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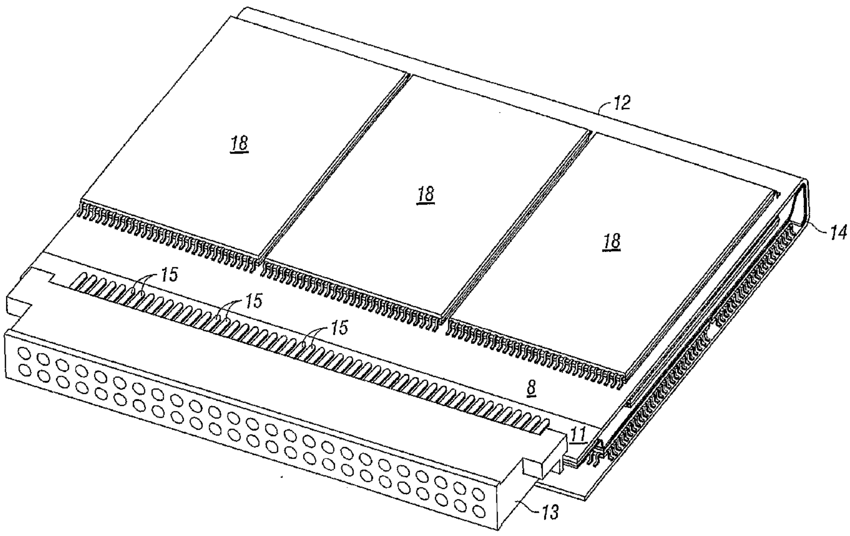
(54) **Title:** COMPACT MODULE SYSTEM AND METHOD



(57) **Abstract:** A flexible circuit is populated on one or both sides and disposed about a substrate to create a circuit module. Along one of its edges, the flex circuit is connected to a connective facility such as a multiple pin connector while the flex circuit is disposed about a thermally-conductive form that provides structure to create a module with plural layers of circuitry in a single module. In preferred embodiments, the form is metallic and, in alternative preferred embodiments, the module circuitry is disposed within a housing. Preferred embodiments may be devised that present a compact flash module within a housing that may be connected to or into a system or product through a connective facility that is preferably a male or female socket connector while the housing is configured to mechanically adapt to an application environment.

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COMPACT MODULE SYSTEM AND METHOD

Field:

[001] The present invention relates to systems and methods for creating high density circuit modules and, in particular, systems and methods related to flash memory modules.

Background:

[002] A variety of techniques are used to make high density circuit modules. Memory expansion is one of the many fields in which high density circuit board solutions provide space-saving advantages. For example, the well-known DIMM (Dual In-line Memory Module) board has been used for years, in various forms, to provide memory expansion. A typical DIMM includes a conventional PCB (Printed Circuit Board) with DRAM memory devices and supporting digital logic.

[003] Strategies used to devise and/or increase the capacity of DRAM-mounted DIMMs may be applicable to other memory modules such as, for example, memory modules that employ flash memory storage or added memory for video processing. The module is typically mounted in the host computer system by inserting a contact-bearing edge of the module into a card edge connector. Typically, systems that employ memory modules provide limited space for such devices and most memory expansion boards are somewhat limited in the memory capacity they add to a system. There are several known methods to improve the limited capacity of a memory module. Such methods have various cost or performance impacts. Further, many capacity increasing techniques exacerbate profile issues and contribute to thermal management complexities.

[004] One scheme to increase circuit board capacity is multiple die packages (MDP). This scheme increases the capacity of the memory devices on the module by including multiple semiconductor die in a single device package. The additional heat generated by the multiple die typically requires, however, additional cooling capabilities to operate at maximum operating speed. Further, the MDP scheme may exhibit increased costs because of increased yield loss from packaging together multiple die that are not fully pre-tested.

[005] In yet another strategy, stacked packages are employed to increase module capacity. This scheme increases capacity by stacking packaged integrated circuits to create a high-density circuit module. In some techniques, flexible conductors are used to selectively interconnect packaged integrated circuits. Staktek Group L.P. has developed numerous systems for aggregating leaded or CSP (chipscale packaged) devices in space saving

topologies. The increased component height of some stacking techniques may alter, however, system requirements such as, for example, required cooling airflow or the minimum spacing around a circuit board on its host system.

[006] Typically, the known methods for increasing memory module capacity raise thermal management issues. What is needed, therefore, are methods and structures for providing high capacity circuit boards in thermally efficient, reliable designs that perform well at higher frequencies but are not too large, yet can be made at reasonable cost with commonly available and readily managed materials.

Summary:

[007] A flexible circuit is populated on one or both sides and disposed about a substrate to create a circuit module. Along one of its edges, the flex circuit is connected to a connective facility such as a multiple pin connector while the flex circuit is disposed about a thermally-conductive form that provides structure to create a module with plural layers of circuitry in a single module. In preferred embodiments, the form is metallic and thermally conductive and, in alternative preferred embodiments, the module circuitry is disposed within a housing. Preferred embodiments may be devised that present a compact flash module within a housing that may be connected to or into a system or product through a connective facility that is preferably a male or female socket connector while the enclosure may be configured for mechanical adaptation to an application environment.

Brief Description of the Drawings:

[008] Fig. 1 depicts a perspective view of a module devised in accordance with a preferred embodiment of the present invention.

[009] Fig. 2A depicts one side of a flex circuit employed in a module devised in accordance with a preferred embodiment of the present invention.

[0010] Fig. 2B depicts another side of a flex circuit employed in a module devised in accordance with a preferred embodiment of the present invention.

[0011] Fig. 3 depicts a cross-section view of a module devised in accordance with a preferred embodiment of the present invention.

[0012] Fig. 4 depicts a plan view of a module in accord with an embodiment of the invention.

[0013] Fig. 5 is an enlarged depiction of the area marked “B” in Fig. 3.

[0014] Fig. 6 is an enlarged depiction of the area marked “A” in Fig. 3.

[0015] Fig. 7 is a cross-sectional view of a module and associated enclosure in accord with the invention.

[0016] Fig. 8 is a perspective view of the enclosed module of Fig. 7.

[0017] Fig. 9 is a plan view of an enclosure within which is a module in accord with the present invention.

[0018] Fig. 10 depicts a cross-sectional view of a flex circuit in accord with the present invention.

Detailed Description of Preferred Embodiments:

[0019] Fig. 1 is a perspective view of a module 10 devised in accordance with an embodiment of the present invention. Preferred module 10 includes a flex circuit 12 populated with memory ICs 18 and adjunct IC 19 as further depicted in Fig. 2. Flex circuit 12 is disposed about a metallic substrate 14 that provides a form for the module. Preferably substrate 14 is aluminum but other metallic materials may be thermally superior but more costly such as, for example, copper. Flex circuit 12 is preferably made from conductive layers supported by one or more flexible substrate layers as further described with reference to later Figs. The construction of flex circuitry is known in the art. The entirety of the flex circuit 12 may be flexible or, as those of skill in the art will recognize, the flexible circuit structure 12 may be made flexible in certain areas to allow conformability to required shapes or bends, and rigid in other areas to provide rigid and planar mounting surfaces.

[0020] ICs 18 on flexible circuit 12 may be leaded, CSP or bare die. In the embodiment of Fig. 1, leaded packaged flash memory devices are represented as ICs 18. Other types of memory devices may be aggregated according to the invention but preferred modules are devised for aggregation of flash memory. Typically, flash memory is currently packaged in leaded packages but as chip-scale packaging ("CSP") of flash memory circuitry arises, the invention may be adapted for use with such CSP packaged devices. For purposes of this disclosure, the term "leaded" shall refer to packaged circuits devices that exhibit connection between one or more integrated circuits within a plastic, metal or ceramic or hermetic casing and an environment through leads emergent from one or more peripheral sides of what is typically a rectangular package. Most often such packages exhibit plastic casings as is known in the art. A variety of devices come in leaded packages and the invention is not limited to only aggregation of memory or flash memory devices.

[0021] The term chip-scale or "CSP" shall refer to integrated circuitry of any function with an array package providing connection to one or more die through contacts (often embodied as "bumps" or "balls" for example) distributed across a major surface of the package or die. CSP does not refer to leaded devices. Although CSP excludes leaded devices, references to CSP are to be broadly construed to include the large variety of array devices (and not to be limited to memory only) and whether die-sized or other size such as BGA and micro BGA as well as flip-chip. Embodiments of the present invention may be employed with leaded or CSP devices or other devices in both packaged and unpackaged forms but leaded flash memory devices are a preferred memory circuitry aggregated through the invention as depicted in a preferred embodiment shown in Fig. 1.

[0022] Multiple integrated circuit die may be included in a package depicted a single IC 18. While in this embodiment memory ICs are used to provide a memory expansion, this is not limiting and various embodiments may include a variety of integrated circuits and other components. Such variety may include microprocessors, FPGA's, RF transceiver circuitry, digital logic, as a list of non-limiting examples, or other circuits or systems which may benefit from a high-density module capability. Circuitry 19 shown in Fig. 2 for example may be a buffer or control circuitry as is known in the art.

[0023] Fig. 1 depicts a top or outer side 8 of flex circuit 12 having three leaded ICs 18. Other embodiments may have other numbers of devices mounted on side 8 of flex circuit 12. Contacts such as, for example, pads, are disposed beneath ICs 18 and later shown circuit 19 to provide conductive paths for interconnection to the ICs mounted along flex circuit 12 as appreciated by those of skill in the art. Flex circuit 12 of the embodiment shown in Fig.1 exhibits a contact area 11 where a plurality of contacts are presented to allow connection of the flex circuit and, by extension, those ICs mounted along flex circuit 12, to a connective facility 13 that presents an interface through which the integrated circuitry along the flex circuit may be electrically accessed. An exemplar connective facility is typified by the illustrated female fifty-pin connector. Connector 13 exhibits pins 15 for connection to the contacts of flex circuit 12. Other connective facilities 13 may exhibit differing techniques for connection to flex circuit 12 but those of skill will in the art will be able to readily accommodate such alternative connection strategies with little or no experimentation.

[0024] Flex circuit 12 is wrapped about substrate 14 to place ICs 18 that are populated along side 8 of flex circuit 12 on the outside of module 10 while those ICs that are populated along side 9 of flex circuit 12 (shown in Fig. 2B) are disposed on the inside of exemplar module 10. Substrate 14 is preferably comprised of metallic material to exhibit advantageous thermal characteristics. As shown in this and later Figs., substrate 14 is preferably a planar-like member having first and second major sides proximal to which ICs along side 9 of flex circuit 12 of module 10 may be disposed when flex circuit 12 is wrapped about substrate 14.

[0025] Fig. 2A illustrates a side of a flex circuit employed in an exemplar module 10. As shown, flex circuit 12 has three leaded ICs 18 mounted along a first half of side 8 and exhibits a plurality of contacts 22 proximal to flex edge 23 for connection of flex circuit 12 to a connective facility such as a connector as later shown.

[0026] Fig. 2B illustrates another side 9 of flex circuit 12 as may be employed in a preferred embodiment of the present invention. In a typical preferred embodiment, side 9 becomes an inner side of flex circuit 12 with respect to module 10 and side 8 of flex circuit 12. As shown, five ICs 18 are populated along side 9 of flex circuit 12 along with adjunct circuit 19 which may be a control or buffer circuitry, for example. As shown in earlier Fig.1, three ICs are disposed along side 8 of flex circuit 12 and thus, module 10 in the depicted embodiment exhibits eight leaded ICs 18. Those of skill will recognize that other numbers of ICs 18 may be aggregated in embodiments of the invention and the invention in adaptable to ICs that are leaded or are CSPs.

[0027] Fig. 3 is a cross-sectional depiction of a module 10 devised in accordance with a preferred embodiment of the present invention. Substrate 14 is shown in cross-section and flex circuit 12 is depicted disposed about substrate 14 to place upper sides 16 of ICs 18 disposed along inner side 9 of flex circuit 12 adjacent to substrate 14. Adhesive 30 may be employed to secure ICs 18 to substrate 14 and thermally conductive adhesives are preferred. Pins 15 are shown connected along outer side 8 of flex circuit 12 to contacts 22 (not visible in Fig. 3) while substrate 14 is attached to side 9 of flex circuit 12 proximal to connector 13 as shown in this embodiment. Other arrangements may dispose substrate 14 differently such as, for example, fixing substrate 14 with connective facility 13 by inserting substrate 14 into connective facility 13. Substrate 14 may be devised in a variety of configurations and materials to provide, for example, an appropriate radius for the flex to transit about the substrate or wells into which module ICs may be disposed.

[0028] Fig. 4 depicts a plan view of a module 10 devised in accordance with a preferred embodiment of the present invention. Illustrated module 10 exhibits three flash memory leaded package ICs 18 disposed along side 8 of flex circuit 12. Those of skill will recognize that the present invention will be advantageous in aggregating fewer or more ICs 18 than the eight depicted in the earlier Figs. ICs 18 exhibit leads 17 emergent from peripheral sides 21 of ICs 18. Pins 15 of connector 13 are soldered in the depicted preferred embodiment to pads 22 of connective area 11 of flex circuit 12.

[0029] Fig. 5 depicts an enlarged view of the area marked with "B" in Fig. 3. Shown are ICs 18 mounted along flex circuit 12 with two of the ICs 18 that are mounted along inner side 9 of flex circuit 12 being shown with their respective upper sides 16 in proximity to substrate 14 which exhibits transit 14A to allow preferred multi-layer flex circuit 12 to transit about the substrate in the depicted preferred embodiment.

[0030] Fig. 6 is an enlarged view of a portion of module 10 identified by "A" in Fig. 3. Connector 31 is shown with solder pins 15 attached to flex circuit 12 while substrate 14 is attached to flex circuit 12 with adhesive 30. Major sides 24 and 25 of substrate 14 are identified in this enlarged view. IC 18 populated along side 9 of flex circuit 12 is shown disposed proximal to one of the two major sides of substrate 14. Depicted IC 18 may either contact substrate 14 along parts or all of its upper surface 16 or it may be located proximal to substrate 14 but distanced from it by adhesive which in preferred embodiments is a thermally conductive adhesive.

[0031] Fig. 7 is a cross-sectional view of a module 10 disposed in enclosure "E" to present a compact flash module for connection to an environment through exemplar 50 pin connector 31. Enclosure E may be comprised of a variety of materials such as, for example, high impact resistant plastics being just one of many preferred variations that those of skill will be able to select in accordance with this invention and the relevant operating environment and manufacturing and cost constraints. Upper surface 16 of an IC 18 may be attached to enclosure E with adhesive 30 as represented in Fig. 7. A portion of surface 8 of flex circuit 12 may also be affixed to enclosure E to provide a more integrated enclosed module.

[0032] Fig. 7 portrays a medial line S_M depicting a plane through substrate 14 and a medial line F_M demarking a plane through flex circuit 12 on one side of substrate 14. Three layers of ICs are identified by references L1, L2, and L3. As shown, two layers of ICs which comprise, in the exemplar module 10 depicted in Fig. 7, two layers of flash memory are depicted on one side of substrate 14 while a third layer of ICs are shown on the other side of substrate 14. Consequently, in the depicted module, three layers of memory are shown aggregated in exemplar module 10.

[0033] Fig. 8 depicts a perspective view of a preferred compact flash module 10M in accordance with the present invention that is devised to provide flash memory capability for a variety of systems and products. The particular preferred embodiment shown in Fig. 8 is configured with mounting structures 35 to provide ready mating with application structures to affix module 10M to the environment while electrical communication between the environment and module 10M is provided through connector 31.

[0034] Fig. 9 depicts an exemplar module 10M with enclosure E and connector 31 for connection to the ICs 18 and, typically, IC 19 within enclosure E. The depiction of Fig. 9 illustrates the dimensions of a typical module 10M that provides flash memory storage with eight flash memory ICs 18 as earlier depicted. Dimension X is approximately 42 mm. and dimension Y is approximately 36 mm. although those of skill will appreciate that these dimensions are arbitrary and modules 10M in accordance with the present invention may be devised that illustrate a large variety of dimensions and that enclosure E may, for example, be configured in a variety of configurations to make module 10M mechanically adaptable to a multiplicity of applications.

[0035] Fig. 10 is an exploded depiction of a flex circuit 12 cross-section according to one embodiment of the present invention. The depicted preferred flex circuit 12 has four conductive layers 101 – 104 and seven insulative layers 105 – 111. The numbers of layers described are merely those of one preferred embodiment, and other numbers and layer arrangements may be used.

[0036] Top conductive layer 101 and the other conductive layers are preferably made of a conductive metal such as, for example, copper or copper alloy. In this arrangement, conductive layers 101, 102, and 104 express signal traces 112 that make various connections on flex circuit 12. These layers may also express conductive planes for ground, power, or reference voltage. For example, top conductive layer 101 may also be provided with a flood, or plane, of to provide the VDD to ICs mounted to flex circuit 12.

[0037] In this embodiment, inner conductive layer 102 expresses traces connecting to and among the various devices mounted along the sides of flex circuit 12. The function of any of the depicted conductive layers may, of course, be interchanged with others of the conductive layers. Inner conductive layer 103 expresses a ground plane, which may be split to provide VDD return for pre-register address signals. Inner conductive layer 103 may further express other planes and traces. In this embodiment, floods, or planes, at bottom conductive layer 104 provides VREF and ground in addition to the depicted traces.

[0038] Insulative layers 105 and 111 are, in this embodiment, dielectric solder mask layers which may be deposited on the adjacent conductive layers. Insulative layers 107 and 109 are made of adhesive dielectric. Other embodiments may not have such adhesive dielectric layers. Insulative layers 106, 108, and 110 are preferably flexible dielectric substrate layers made of polyamide. Any other suitable flexible circuit substrate material may be used.

[0039] Although the present invention has been described in detail, it will be apparent to those skilled in the art that many embodiments taking a variety of specific forms and reflecting changes, substitutions and alterations can be made without departing from the spirit and scope of the invention. The described embodiments illustrate the scope of the claims but do not restrict the scope of the claims.

Claims:

1. A memory module comprising:

a flex circuit having first and second sides populated with memory ICs, the flex circuit having an edge near which are disposed a plurality of contacts for connection of the flex circuit to a connective facility;

a substrate comprised of metallic material about which the flex circuit is wrapped to place on one side of the substrate, two layers of memory ICs and at least a third layer comprised of at least one memory IC on the other side of the substrate; and

a connective facility connected to the plurality of contacts.

2. The memory module of claim 1 in which the connective facility is a multi-pin connector.

3. The memory module of claim 1 in which the substrate is comprised of aluminum.

4. The memory module of claim 1 in which the flex circuit has more than one conductive layer.

5. The memory module of claim 1 in which the flex circuit has four metal layers.

6. The memory module of claim 1 in which the memory ICs are flash memory circuits in leaded packages.

7. The memory module of claim 1 further comprising an enclosure into which the module is disposed.

8. The memory module of claim 7 in which the enclosure is configured for mechanical adaptation to an application environment.

9. A memory module comprising:

a flex circuit populated with memory circuits, the flex circuit having a plurality of contacts through which the memory circuits may be electrically accessed;

a substrate about which the flex circuit is disposed to place memory circuits on each of the two major sides of the substrate;

a multi-pin connector connected to the plurality of contacts of the flex circuit; and

an enclosure.

10. The memory module of claim 9 in which the flex circuit is populated with memory circuits that are flash memory circuits.

11. The memory module of claim 9 in which the flex circuit is populated on each of its two sides with memory circuits.

12. The memory module of claim 9 in which the substrate is comprised of metallic material.

13. The memory module of claim 9 in which the substrate is comprised of copper.

14. The memory module of claim 9 in which the substrate is comprised of aluminum.

15. The memory module of claim 9 in which the flex circuit is comprised of more than one conductive layer.

16. The memory module of claim 9 in which the flex circuit is comprised of four metal layers.

17. The memory module of claim 9 in which the memory circuits are flash memory circuits and the enclosure is configured for mechanical adaptation to an application environment.

18. The memory module of claim 9 in which the enclosure is comprised of plastic configured for mechanical adaptation to an application environment.

19. A circuit module comprising:

a flex circuit having a plurality of contacts and packaged integrated circuitry along its first and second sides;

a metallic substrate about which the flex circuit is disposed to place two layers of packaged integrated circuitry on one side of the substrate, the two layers separated by the flex circuit and a third layer of packaged integrated circuitry on the other side of the substrate; and a connector connected to the plurality of contacts and presenting an interface through which the packaged integrated circuitry may be electrically accessed.

20. The circuit module of claim 19 in which the flex circuit has at least two conductive layers.

21. The circuit module of claim 19 in which the flex circuit has four metal layers.

22. The circuit module of claim 19 in which the packaged integrated circuitry is flash memory.

23. The circuit module of claim 19 further comprising an enclosure.

24. The circuit module of claim 19 in which the flex circuit comprises at least two conductive layers and the module further comprises an enclosure.

25. The circuit module of claim 19 in which the packaged integrated circuitry is provided in at least eight separate packages.

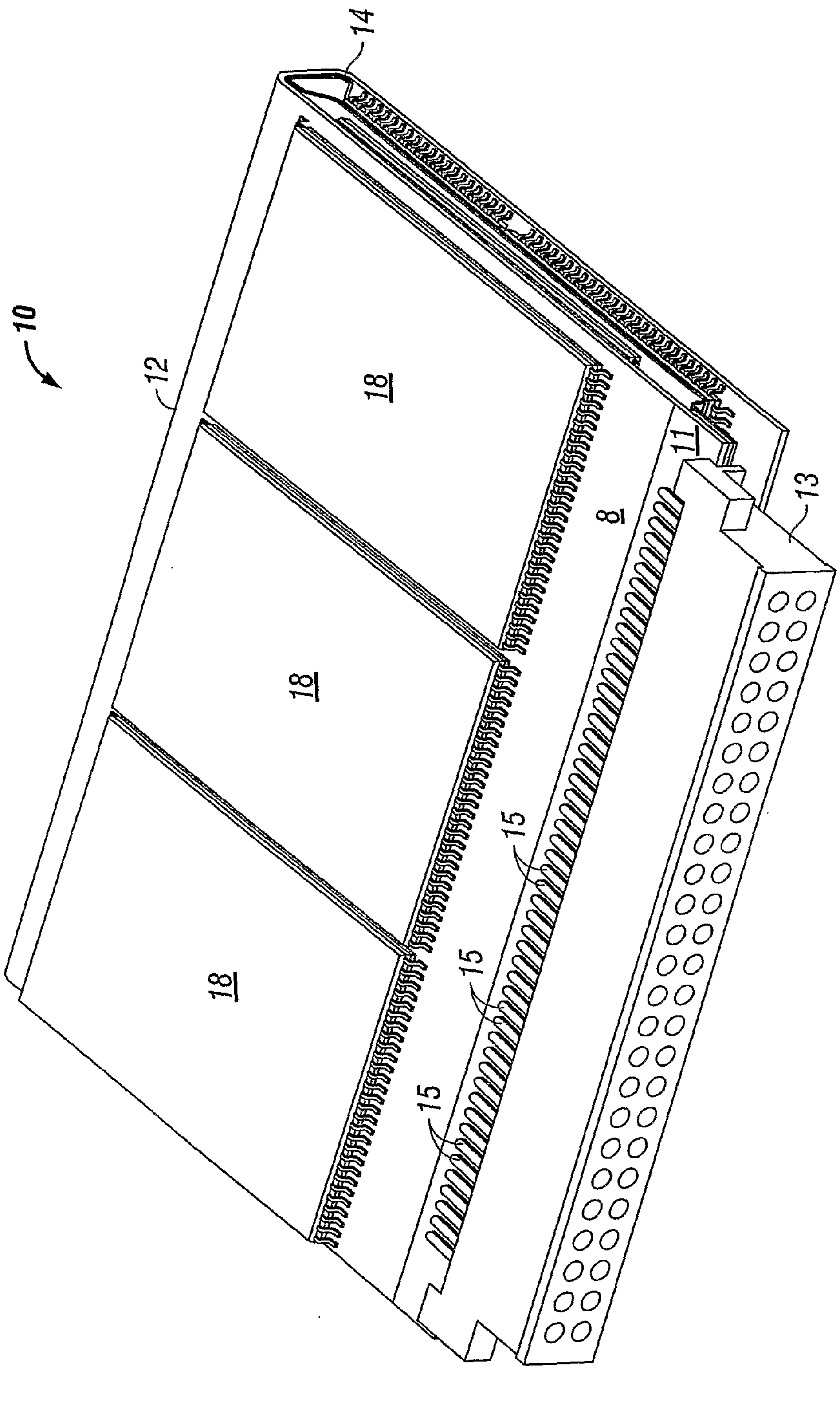

FIG. 1

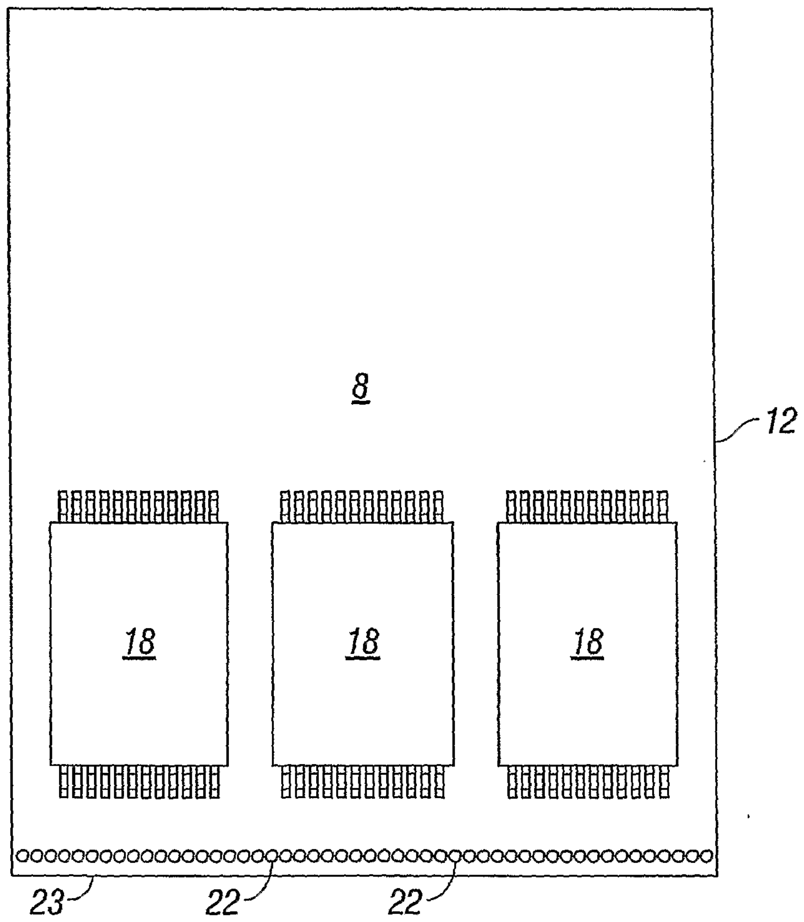

FIG. 2A

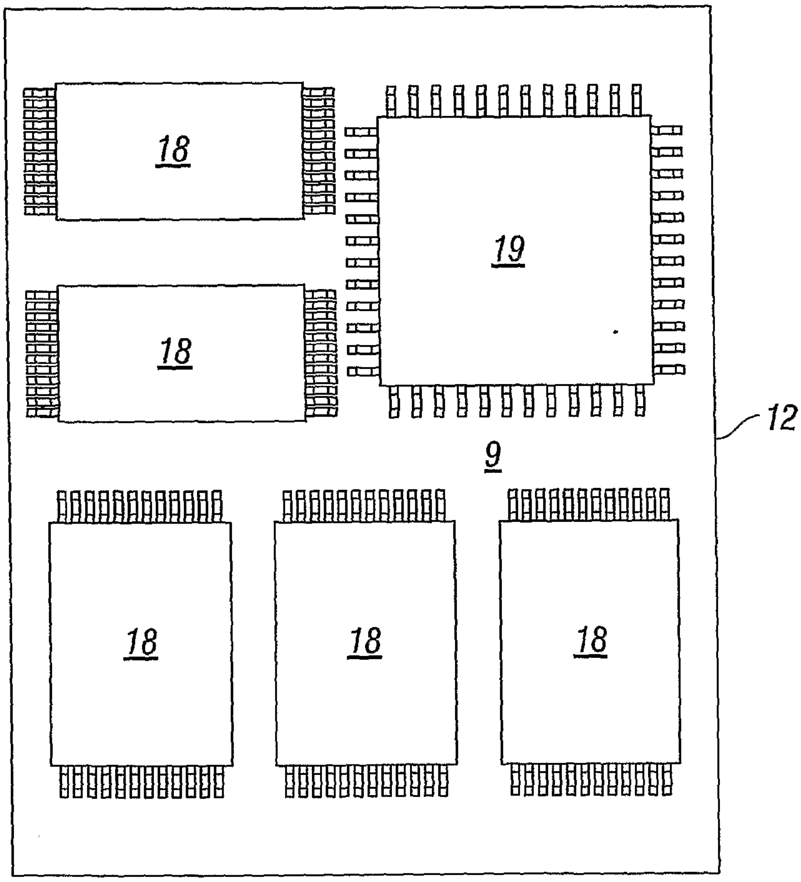

FIG. 2B

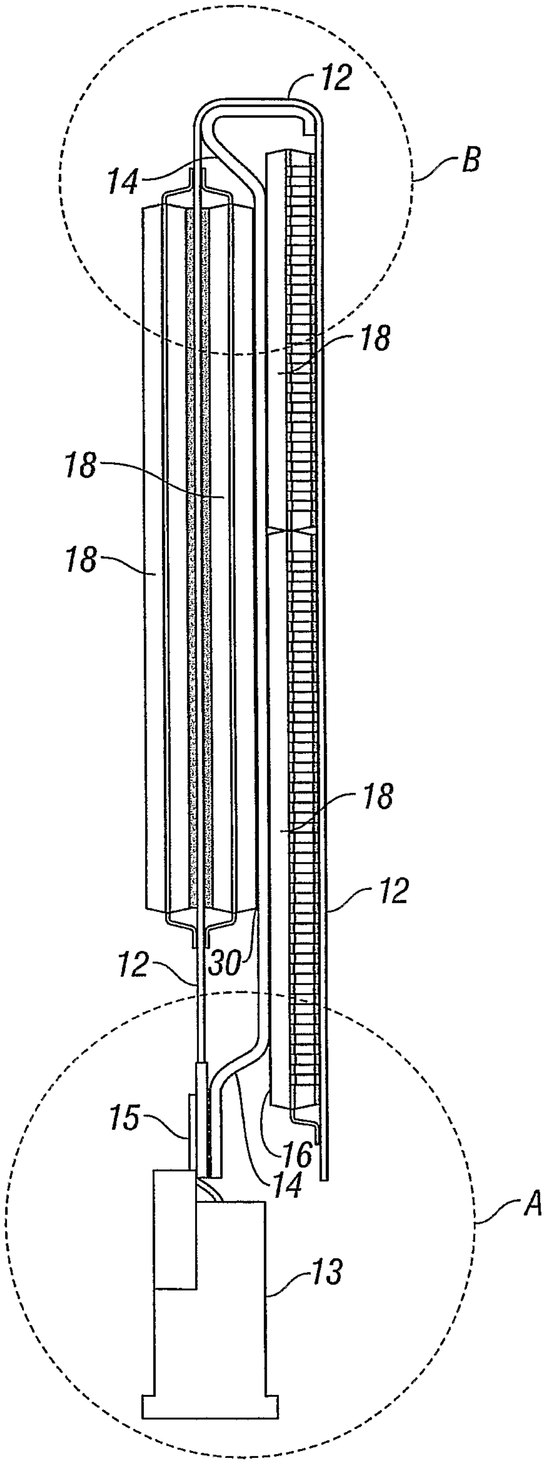

FIG. 3

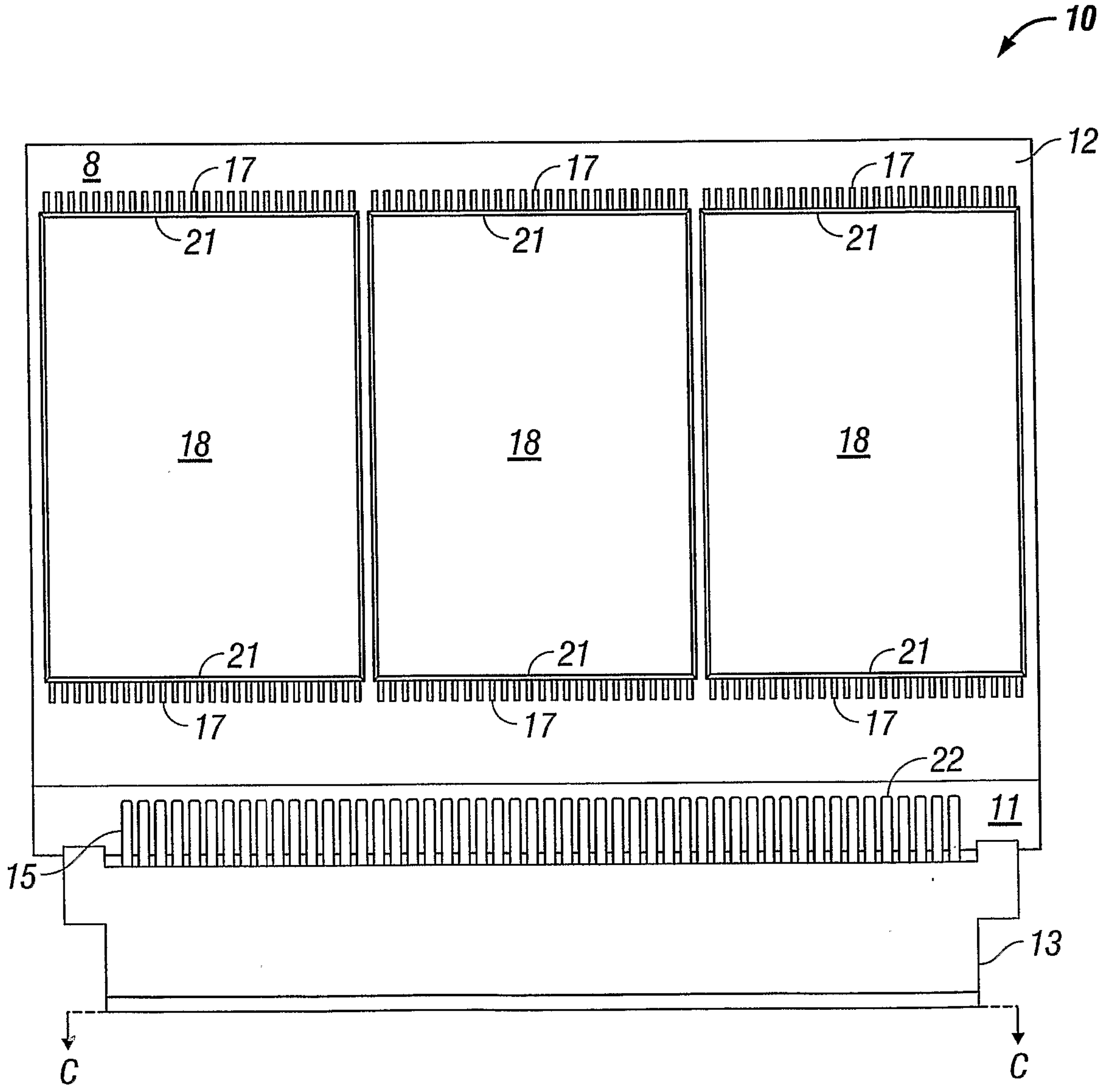

FIG. 4

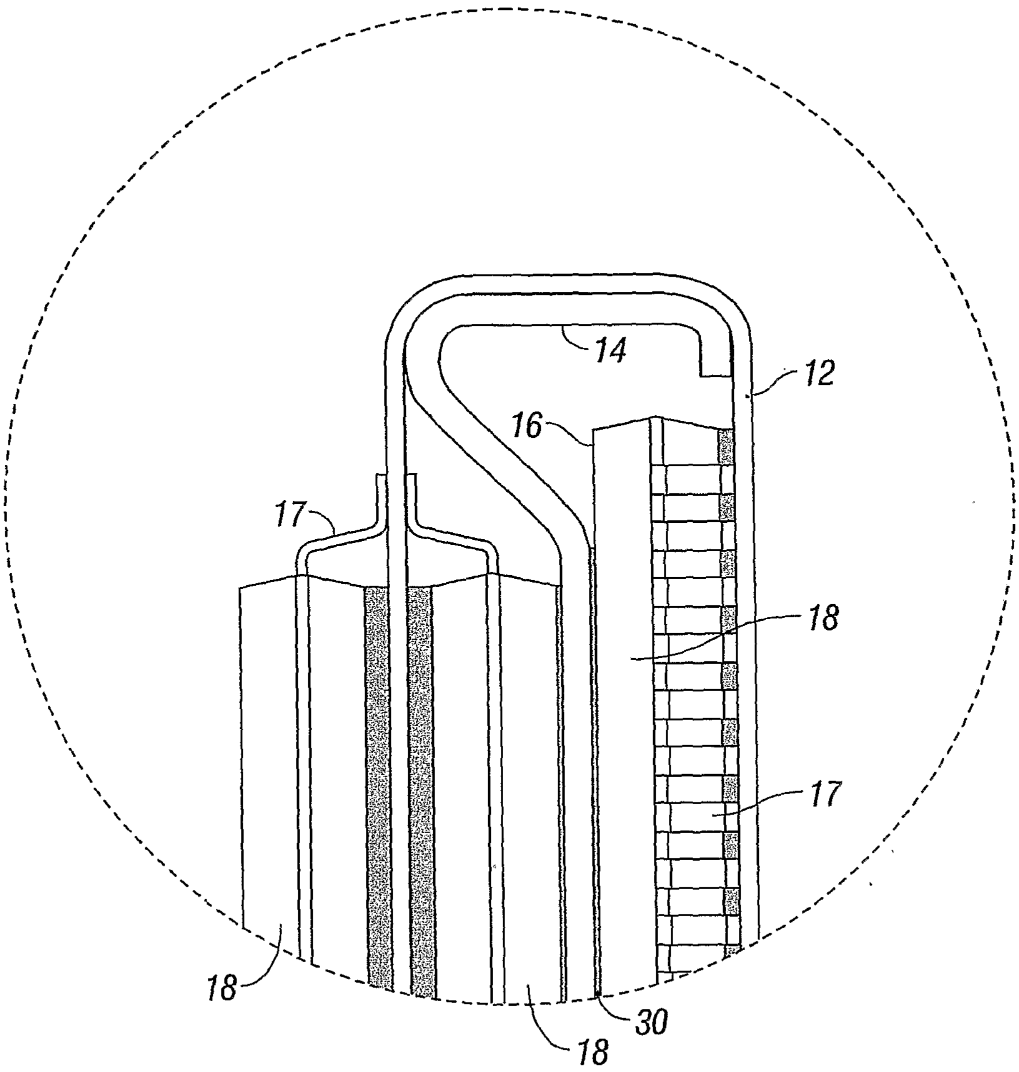

FIG. 5

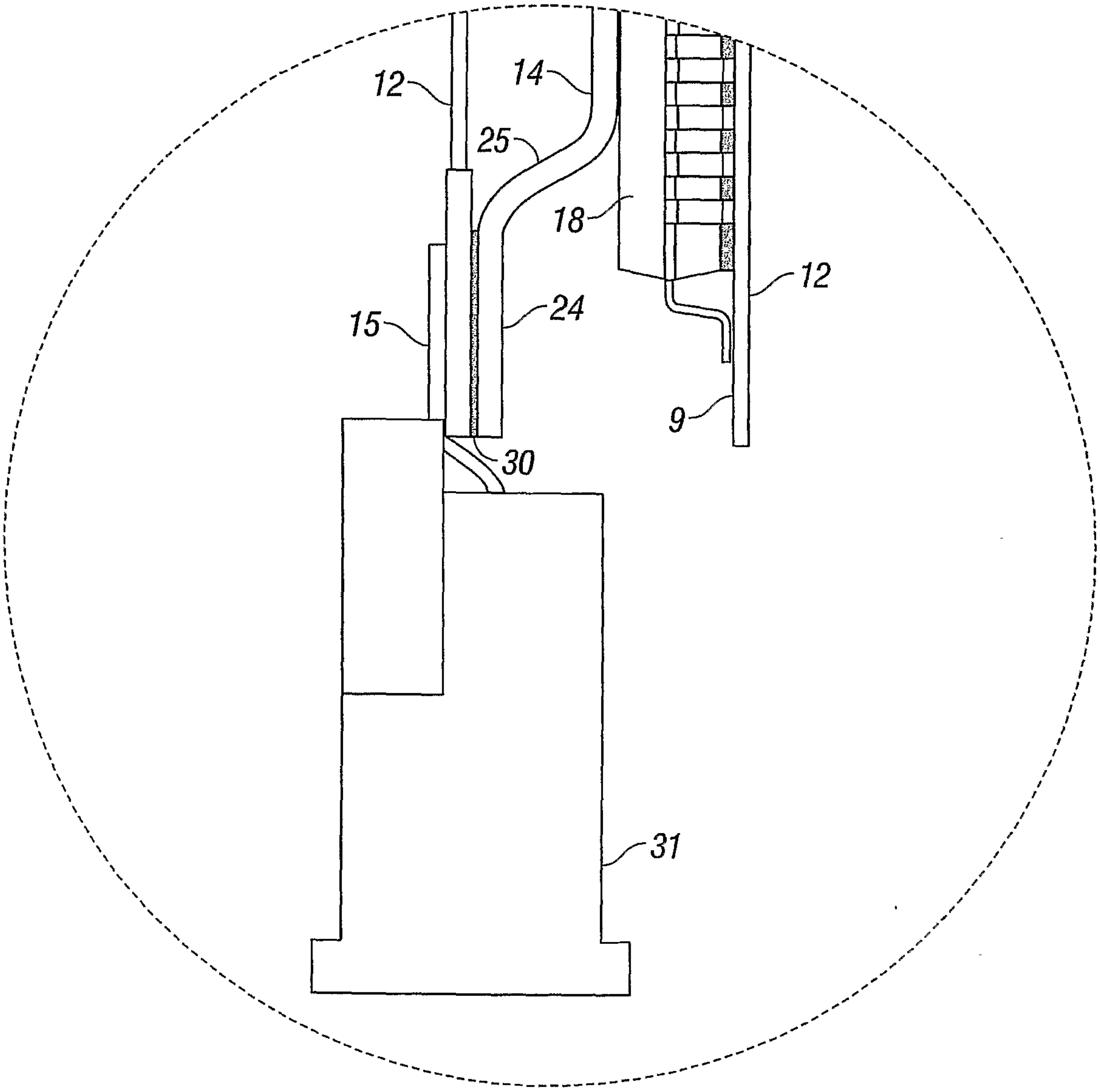

FIG. 6

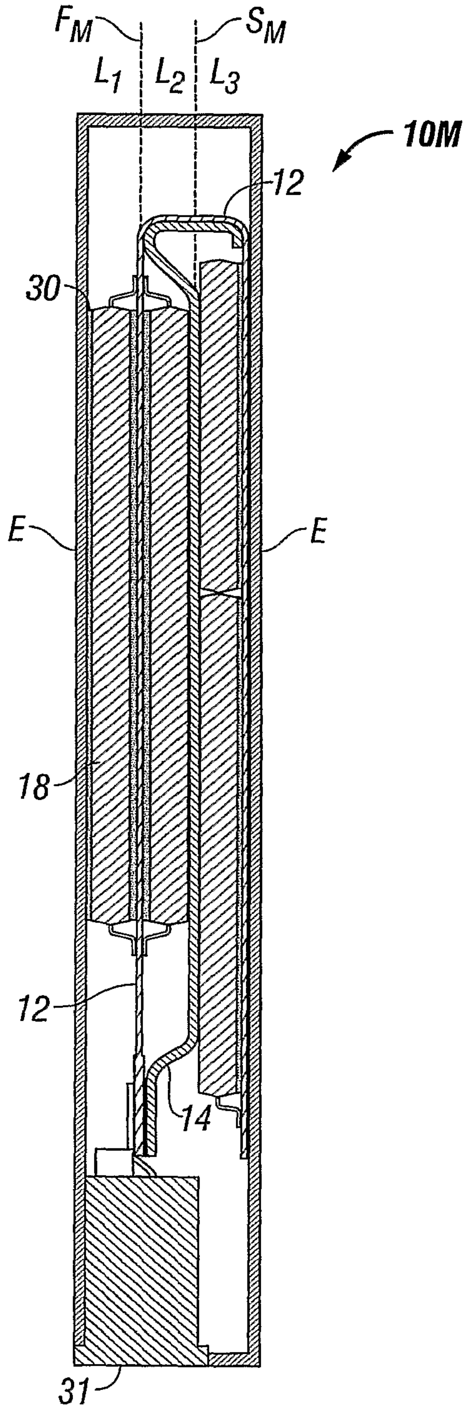

FIG. 7

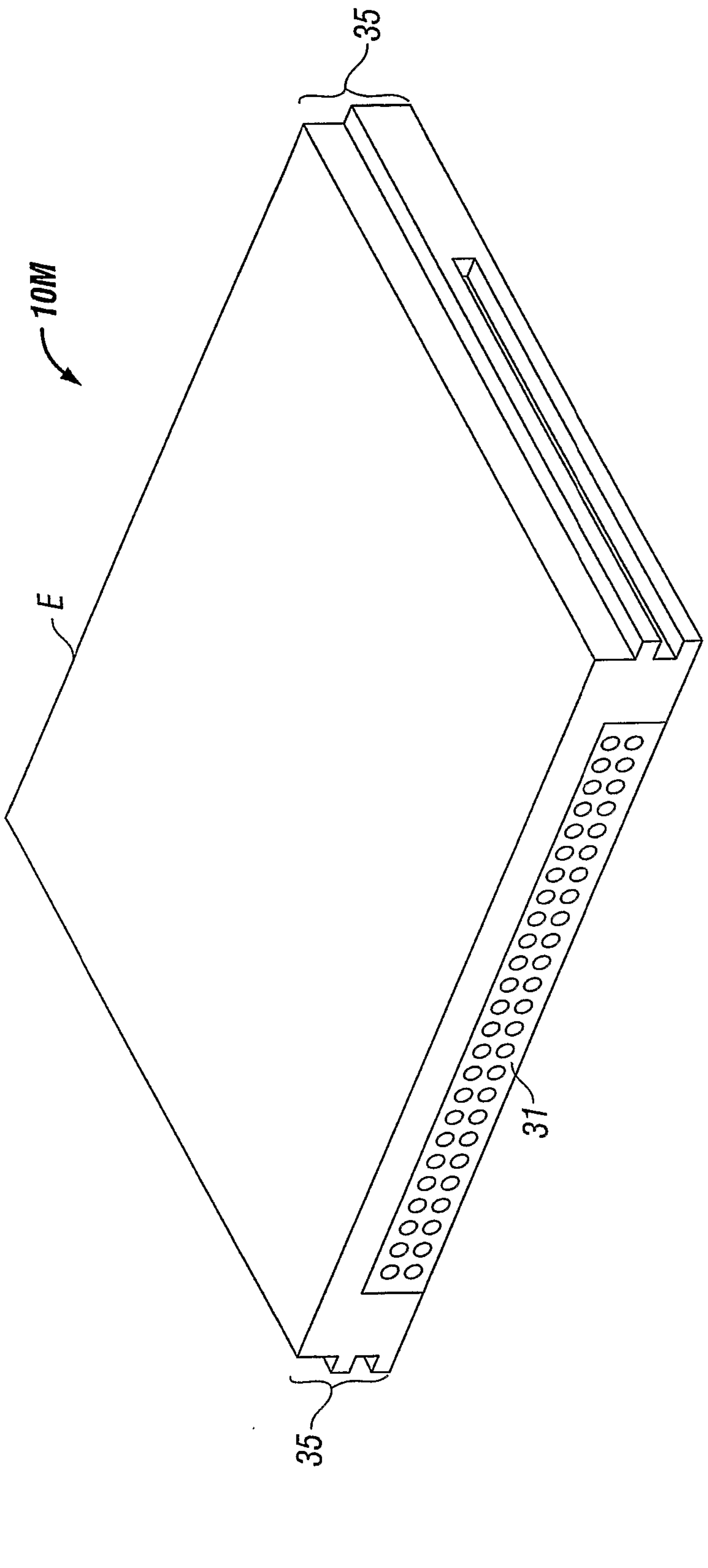

FIG. 8

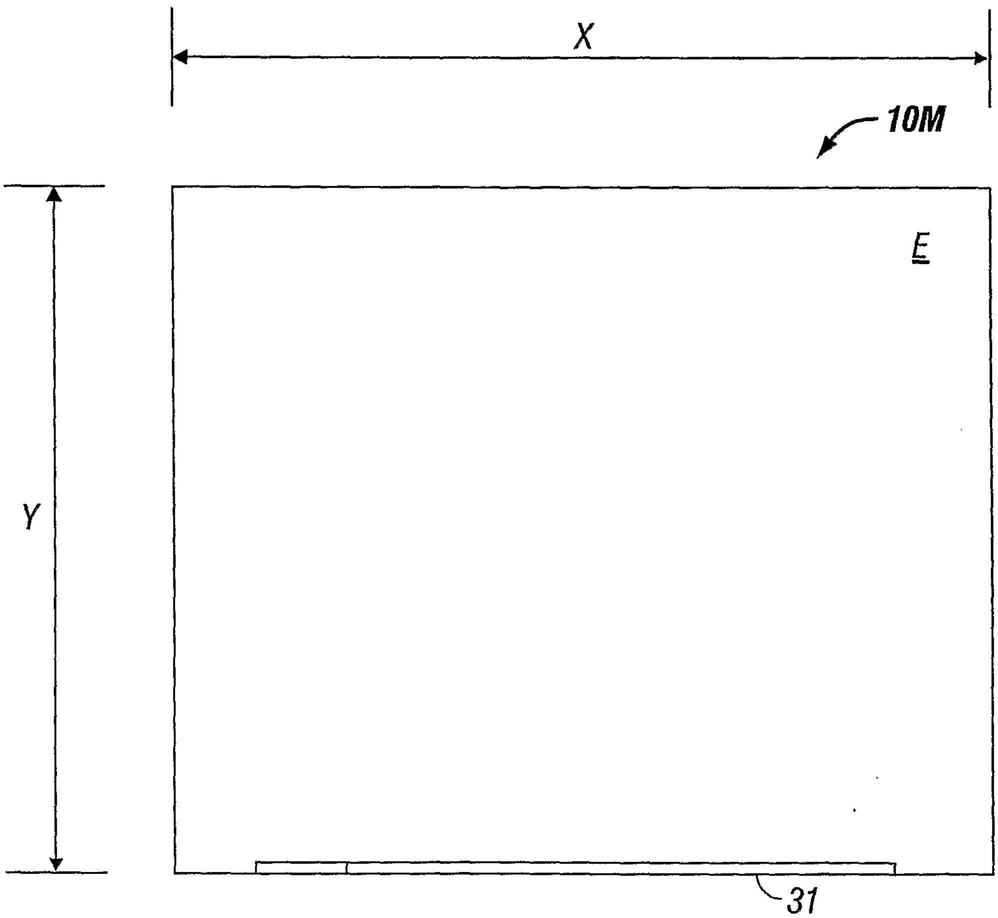

FIG. 9

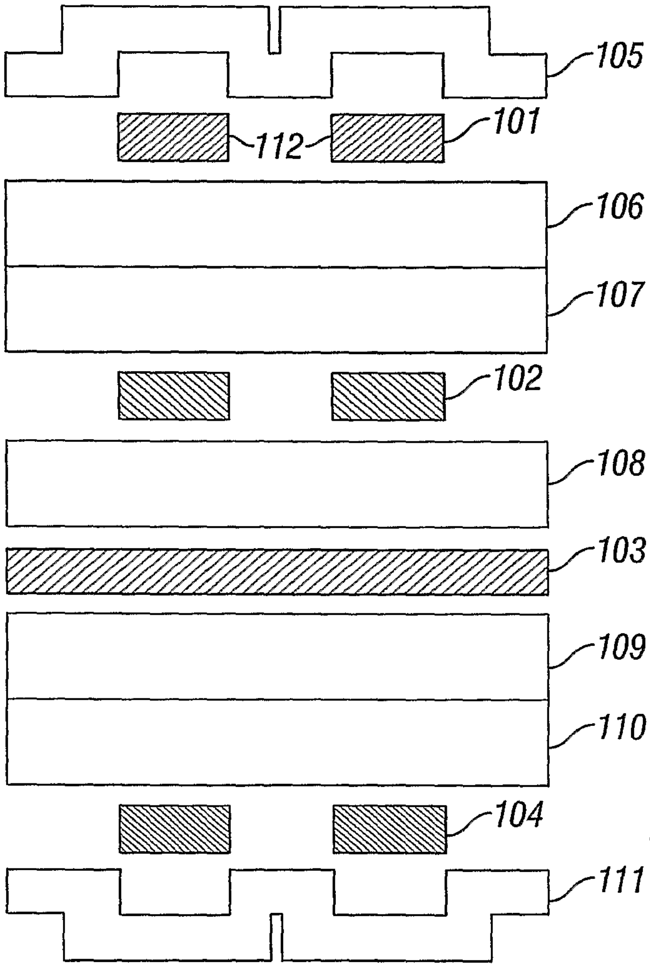

FIG. 10