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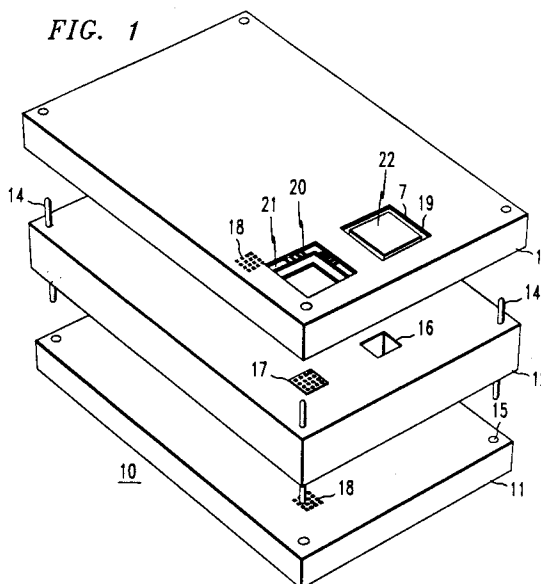
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Woodford Green Essex, IG8 OTU (GB)(54) **Circuit board stack with novel cross-over cells.**

(57) Two substrates 11, 13 are mounted on opposite sides of a structural frame 12. On the exterior side of each substrate are mounted one or more discrete clusters of chips 22. The frame includes interior passages through which cooling fluid is conducted. The frame also includes an array of cross-over cell cavities 16, each being aligned with a corresponding cross-over cell pad array on the adjacent substrate. Slugs of elastomeric one-directional conductive material are placed in each cavity. The slugs nominally are substantially the same volume as the cavity; but until compressed fit only loosely in the cavity. The two substrates are mated, which compresses the elastomeric material a predetermined amount. The slugs expand to fill and firmly lodge in their cavities, and make vertical electrical connection to the pad arrays. The result is an assembly of two (or more) multi-chip module boards with internal cross-over cells which are sealed from contaminant and stabilized in their electrical conductivity by the close control over compressive forces and internal temperatures made possible by the invention.

FIG. 1

FIELD OF THE INVENTION

This invention relates to cross-over connections between circuit boards and particularly to effecting very short, high-density electrical connections in assemblies of such boards without having to use the front or exposed surfaces of the boards.

GOVERNMENT CONTRACT

The government has rights in this invention pursuant to Contract No. F33615-89-C-1036 awarded by the United States Air Force.

BACKGROUND OF THE INVENTION

Circuit boards embodying complex computer architectures frequently are stacked or paired. Such boards typically mount "chips" which may, for example, be processors or memory stores. Frequently, several chips are mounted in a planar gang on a multichip module. As the computing and storage capacities of these equipments grow to meet new demands of speed and computing power, there is a need to package the chip boards more effectively and to realize more effective communications paths between adjacent boards.

The traditional way to make connections or "cross-overs" between adjacent boards is to bring the internal circuits out to a pad array along the edge of the board, and then to connect the perimeter pads. An example of such a connection scheme is described in the patent application of Y. Lee-J. M. Segelken 1-6, Serial No. 07/387,480, filed 7/28/90, assigned to Applicant's assignee. That teaching relies on elastomeric one-directional conductive material to effect board-to-board connections.

Many modern computers use modular card structures consisting of structural frames sandwiched between two circuit cards. The frame also contains ducts or paths for cooling the assembly. Communications interconnections between the cards typically are made via cross-over cables located in the card-edge connector or at the top edge of the card.

This approach, however, places limitations on the number of cross-over paths that can be provided. These cross-over paths require that large amounts of board real estate be dedicated to cross-over pads and solder attachments. There also is a high risk of damage or contamination to the exposed cross-overs, which even delicate and careful handling does not always eliminate.

The prior art cross-over cables also require substantial wiring lengths of, for example, three inches or more which significantly limits the speeds at which the computer may operate. An even fur-

ther problem of the prior art design relates to crosstalk between crossover paths.

Also, the successful use of directional conducting elastomers requires careful attention to containing the material and maintaining it in a relatively controlled compression. Prior art cross-over designs using elastomeric one-directional conductive material have experienced unacceptable variability of performance.

OBJECTS OF THE INVENTION

Accordingly, one object of the invention is to provide a more reliable interconnection between adjacent chip-mounting circuit boards.

Another object of the invention is to improve the speed of operation of stacked arrays of chip-containing circuit boards.

A further object of the invention is to facilitate and simplify the assembly of such board arrays.

A still further object of the invention is to make more reliable use of elastomeric one-directional conductive material to effect board-to-board connections.

Another object of the invention is to realize a more dense packaging of computer components, particularly processors and memory chips.

SUMMARY OF THE INVENTION

This invention is a highly efficient mechanism for achieving cross-over paths through a structural frame, using elastomeric one-dimensional conductive material. According to the invention, two chip-mounting substrates or boards are mounted on opposite sides of a structural frame. On the exterior side of each substrate are mounted one or more chips or discrete clusters of chips. One or more (usually several) discrete and separate areas on the interior side of each substrate are dedicated for the mounting of arrays of contact pads. These pads connect by various paths through and within the substrate to leads of the chips or chip arrays on the exterior side of the substrate. The frame includes interior passages through which either a gaseous or a liquid cooling fluid is conducted.

In accordance with the invention, the frame is provided with an array of cross-over cell cavities which for example may be substantially square in cross-section. Each cavity is aligned with a corresponding cross-over cell pad array on the adjacent substrate. Slugs of elastomeric one-directional conductive material are placed in each cavity. Advantageously, each cavity is nominally of substantially the same volume as an uncompressed slug. Thus, for example, each slug may be formed with a somewhat lesser cross-sectional area than the cavity cross-section, but with a somewhat greater

height than the thickness of the frame to provide an appropriate initial slug volume.

Guide means are provided to align each substrate on respective sides of the frame so that the contact pad areas are facing each other and the intervening elastomer slug. Means also are provided for holding the two substrates together to compress the elastomeric material a predetermined amount while at the same time fastening the assembly. The elastomeric material thus compressed expands to fill and firmly lodge in its support chamber. The result is an assembly of two (or more) multi-chip module boards with internal cross-over cells which are sealed from contaminant and stabilized in their electrical conductivity by the close control over compressive forces and internal temperature made possible by the invention.

DESCRIPTION OF THE DRAWING

FIG. 1 is an exploded perspective view of an assembly of the invention;

FIG. 2 is partial sectional side view of the frame portion;

FIG. 3 is an exploded side schematic view of the assembly;

FIG. 4 is a side view of the assembly;

FIG. 5 is a top perspective schematic view of the frame portion;

FIG. 6 is a graph showing electrical performance of the elastomeric one-directional conductive material according to the invention; and

FIG. 7 is a side perspective diagram of a circuit board or card enclosure for housing the assemblies.

DETAILED DESCRIPTION OF AN ILLUSTRATIVE EMBODIMENT

Referring to FIG. 1, the invention may be embodied in a assembly such as module assembly 10 which consists of two circuit card substrates 11 and 13 sandwiching a frame 12. An array of cross-over cell cavities 16 seen in FIG. 5 are formed through frame 12. The cavities 16 are shown uniformly arrayed, but may be placed in any convenient fashion.

One way to construct frame 12 with its cavities 16 is to form the cavities out of hollow open-ended square blocks, such as block 9 seen in FIG. 5, which fit into square openings provided in top and bottom plates of the frame 12 (plates not shown). The remainder of the interior space between the top and bottom plates may be provided with any desired shape to accommodate cooling fluid which, for example, may enter the assembly at coolant inlet 25 and exit at coolant outlet 26. The coolant may be gaseous, such as forced air or alternatively

liquid such as ordinary brake fluid.

In accordance with the invention, slugs of elastomeric one-directional conductive material 17 are placed in the cavities 16. If the cavities are square in cross-section as in the instant embodiment, the slugs are substantially square in cross-section also. It is advantageous to shape the slugs so that each has a somewhat lesser cross-sectional area than that of the cavity as suggested by the dimension denoted 8 in FIG. 2. At the same time, the height of each slug 17 is made to be greater than the depth or top-to-bottom dimension of the cavity 16 denoted 24 in FIG. 2. In a preferred embodiment of the invention, the volume of the slugs 17, when compressed in the manner to be described, will approximate the volume of the cavity 16 and preferably will at least equal it.

The substrates 11 and 13 include alignment holes 15 at each corner, which as seen also in FIGS. 3 and 4, mate with the four alignment pins 14 of frame 12. The alignment achieved is to assure that the cross-over cell pad arrays 18 appearing on the top surface of substrate 11 and the corresponding crossover cell pad arrays shown in dotted lines on the bottom of substrate 13 are in close vertical register.

FIG. 1 shows an array of chip cavities 19 formed on the surface of substrate 13. Similar cavities (not shown) are formed in the substrate 11, the latter being symmetrically located with respect to the cavities 19 of substrate 11. The chip cavities 19 are a conventional way for containing in a frame such as frame 14, a multiplicity of semiconductor integrated circuits such as a multichip module 22. The cavities 19 have a conventional bonding ledge 16 inset within the cavity on all four sides of which bonding ledge pads 20 appear. Wire bond connections such as wire 7 in FIG. 1 are conventionally effected from the multichip module 7 to the pads 20.

The pads 20, seen in FIG. 1, are connected by layered routing paths (not shown) within the interior of the substrates 11 and 13 in substantially any pattern or routing that is necessary to achieve the design of the computer architecture. The expedient of interior routing is well-known in the art; but while it does not form part of this invention, the invention greatly adds to the utility of the internal routing layers.

The connections from the pads 20 in each of the chip cavities 19 following internal routing eventually make appearances in cross-over cell pad arrays such as arrays 18 disposed on the interior surfaces of substrates 11 and 13.

Returning to FIG. 2, it is seen that the slug 17 contains a series of vertical conductive paths denoted 23. Slugs of elastomeric material with vertical or one-directional paths that are usable in this

invention may be formed by any of several methods of fabrication. For example, .010 mil thick elastomer sheets with closely spaced gold conductive paths silk-screened on one side thereof may be adherently stacked and slugs of the desired length and cross-section then cut from the stack.

It will be appreciated that the cross-section of the vertically conductive paths 23 of the slugs 17 should be substantially less than the spacing between adjacent contact pads of the pad arrays 18 in order to prevent the shorting out of adjacent pads. Within this limitation, the conductor-to-conductor spacing of the paths 23 should be appropriately dense to assure a maximum of electrically conductive paths between corresponding contact elements of the oppositely disposed cross-over cell pad arrays 18.

With the several modules 23 solder-connected to the bonding ledge pads 20, and the appropriately sized slugs 17 placed in their respective cell cavities 16, the components of the assembly 10 are positioned as in FIG. 3 and then brought together by sliding the alignment holes 15 of the substrates 11 and 13 onto the alignment pins 14. In the assembled position, shown in FIG. 4, the slugs are compressed to substantially fill the cavities 16 with their compressed volume. For permanent sealing, the assembly may be bonded.

Desirably, the compression results in a firm frictional fit such as will hold the slugs in a permanent and stable position in their cavities. FIG. 6 graphs roughly the behavior of one elastomeric vertically conductive material that may be used in the present invention. Elastomeric connectors may, for example, be realized by starting with an array of metal strips running linearly through a silicone rubber body typically .0005" thick and .002" wide arranged in rows approximately .004", which then are laminated together to form a bulk of directionally conductive material. Silicone formulations have the advantage of flexibility at temperatures below -65 degrees C, yet are tolerant of elevated temperatures up to +175 degrees C. Further, silicones are unaffected by aging and typically do not become sticky, brittle or cracked. Silicones show little or no degradation when exposed to ultra-violet radiation, oxygen, ozone or humidity. One suitable elastomeric material is available under the tradename "Matrix MOE" from Elastomeric Technologies, Inc. of Hatsboro, PA. Its behavior is depicted in FIG. 6. It is seen that as this material is compressed, its conductivity increases up to a point. An optimum range of maximum conductivity can be identified as a function of the pounds of applied compressive force in pounds per square inch occurring within a certain range. Thereafter, the conductivity decreases. It is necessary, therefore, to identify the conductivity variability of the

elastomeric vertically conductive material with compression and, based on that assessment, select the volume of each slug such that as it compresses to substantially fill the receiving cavity the conductivity falls within the desired maximum range. The appealing aspect of the instant invention is that the material cannot be over-compressed provided the arithmetic of the volume calculation has been performed properly.

FIG. 7 shows the invention being used in a conventional circuit board or card enclosure 29. The backplane 30 of the enclosure 29 contains the usual array of pin connectors 32. Rails 31 mount one or more (usually many) assemblies 10. The female gang connectors 33 which serve in conventional fashion as circuit paths to the outside world for each assembly 10 mate with pin connectors 32.

Claims

1. A circuit board assembly CHARACTERIZED BY:

first and second circuit board substrates each CHARACTERIZED BY one or more exterior-mounted chip modules each chip having connections to symmetrically located discrete pad clusters disposed on the interior side of said substrates; and

cross-over connections between the corresponding said pad clusters, CHARACTERIZED BY:

a two-sided frame for receiving on opposite sides thereof said respective substrates;

cross-over cell cavities through said frame and aligned with said corresponding pad clusters; and

an elastomeric one-directional conductive material slug disposed in each said cell cavity, the volume of each slug when compressed approximating the volume of said cell cavity.

2. Apparatus in accordance with claim 1, wherein said substrates further comprise two or more alignment holes at the substrate corners, and wherein said frame further comprises alignment pins for engaging said alignment holes, thereby to assure that said cross-over cell pad arrays appearing on the top surface of said first substrate and the corresponding cross-over cell pad arrays on the bottom surface of said second substrate are in close vertical register.

3. Apparatus in accordance with claim 2, wherein each said slug comprises a plurality of vertical conductive paths the ends thereof terminating at the exterior opposite vertical surfaces of each slug to make electrical contact with the

pads of said pad clusters.

4. Apparatus in accordance with claim 3, wherein the cross-section of the vertically conductive paths of said slugs is substantially less than the lateral spacing between adjacent contact pads of said pad arrays. 5
5. Apparatus in accordance with claim 4, wherein said slug-receiving cavities are formed from hollow open-ended square blocks. 10
6. Apparatus in accordance with claim 5, further CHARACTERIZED BY bonding means to adhere said frame to said first and second substrates. 15
7. Apparatus in accordance with claim 6, wherein said elastomeric slugs are compressed to a degree which places the resulting slug conductivity within substantially the maximum conductivity range of which the material is capable. 20
8. Apparatus in accordance with claim 7, wherein the interior of said frame is hollow, said apparatus further CHARACTERIZED BY means for flowing coolant into and out of said interior. 25
9. Apparatus in accordance with claim 8, wherein the volume of each slug when compressed substantially equals the volume of said slug-receiving cavity. 30
10. Apparatus in accordance with claims 1, 2, 3, 4, 5, 6, 7, 8, and 9, further CHARACTERIZED BY enclosure means for housing one or more said assemblies, said means CHARACTERIZED BY a backplane including a pin array, dual rail means slidably mounting individual said assemblies and female gang connectors connecting said assembly to said pin array when said assembly is positioned on said slides onto said backplane. 35
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FIG. 1

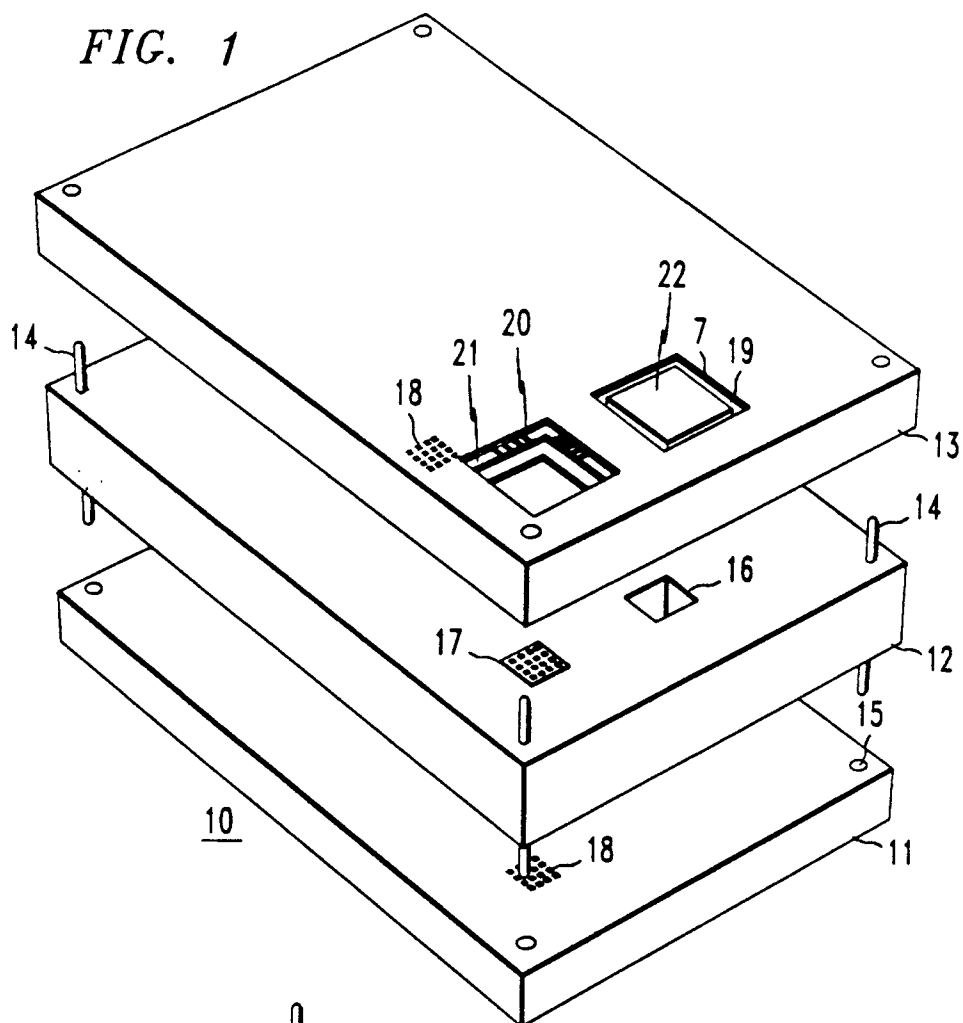
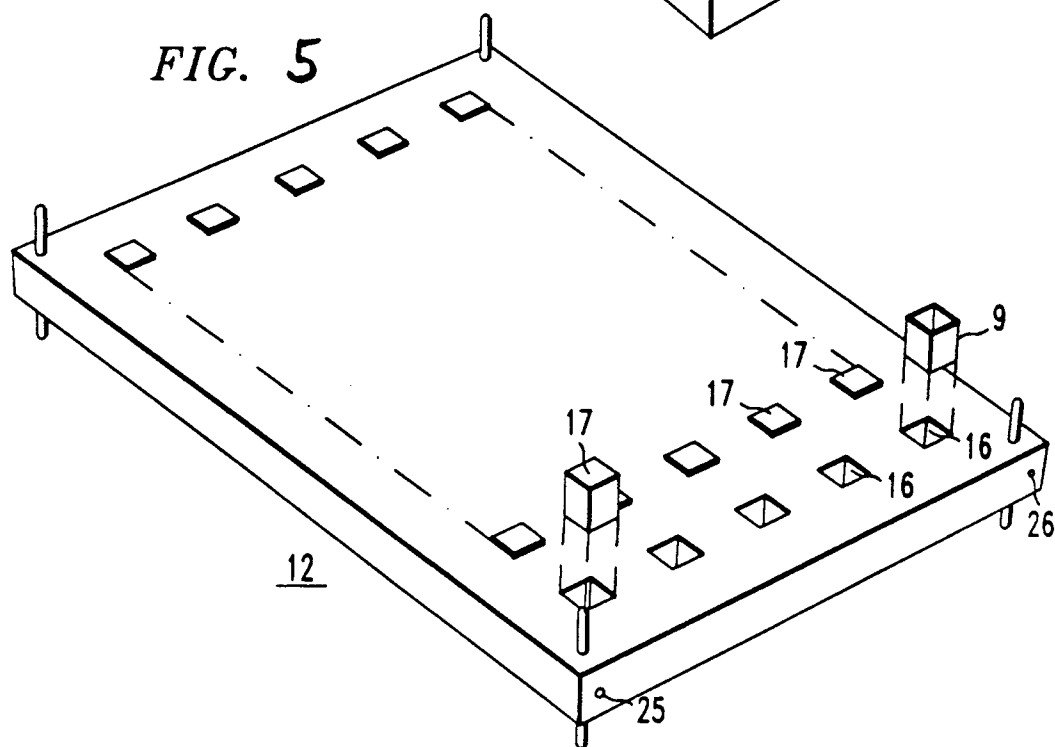


FIG. 5



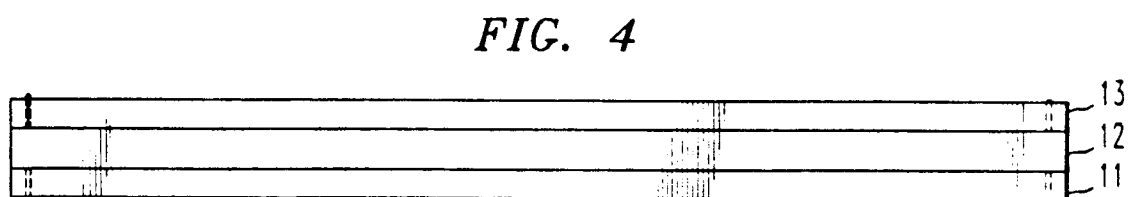
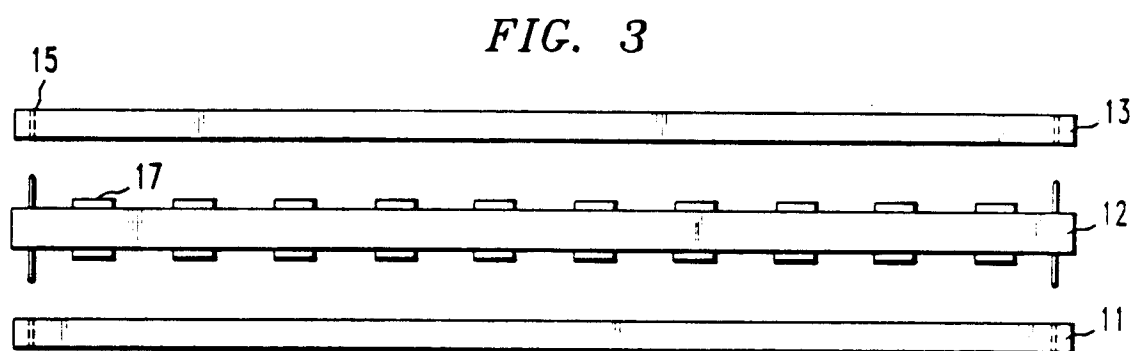
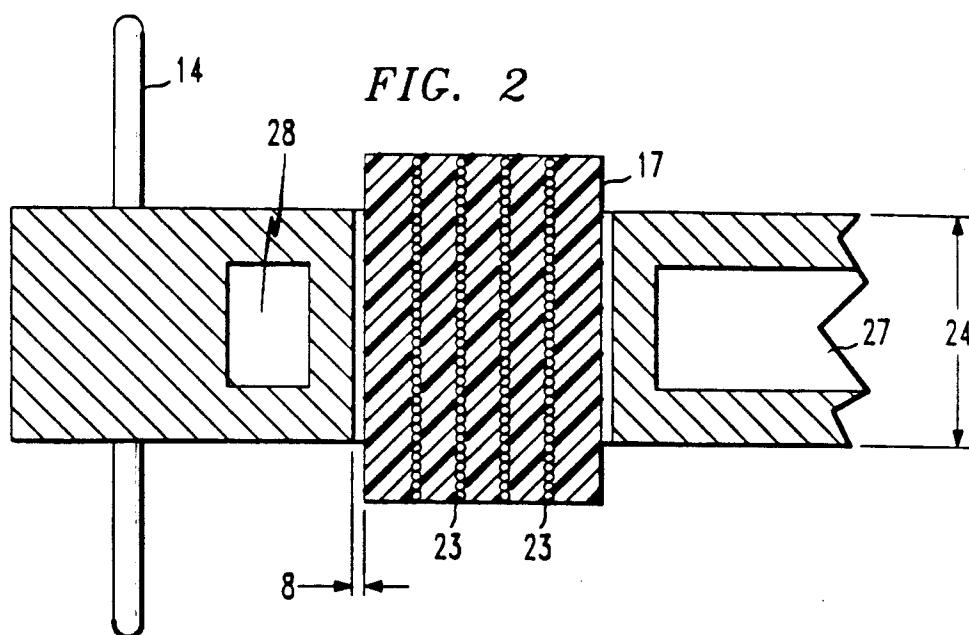


FIG. 6

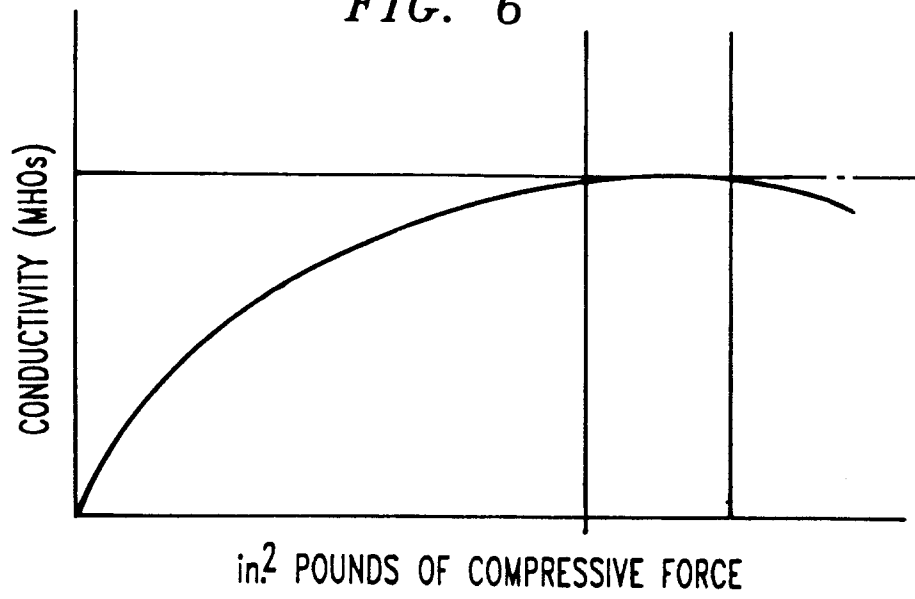


FIG. 7

