in the through holes **708** during the movement of the device carrier **704** relative to the motherboard **702.** The plugs **706** serve as an adjustable spacer between the device carrier **704** and the motherboard **702.**

Fig. 8 shows a cross-sectional diagram of a joint structure **800** between a device carrier and a plug, which are held together by a filler material **801** such as solder or epoxy. This diagram includes a motherboard **802**, a device carrier **804**, and a plug **806**. The device carrier **804** is connected to the motherboard **802** by inserting the plug **806** into a through hole **808**, which is provided in the device carrier **804**. The plug **806** closely fit into the through hole **808**, so the clearance is large enough for plug to slip through the hole **808** without much insertion force, yet small enough to hold the pin and device carrier together by friction. Through hole **808** is provided in the assembly to confine epoxy or solder at the joint **800** and form a channel to allow plug **806** to slide up and down during movement of the device carrier **804** relative to the motherboard **802**. The clearance is exaggerated in Fig. 8 for the sake of clarity. The joint structure **800** allows maximum adhesive contact area between the device carrier **804** and the plug **806**. After the device carrier **804** is aligned spatially and angularly, a filler material, such as solder or epoxy, fills the clearance between the plug **806** and the hole **808** and the gap **810** between the device carrier **804** and the motherboard **802** to secure the device carrier **804** to the motherboard **802**.

It will be clear to one skilled in the art that the above embodiment may be altered in many ways without departing from the scope of the invention. Accordingly, the scope of the invention should be determined by the following claims and their legal equivalents.

CLAIMS

What is claimed is:

1. An apparatus for attachment and alignment of optical devices to a motherboard comprising:
at least one device carrier;
at least three adjustable plugs configured to fit into openings in the device carrier or in the motherboard; and
a filler material that fills the space between the device carrier and the motherboard.

2. The apparatus of claim 1, wherein the device carrier has one or more sides containing the openings.

3. The apparatus of claim 1, wherein the device carrier is made from a material with a low thermal expansion.

4. The apparatus of claim 3, wherein the device carrier is made from a material selected from the group consisting of aluminum, ceramic, hardened steel, glass, or silicon.

5. The apparatus of claim 1, wherein the plugs are in the form of pins or balls.

6. The apparatus of claim 1, wherein the plugs are made from a material with low thermal expansion.

7. The apparatus of claim 6, wherein the plugs are made from a material selected from the group consisting of aluminum, ceramic, hardened steel, glass, or silicon.

8. The apparatus of claim 1, wherein the plugs further comprise a soldering material for securing the device carrier.

9. The apparatus of claim 8, wherein the soldering material selected from the group consisting of tin-lead and gold-tin.

10. The apparatus of claim 1, wherein the plugs are plated for soldering.

11. The apparatus of claim 1, wherein the plugs have shapes that provide maximum contact area.

12. The apparatus of claim 11, wherein the plugs have round shape.

13. The apparatus of claim 11, wherein the plugs have square shape.

14. The apparatus of claim 1, wherein the filler material is selected from the group consisting of epoxy and solder.

15. A method for attachment and alignment of optical devices to a motherboard comprising the steps of:

providing a device carrier having at least three through holes;

inserting a plug into each of at least three through holes;

securing a device to the device carrier;

aligning the device carrier spatially and angularly to align the device;

tacking the plugs to maintain an alignment of the device carrier; and

filling the space between the device carrier and the motherboard by a filler material.

16. The method of claim 15, wherein the plugs closely -fit into the holes.

17. The method of claim 15, wherein the plugs can slip up and down through the holes during movement of the device carrier relative to the motherboard.

18. The method of claim 15, wherein the plugs are used as an adjustable spacer between the device carrier and the motherboard.

19. The method of claim 15, wherein the filler material and plugs secure the device carrier to the motherboard.

20. The method of claim 15, wherein the adhesive is confined and evenly distributed around the plugs, so that horizontal stresses on the adhesive in the space between the device carrier and the motherboard are equally cancelled out.

21. A method for attachment and alignment of optical devices to a motherboard comprising the steps of:

providing at least three through holes in the motherboard;

inserting a plug into each of at least three through holes;

securing the device to the device carrier;

aligning the device carrier spatially and angularly to align the device;

tacking the plugs to maintain an alignment of the device carrier; and

filling the space between the device carrier and the motherboard by a filler material.

22. The method of claim 21, wherein the plugs closely -fit into the holes.

23. The method of claim 21, wherein the plugs can slip up and down through the holes during movement of the device carrier relative to the motherboard.

24. The method of claim 21, wherein the plugs are used as an adjustable spacer between the device carrier and the motherboard.

25. The method of claim 21, wherein the filler material and plugs secure the device carrier to the motherboard.The method of claim 21, wherein the adhesive is confined and evenly distributed around the plugs, so that horizontal stresses on the adhesive in the space between the device carrier and the motherboard are equally cancelled out.

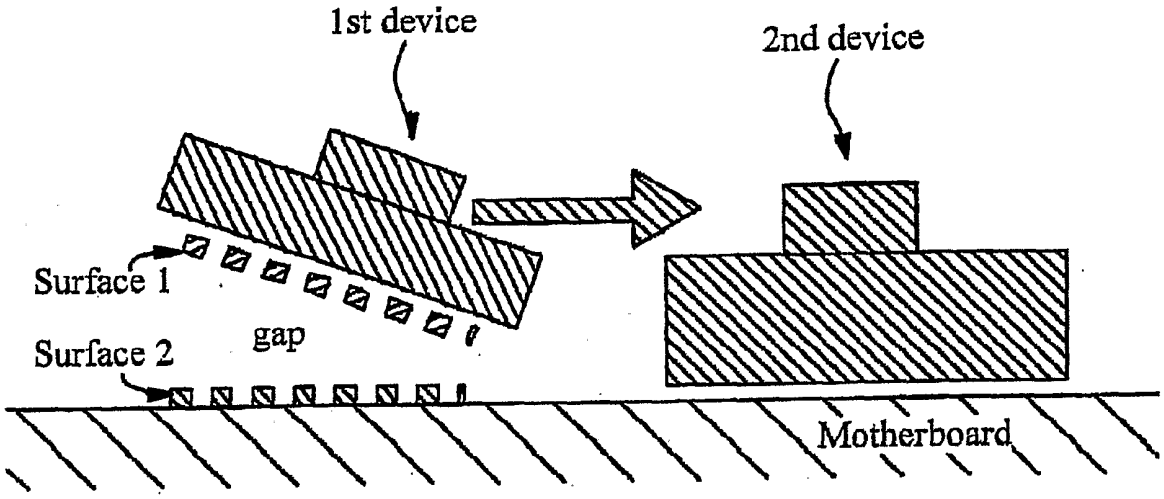

Fig. 1 (Prior Art)

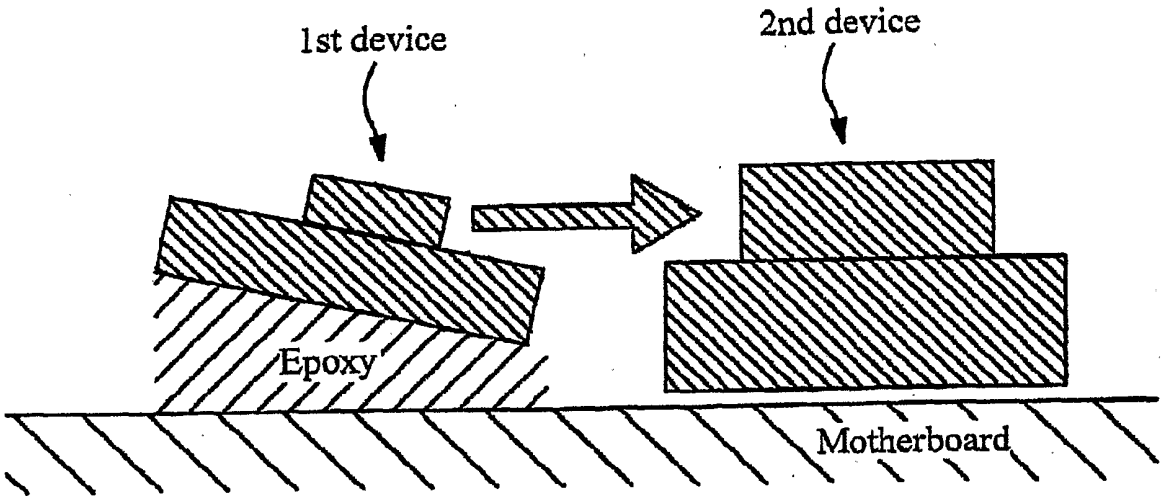

Fig. 2 (Prior Art)

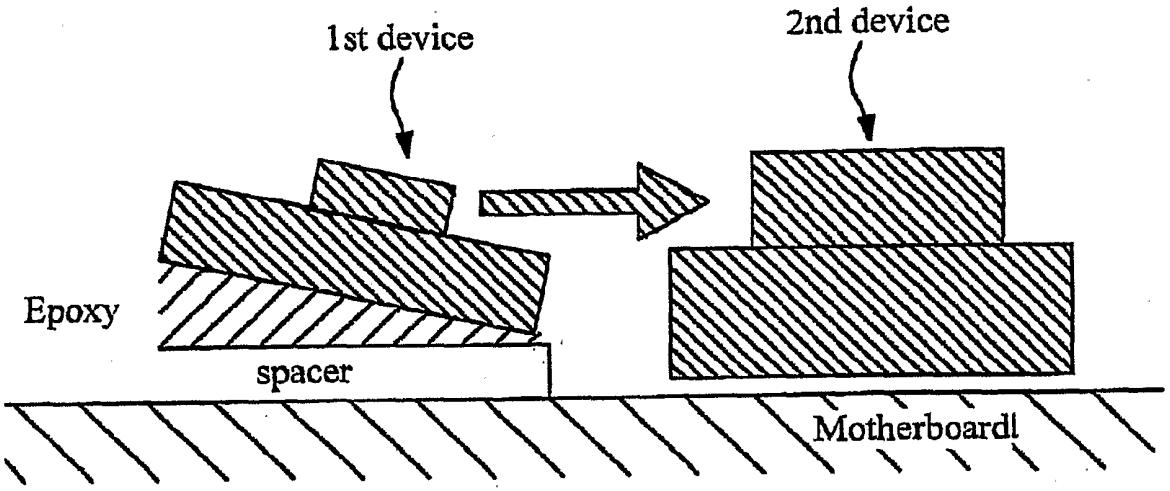

Fig. 3 (Prior Art)

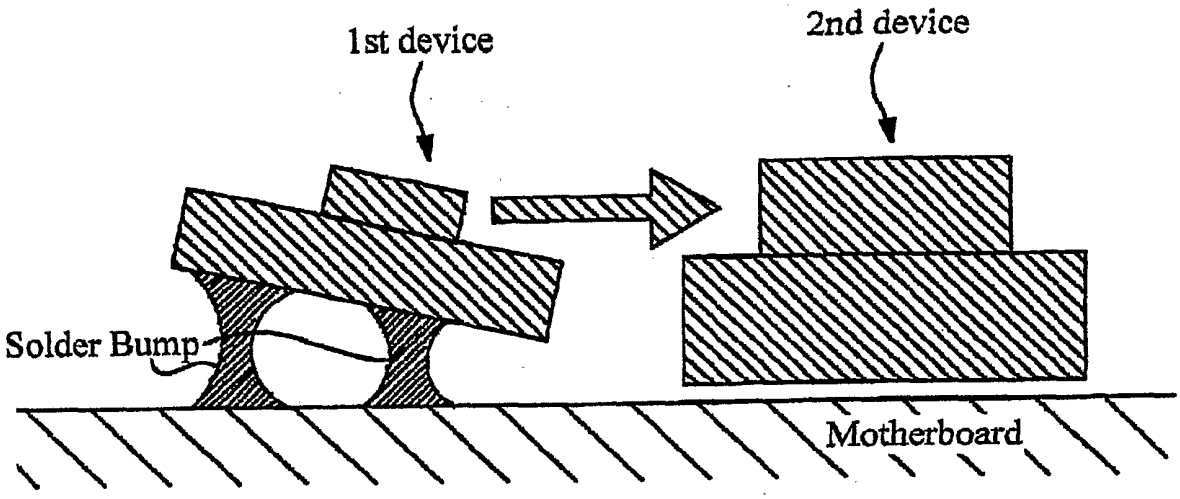

Fig. 4 (Prior Art)

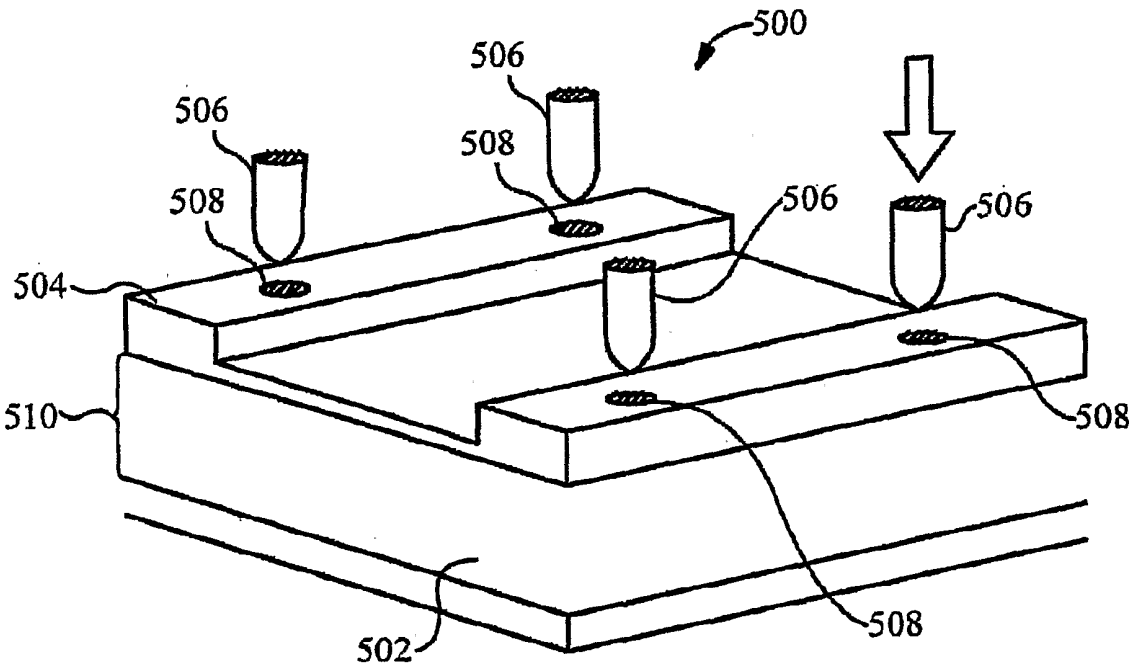

Fig. 5

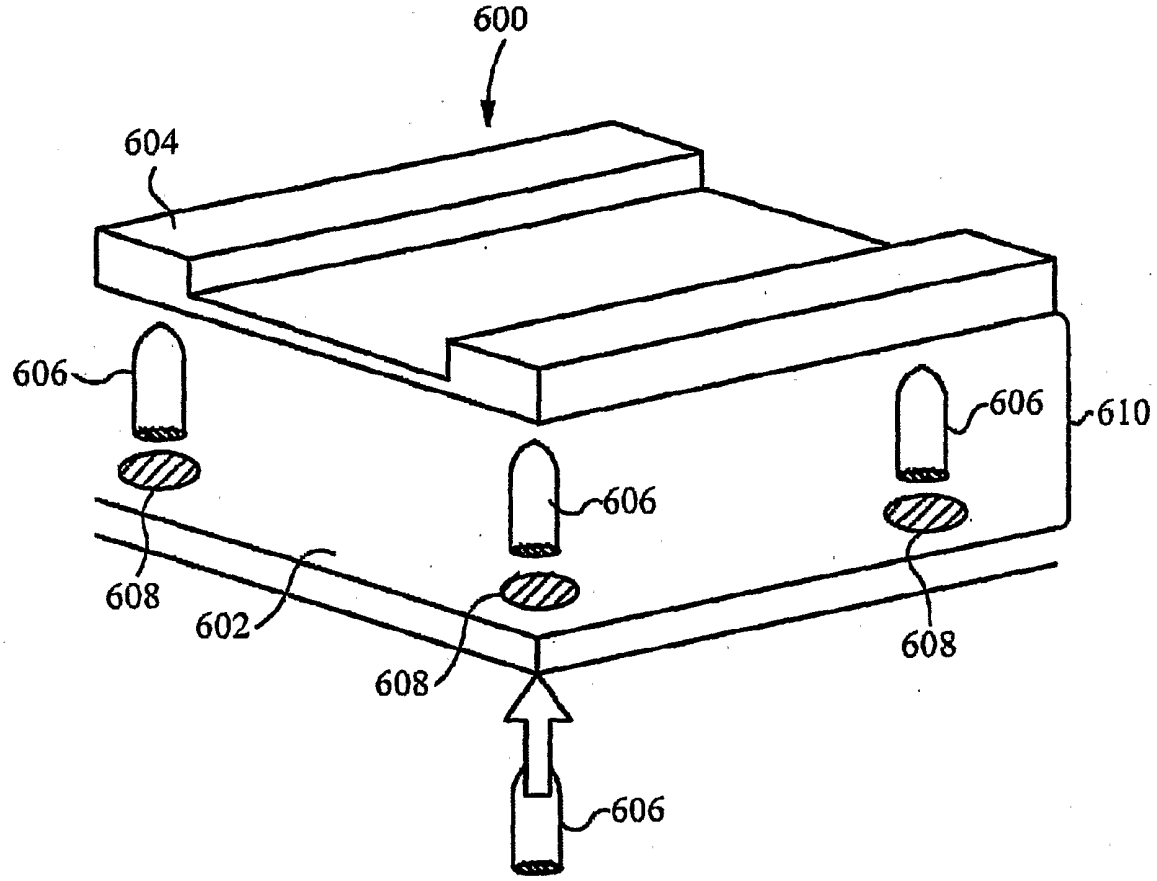
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Fig. 6

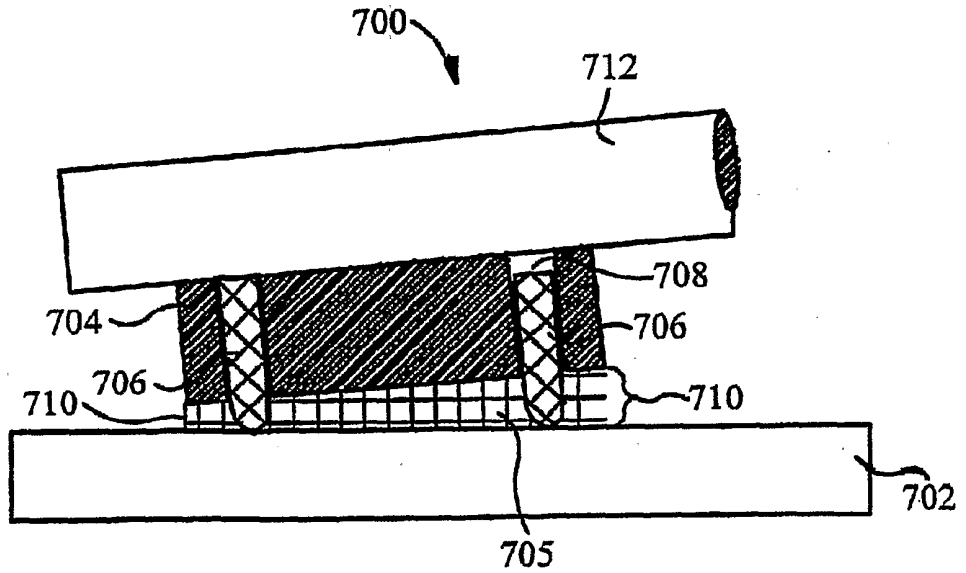
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Fig. 7

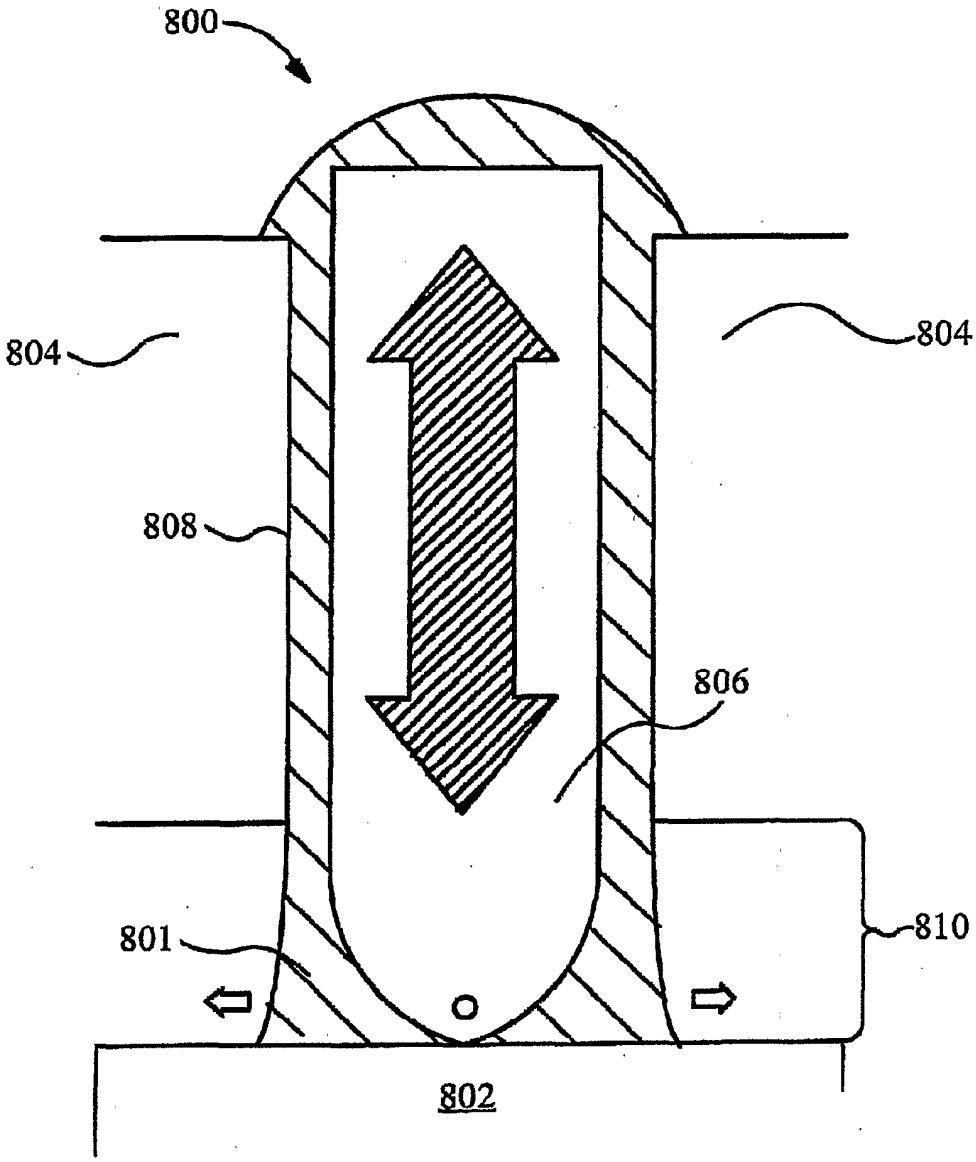

Fig. 8