

(12) **United States Patent**
Iihola et al.

(10) **Patent No.:** **US 11,716,816 B2**
(45) **Date of Patent:** **Aug. 1, 2023**

(54) **METHOD FOR MANUFACTURING AN ELECTRONIC MODULE AND ELECTRONIC MODULE**

(58) **Field of Classification Search**
CPC H01L 23/5383; H01L 23/5385; H01L 23/5389; H01L 24/24; H01L 25/0655; H01L 2224/04105

(71) Applicant: **IMBERATEK, LLC**, Cedar Park, TX (US)

(Continued)

(72) Inventors: **Antti Iihola**, Helsinki (FI); **Timo Jokela**, Halikko (FI)

(56) **References Cited**

U.S. PATENT DOCUMENTS

(73) Assignee: **IMBERATEK, LLC**, Cedar Park, TX (US)

3,729,820 A 5/1973 Ihochi et al.
4,237,607 A 12/1980 Ohno

(Continued)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 89 days.

FOREIGN PATENT DOCUMENTS

DE 4141775 A1 6/1993
EP 0774888-X 5/1997

(Continued)

(21) Appl. No.: **17/364,593**

(22) Filed: **Jun. 30, 2021**

OTHER PUBLICATIONS

(65) **Prior Publication Data**
US 2021/0329788 A1 Oct. 21, 2021

Lau, "Low Cost Flip Chip Technologies: For DCA, WLCSP, and PBGA Assemblies." 2000. New York: McGraw-Hill.

(Continued)

Related U.S. Application Data

(63) Continuation of application No. 16/788,701, filed on Feb. 12, 2020, now abandoned, which is a (Continued)

Primary Examiner — Nitin Parekh

(74) *Attorney, Agent, or Firm* — Rossi, Kimms & McDowell LLP

Foreign Application Priority Data

(30) Sep. 18, 2003 (FI) 20031341

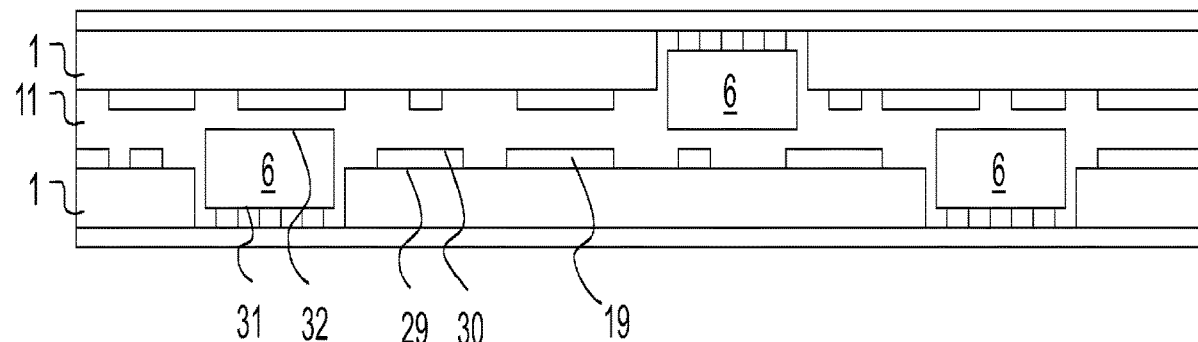
(57) **ABSTRACT**

This publication discloses an electronic module, comprising a first conductive pattern layer and a first insulating-material layer on at least one surface of the first conductive pattern layer, at least one opening in the first insulating-material layer that extends through the first insulating-material layer, a component having a contact surface with contact terminals, the component being arranged at least partially within the opening with its contact terminals electrically coupled to the first conductive pattern layer, a second insulating-material layer provided on the first insulating-material layer, and a conductive pattern embedded between the first and second insulating material layers. This publication additionally discloses a method for manufacturing an electronic module.

(51) **Int. Cl.**
H05K 7/00 (2006.01)
H05K 1/18 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC **H05K 1/188** (2013.01); **H01L 21/4857** (2013.01); **H01L 23/5383** (2013.01);
(Continued)

14 Claims, 14 Drawing Sheets



Related U.S. Application Data

continuation of application No. 14/580,257, filed on Dec. 23, 2014, now Pat. No. 10,798,823, which is a continuation-in-part of application No. 10/572,340, filed as application No. PCT/FI2004/000053 on Sep. 15, 2004, now Pat. No. 7,696,005.

(51) Int. Cl.

H01L 23/538 (2006.01)
H01L 23/00 (2006.01)
H01L 25/065 (2023.01)
H01L 25/00 (2006.01)
H01L 21/48 (2006.01)
H05K 3/46 (2006.01)

(52) U.S. Cl.

CPC **H01L 23/5385** (2013.01); **H01L 23/5389** (2013.01); **H01L 24/19** (2013.01); **H01L 24/24** (2013.01); **H01L 24/82** (2013.01); **H01L 25/0655** (2013.01); **H01L 25/50** (2013.01); **H01L 2224/04105** (2013.01); **H01L 2224/24227** (2013.01); **H01L 2224/82039** (2013.01); **H01L 2224/92144** (2013.01); **H01L 2924/01005** (2013.01); **H01L 2924/01006** (2013.01); **H01L 2924/01015** (2013.01); **H01L 2924/01019** (2013.01); **H01L 2924/01029** (2013.01); **H01L 2924/01033** (2013.01); **H01L 2924/01057** (2013.01); **H01L 2924/01079** (2013.01); **H01L 2924/01082** (2013.01); **H01L 2924/07802** (2013.01); **H05K 3/4602** (2013.01); **H05K 3/4611** (2013.01); **H05K 3/4652** (2013.01); **H05K 2201/0355** (2013.01); **H05K 2201/0394** (2013.01); **H05K 2201/10674** (2013.01); **H05K 2203/063** (2013.01); **Y10T 29/4913** (2015.01); **Y10T 29/49126** (2015.01); **Y10T 29/49139** (2015.01); **Y10T 29/49144** (2015.01); **Y10T 29/49156** (2015.01)

(58) Field of Classification Search

USPC 257/773, 786
 See application file for complete search history.

(56) References Cited**U.S. PATENT DOCUMENTS**

1,246,595 A 1/1981 Oyori et al.
 1,618,739 A 10/1986 Theobald
 4,731,645 A 3/1988 Parmentier et al.
 4,993,148 A 2/1991 Adachi et al.
 5,042,145 A 8/1991 Boucquet
 5,048,179 A 9/1991 Shindo et al.
 5,073,814 A 12/1991 Cole, Jr. et al.
 5,081,562 A 1/1992 Adachi et al.
 5,098,864 A 3/1992 Mahulikar
 5,102,829 A 4/1992 Cohn
 5,216,806 A 6/1993 Lam
 5,227,338 A 7/1993 Kryzaniwsky
 5,227,583 A 7/1993 Jones
 5,241,456 A 8/1993 Marcinkiewicz et al.
 5,248,852 A 9/1993 Kumagai
 5,306,670 A 4/1994 Mowatt et al.
 5,324,687 A 6/1994 Wojnarowski
 5,353,195 A 10/1994 Fillion et al.
 5,355,102 A 10/1994 Kornumpf et al.
 5,397,917 A 3/1995 Ommen et al.
 5,401,688 A 3/1995 Yamaji
 5,407,864 A 4/1995 Kim
 5,441,918 A 8/1995 Morisaki
 5,497,033 A 3/1996 Fillion et al.
 5,506,632 A 4/1996 Kohayakawa et al.

5,510,580 A 4/1996 Shirai et al.
 5,552,633 A 9/1996 Sharma
 5,616,520 A 4/1997 Nishiuma et al.
 5,633,204 A 5/1997 Tago et al.
 5,637,919 A 6/1997 Grabbe
 5,654,220 A 8/1997 Leedy
 5,656,863 A 8/1997 Yasunaga et al.
 5,711,694 A 1/1998 Levine et al.
 5,796,165 A 8/1998 Koshikawa et al.
 5,814,894 A 9/1998 Garashi et al.
 5,838,545 A 11/1998 Clocher et al.
 5,840,593 A 11/1998 Leedy
 5,841,193 A * 11/1998 Eichelberger H01L 24/19
 257/773
 5,861,670 A 1/1999 Akasaki
 5,870,289 A 2/1999 Tokuda et al.
 5,882,957 A 3/1999 Lin
 5,929,510 A 7/1999 Geller et al.
 5,936,847 A 8/1999 Kazle
 5,985,693 A 11/1999 Leedy
 5,994,166 A 11/1999 Akram et al.
 6,037,665 A 3/2000 Miyazaki
 6,038,133 A 3/2000 Nakatani et al.
 6,084,781 A 7/2000 Klein
 6,093,970 A 7/2000 Ohsawa et al.
 6,154,366 A 11/2000 Ma et al.
 6,232,666 B1 5/2001 Corisis et al.
 6,242,282 B1 6/2001 Fillion et al.
 6,271,469 B1 8/2001 Ma et al.
 6,274,391 B1 8/2001 Wachtler et al.
 6,284,564 B1 9/2001 Balch et al.
 6,288,905 B1 9/2001 Chung
 6,292,366 B1 9/2001 Platt
 6,396,148 B1 * 5/2002 Eichelberger H01L 21/568
 257/781
 6,402,970 B1 6/2002 Lin
 6,404,052 B1 6/2002 Kurita et al.
 6,472,735 B2 * 10/2002 Isaak H05K 1/141
 257/777
 6,475,877 B1 11/2002 Saia et al.
 6,476,503 B1 11/2002 Imamura et al.
 6,506,632 B1 1/2003 Cheng et al.
 6,537,848 B2 3/2003 Camenforte et al.
 6,538,210 B2 3/2003 Sugaya et al.
 6,551,861 B1 4/2003 Lin
 6,555,906 B2 * 4/2003 Towle H01L 21/568
 257/723
 6,570,469 B2 5/2003 Yamada et al.
 6,576,493 B1 6/2003 Lin
 6,590,291 B2 7/2003 Akagawa
 6,607,943 B1 8/2003 Kinsman
 6,701,614 B2 3/2004 Ding et al.
 6,709,897 B2 * 3/2004 Cheng H01L 24/05
 438/126
 6,710,458 B2 3/2004 Seko
 6,710,614 B1 3/2004 Ding et al.
 6,713,859 B1 3/2004 Ma
 6,734,534 B1 * 5/2004 Vu H01L 24/19
 257/680
 6,734,542 B2 5/2004 Nakatani et al.
 6,783,077 B1 8/2004 Fannasch
 6,784,765 B2 8/2004 Yamada et al.
 6,790,712 B2 9/2004 Bai
 6,806,428 B1 10/2004 Kimura et al.
 6,876,072 B1 4/2005 Wang et al.
 6,975,516 B2 12/2005 Asahi et al.
 6,979,596 B2 12/2005 Corisis et al.
 6,985,364 B2 * 1/2006 Higashitani H01L 25/165
 361/764
 6,991,966 B2 1/2006 Tuominen
 7,061,119 B1 6/2006 Jiang
 7,161,241 B2 1/2007 Kimura
 7,183,658 B2 2/2007 Towle et al.
 7,220,989 B2 * 5/2007 Chuan G01R 1/0483
 257/E23.179
 7,294,529 B2 11/2007 Tuominen
 7,609,527 B2 10/2009 Tuominen et al.
 7,663,215 B2 2/2010 Tuominen et al.

(56)

References Cited

U.S. PATENT DOCUMENTS

7,673,387	B2	3/2010	Tuominen et al.
2002/0017711	A1	2/2002	Kwon et al.
2002/0053465	A1	5/2002	Kawakita et al.
2002/0084524	A1	7/2002	Roh et al.
2002/0117743	A1	8/2002	Nakatani et al.
2002/0149117	A1	10/2002	Shibata
2002/0159242	A1	10/2002	Nakatani et al.
2002/0185303	A1	12/2002	Takeuchi et al.
2003/0067074	A1	4/2003	Kinsman
2003/0068852	A1	4/2003	Towle et al.
2003/0068877	A1	4/2003	Kinsman
2003/0090883	A1	5/2003	Asahi et al.
2003/0100142	A1	5/2003	Shin et al.
2003/0137045	A1	7/2003	Sugaya et al.
2003/0159852	A1	8/2003	Nakamura
2003/0209796	A1	11/2003	Kindo et al.
2004/0000710	A1	1/2004	Oya
2004/0266067	A1	12/2004	Bai et al.
2005/0000729	A1	1/2005	Iijima et al.
2005/0001331	A1	1/2005	Kojima et al.
2005/0285244	A1	12/2005	Chen
2006/0105500	A1	5/2006	Chang
2006/0163740	A1	7/2006	Ohno
2006/0278967	A1	12/2006	Tuominen et al.
2007/0141759	A1	6/2007	Nagase
2007/0166886	A1	7/2007	Iihola et al.
2007/0267136	A1	11/2007	Tuominen et al.
2008/0032447	A1	2/2008	Lee
2008/0202801	A1	8/2008	Tuominen et al.
2008/0295326	A1	12/2008	Tuominen et al.
2010/0202115	A1	8/2010	Tuominen et al.
2021/0329788	A1	10/2021	Iihola et al.

FOREIGN PATENT DOCUMENTS

EP	1111662	6/2001
EP	1156525 A	11/2001
FR	2822338 A1	9/2002
GB	2342995	5/2000
JP	04283987	10/1992
JP	H08213425 A	8/1996
JP	2757748	5/1998
JP	11103165	4/1999
JP	2001053447	2/2001
JP	2001068624 A	3/2001
JP	2001156457 A	6/2001
JP	3207174 B2	9/2001
JP	2001274034	10/2001
JP	2001339165 A	12/2001
JP	2001345560	12/2001
JP	2002016327	1/2002

JP	2002083926 A	3/2002
JP	2002158307	5/2002
JP	2002271033	9/2002
JP	2003188314	7/2003
JP	2003204167	7/2003
JP	2003229513	8/2003
JP	2004146634	5/2004
WO	03065778 A1	8/2003
WO	WO 2003065779	8/2003
WO	WO 2004077902	9/2004
WO	WO 2004077903	9/2004
WO	2004089048 A1	10/2004
WO	WO 2005027602	3/2005
WO	2005104636 A1	11/2005

OTHER PUBLICATIONS

Lehmann, "Underflow Process for Direct-Chip-Attachment Packaging," IEEE Transactions on Components, Packaging, and Manufacturing Technology. Jun. 1998: 266-274. Part A vol. 21, No. 2.

Notice of Allowance issued in U.S. Appl. No. 10/572,340 dated Nov. 27, 2009.

Office Action issued in U.S. Appl. No. 10/572,340 dated May 28, 2009.

Office Action issued in U.S. Appl. No. 10/572,340 dated Sep. 12, 2008.

Office Action issued in U.S. Appl. No. 10/572,340 dated Oct. 9, 2007.

Notice of Allowance issued in U.S. Appl. No. 14/580,257 dated Jul. 8, 2020.

Office Action issued in U.S. Appl. No. 14/580,257 dated Mar. 13, 2019.

Office Action issued in U.S. Appl. No. 14/580,257 dated Nov. 30, 2018.

Office Action issued in U.S. Appl. No. 14/580,257 dated Apr. 20, 2018.

Office Action issued in U.S. Appl. No. 14/580,257 dated Dec. 29, 2017.

Office Action issued in U.S. Appl. No. 14/580,257 dated Feb. 21, 2017.

Office Action issued in U.S. Appl. No. 14/580,257 dated Sep. 29, 2016.

Office Action issued in U.S. Appl. No. 14/580,257 dated May 16, 2016.

Office Action issued in U.S. Appl. No. 14/580,257 dated Oct. 29, 2015.

Office Action issued in U.S. Appl. No. 16/788,701 dated Dec. 30, 2020.

Office Action issued in U.S. Appl. No. 16/788,701 dated Sep. 2, 2020.

* cited by examiner

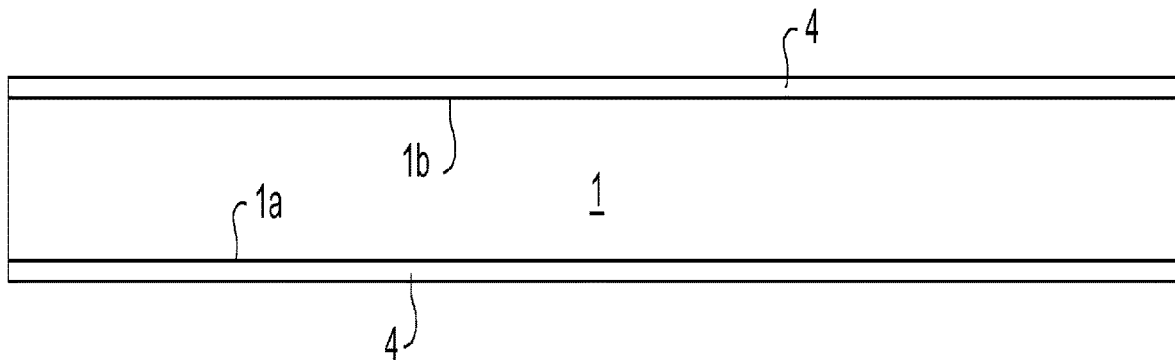


Fig. 1

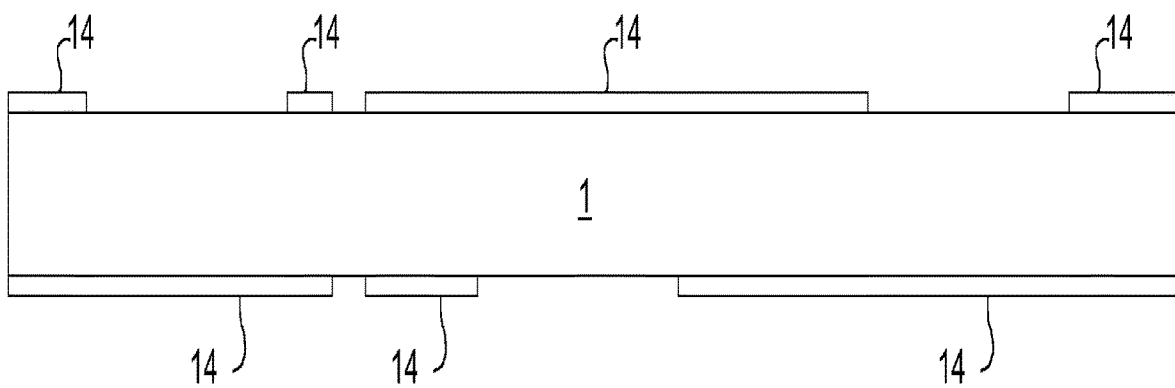


Fig. 2

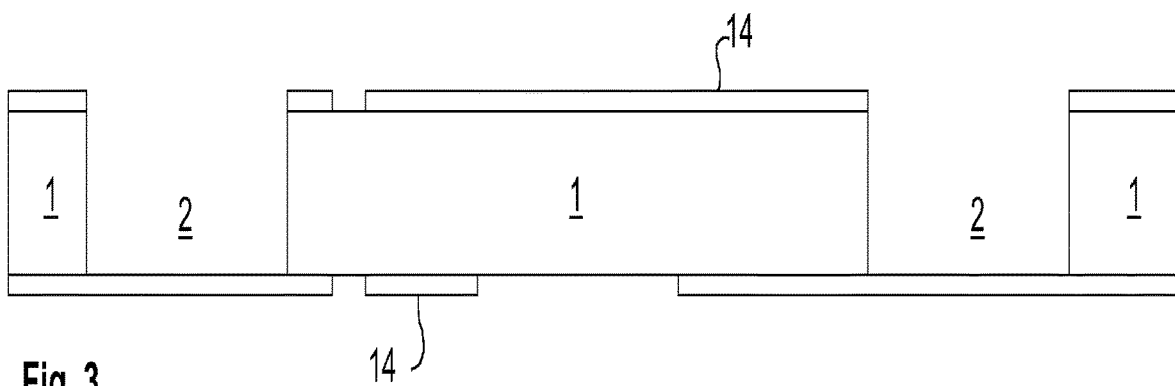


Fig. 3

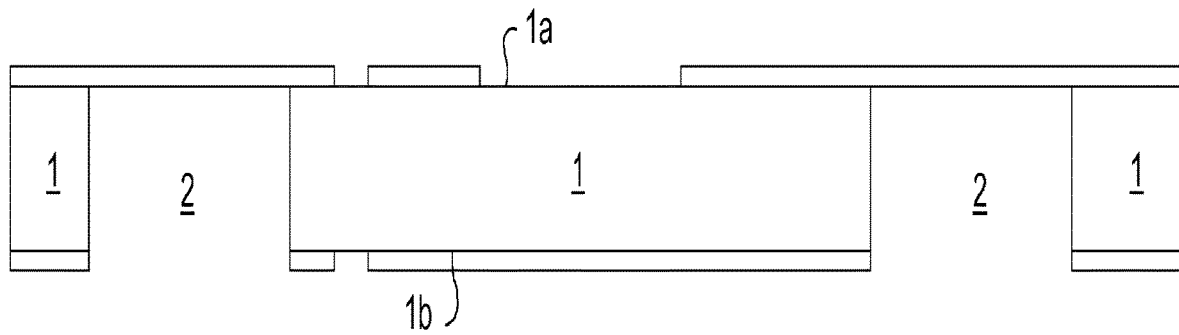


Fig. 4

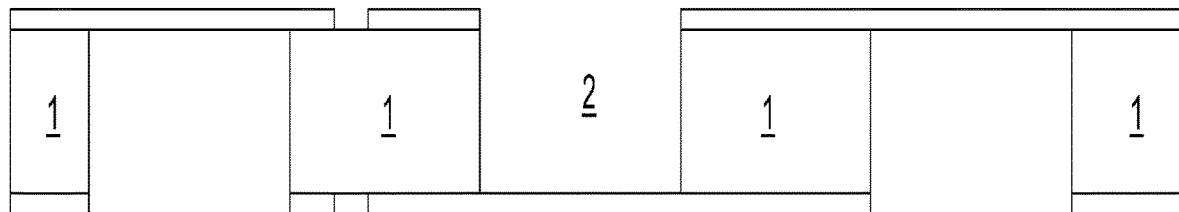


Fig. 5

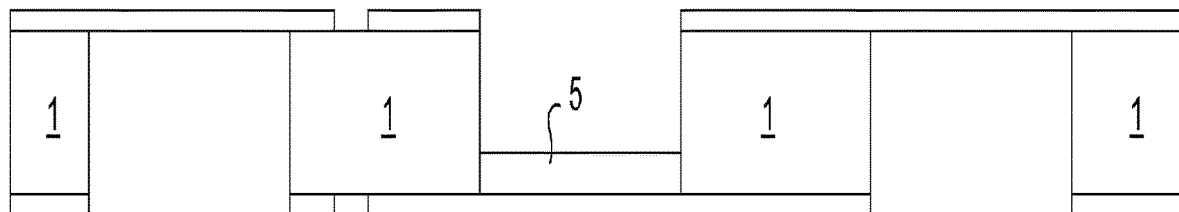


Fig 6

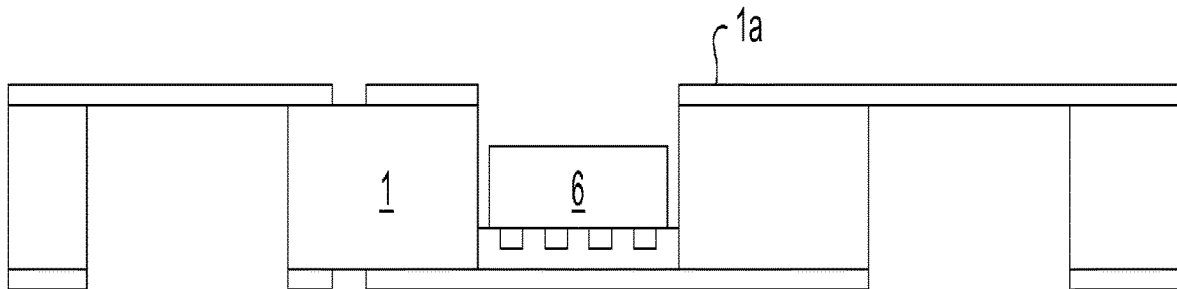


Fig. 7

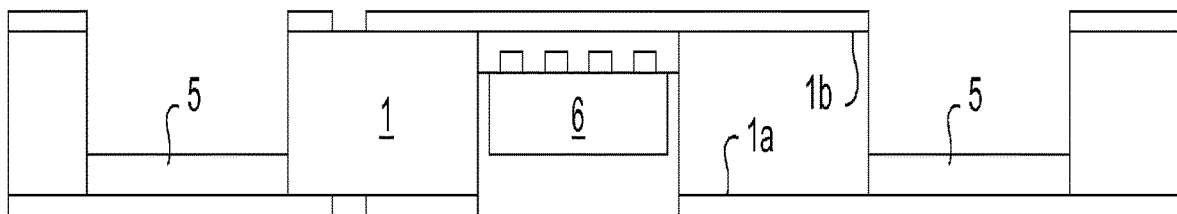


Fig. 8

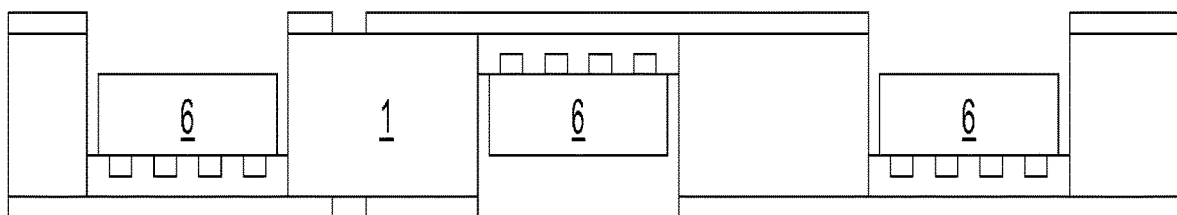


Fig. 9

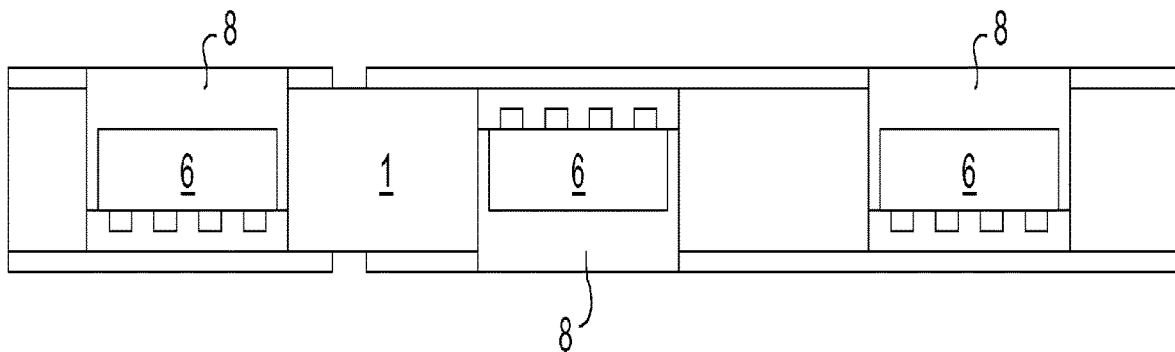


Fig. 10

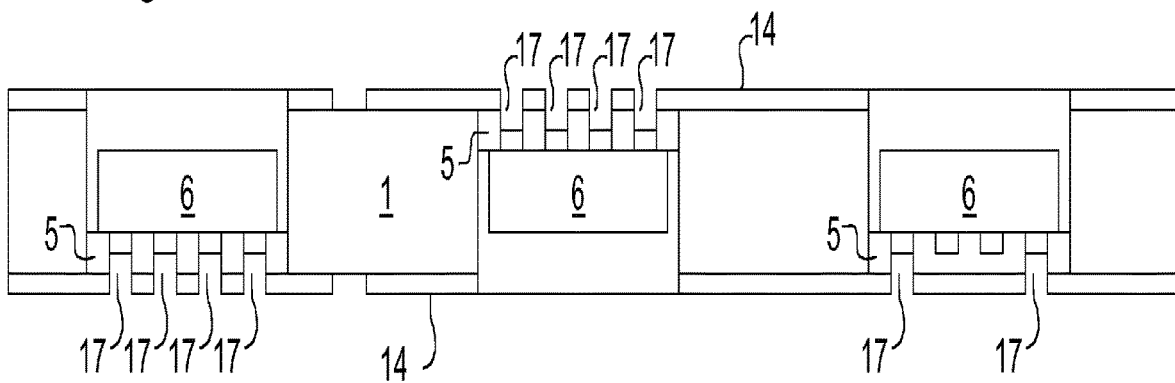


Fig. 11

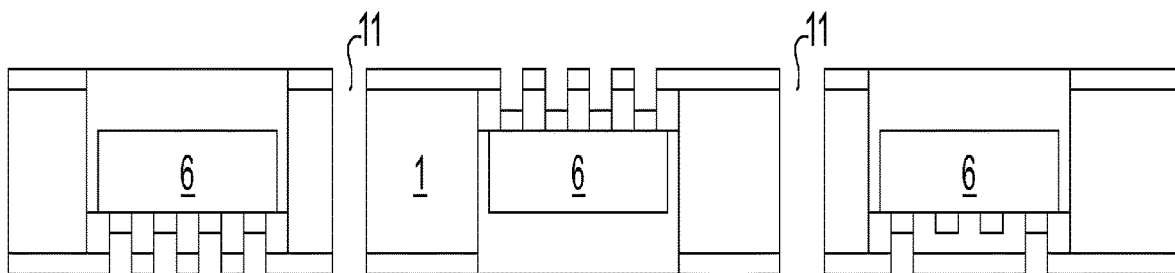


Fig. 12

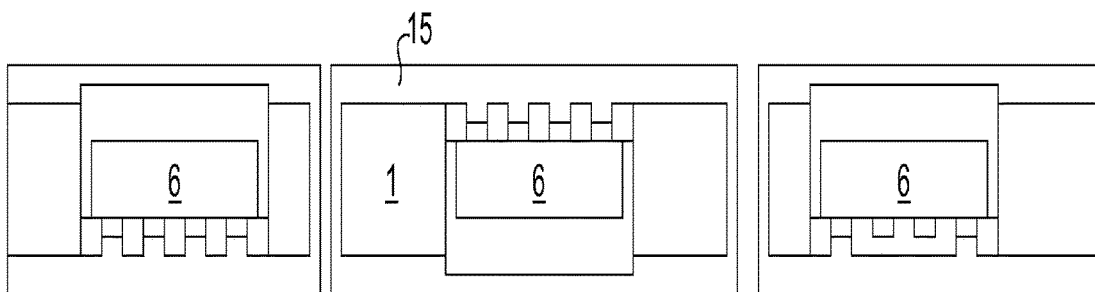


Fig. 13

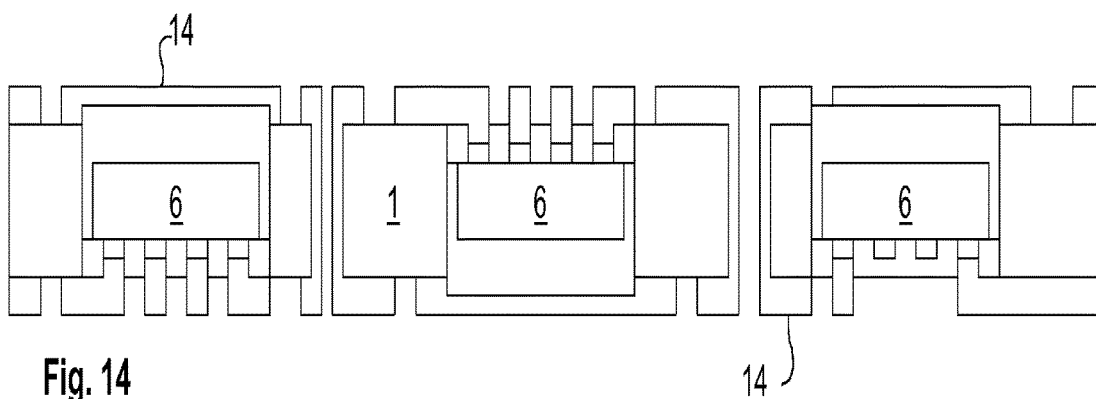


Fig. 14

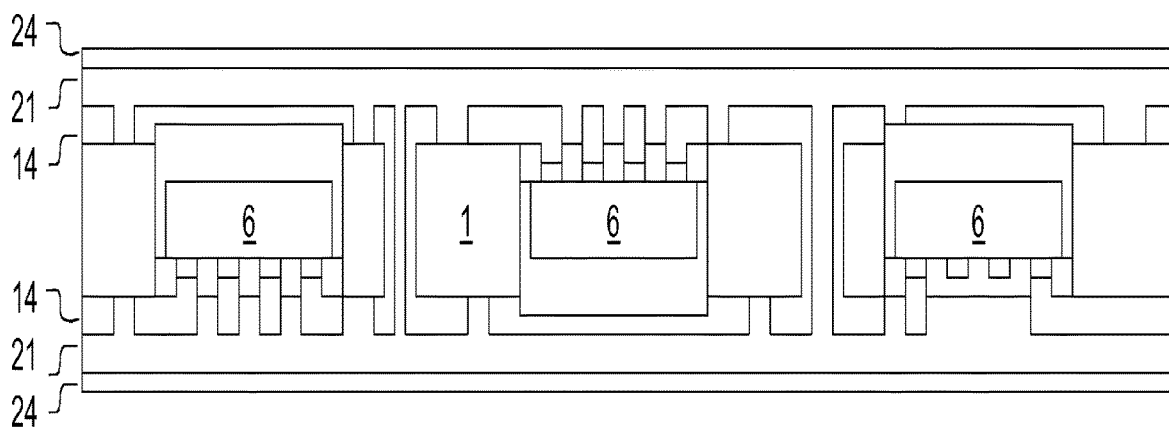


Fig. 15

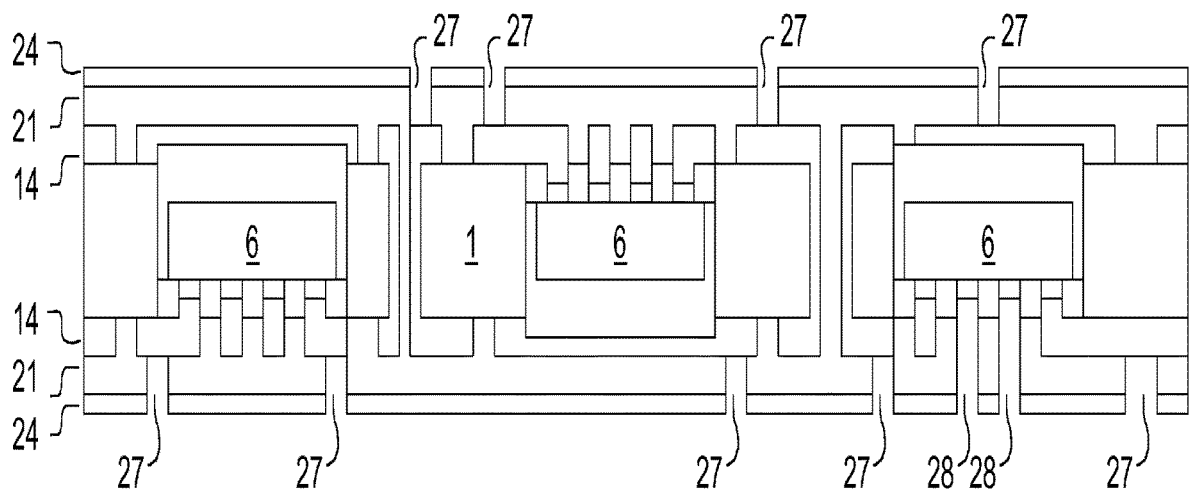


Fig. 16

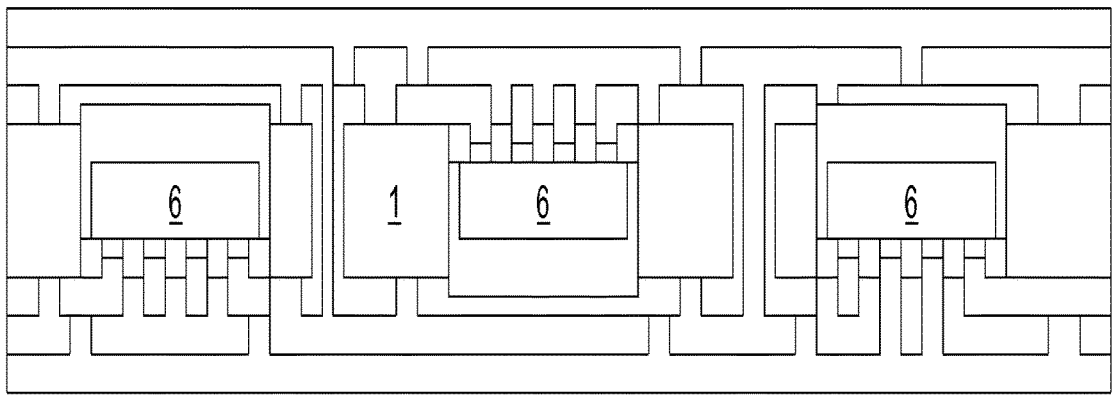
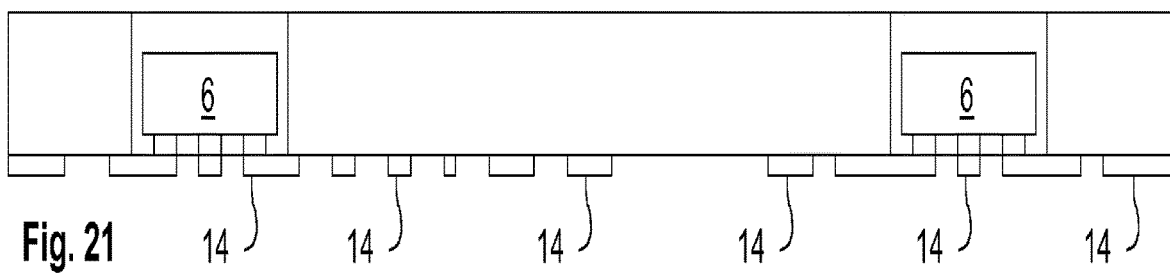
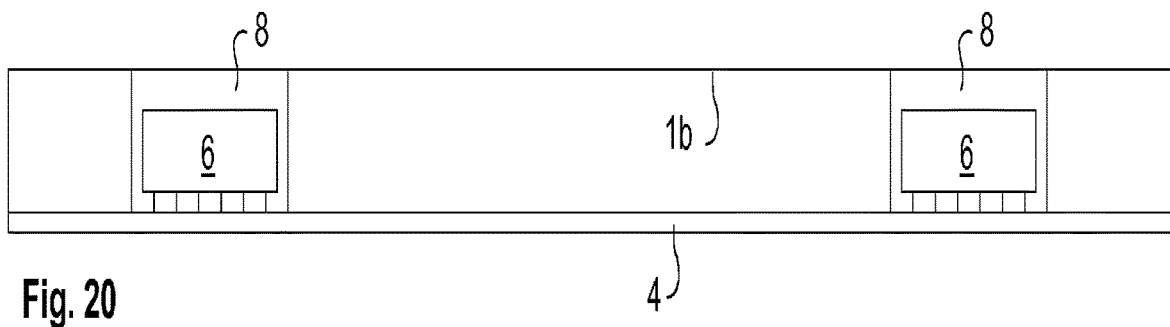
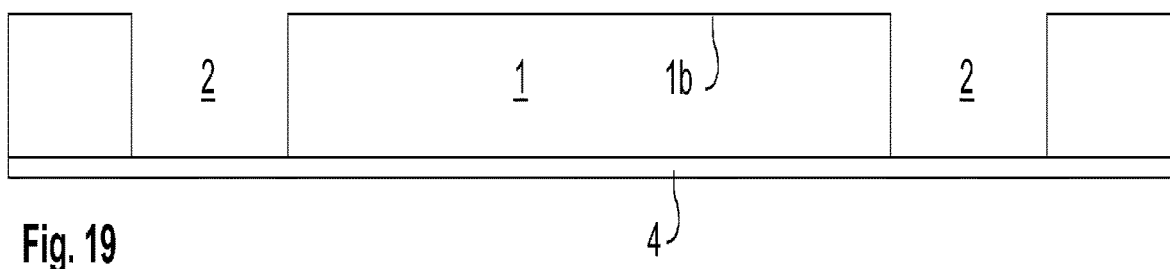
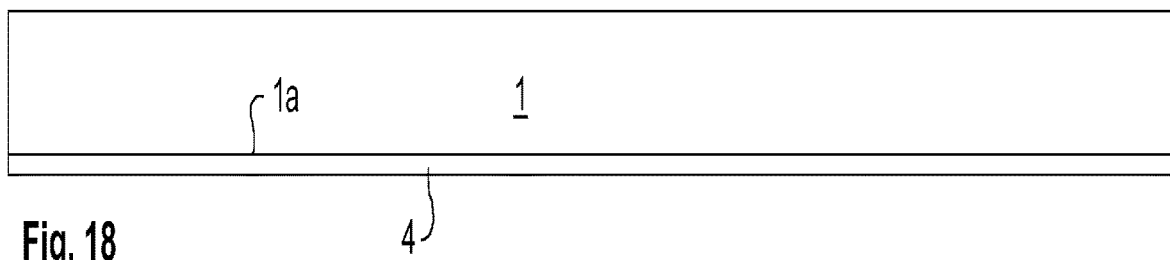


Fig. 17



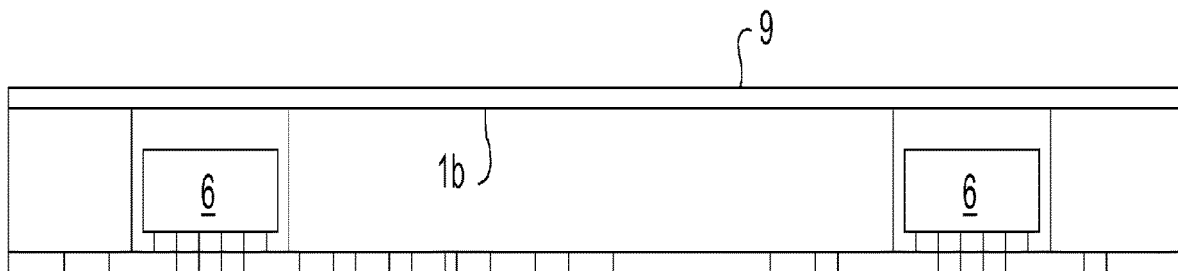


Fig. 22

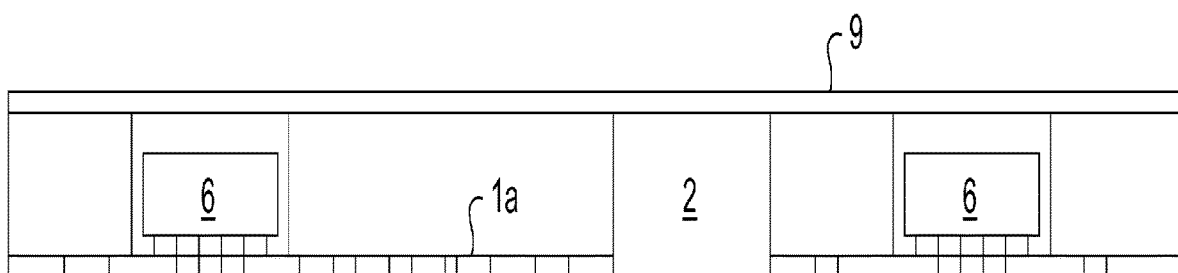


Fig. 23

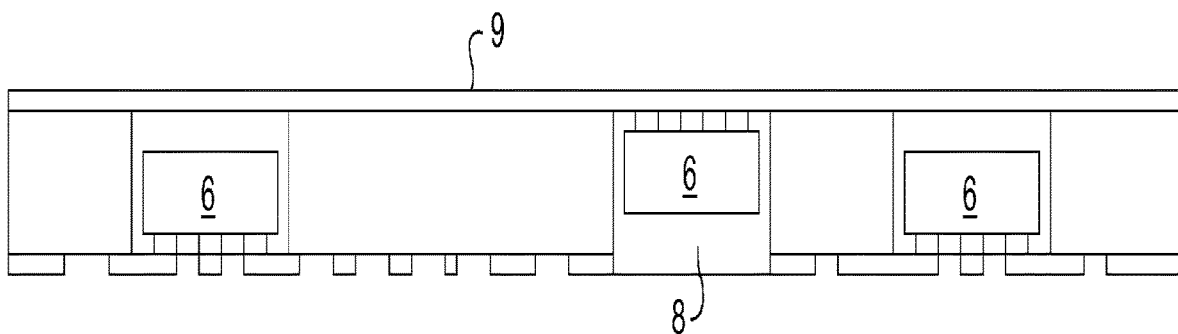


Fig. 24

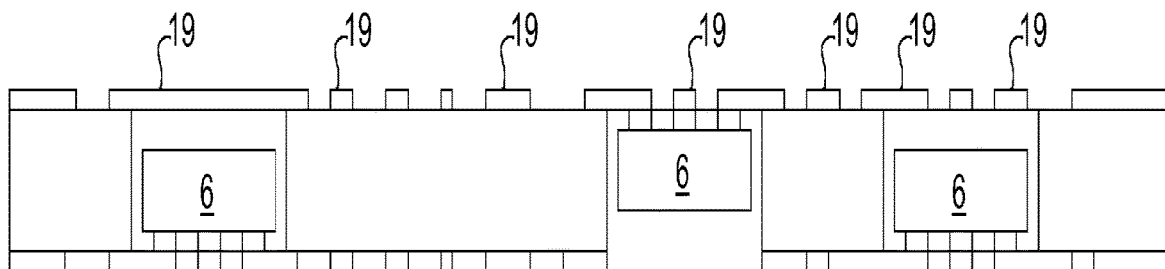


Fig. 25

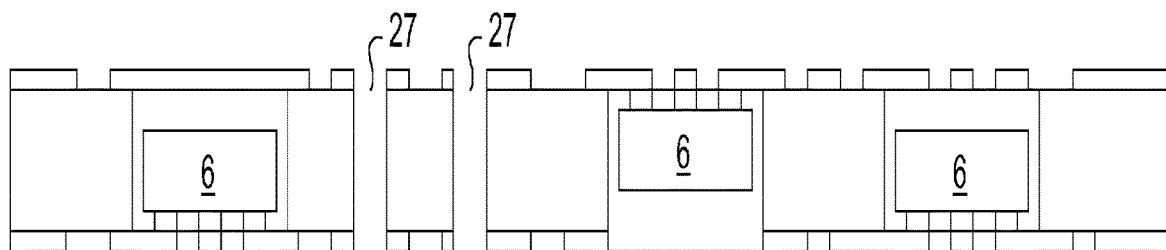


Fig. 26

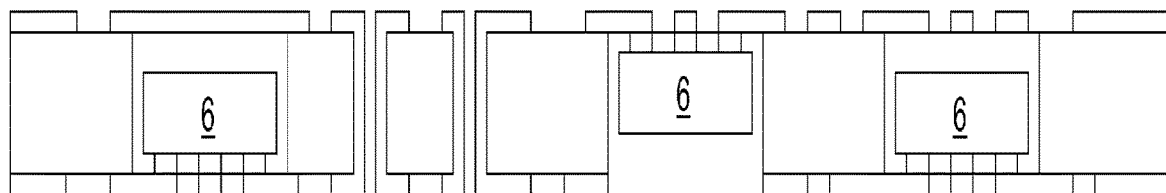
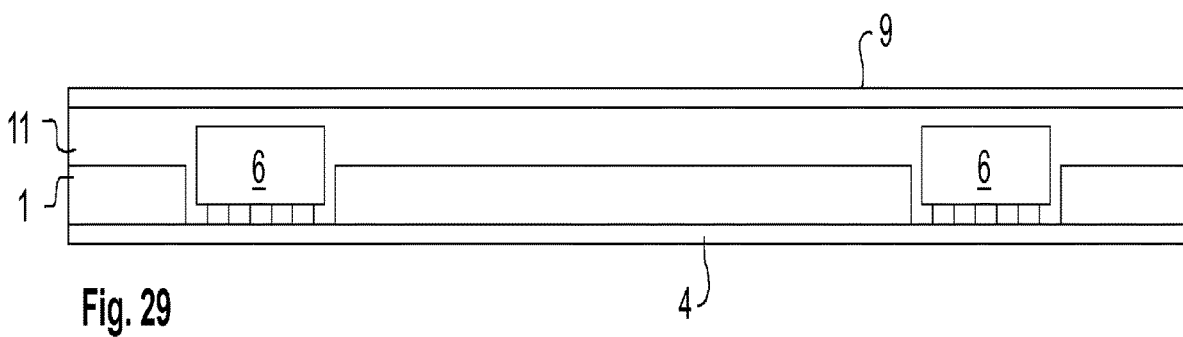
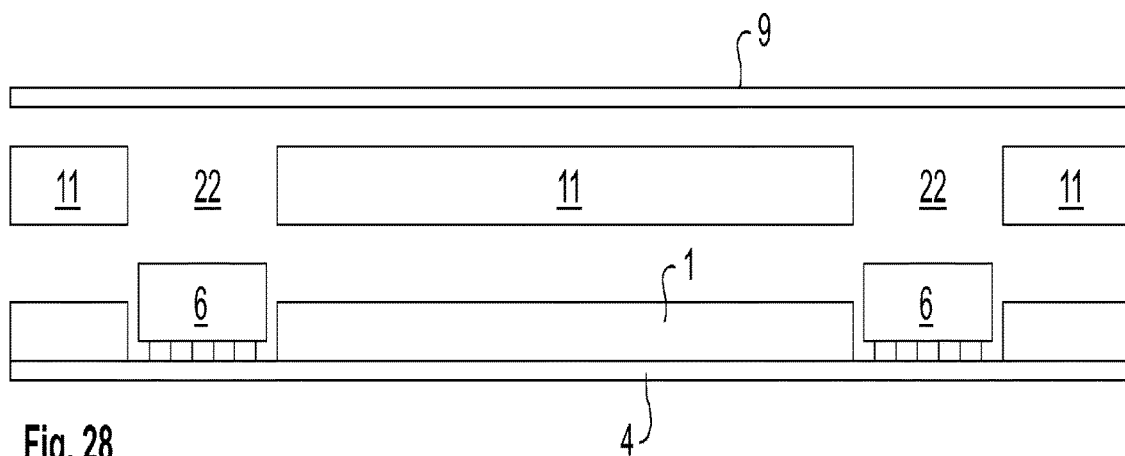
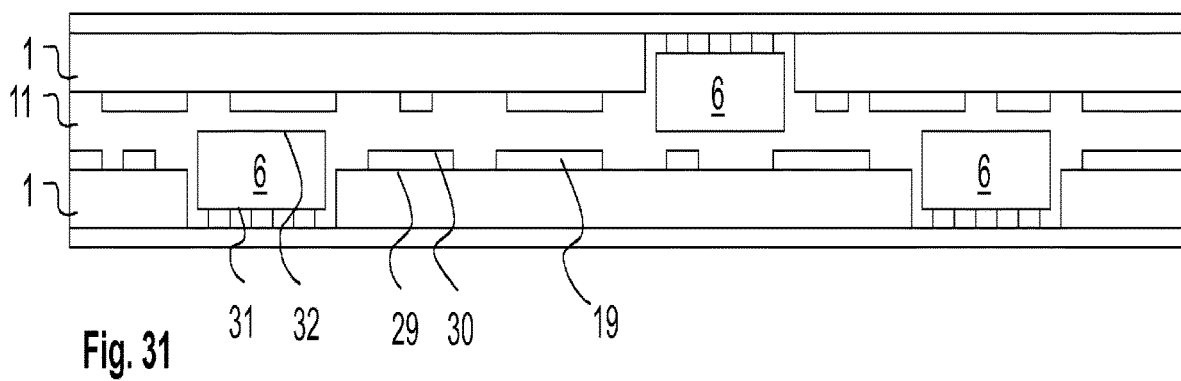
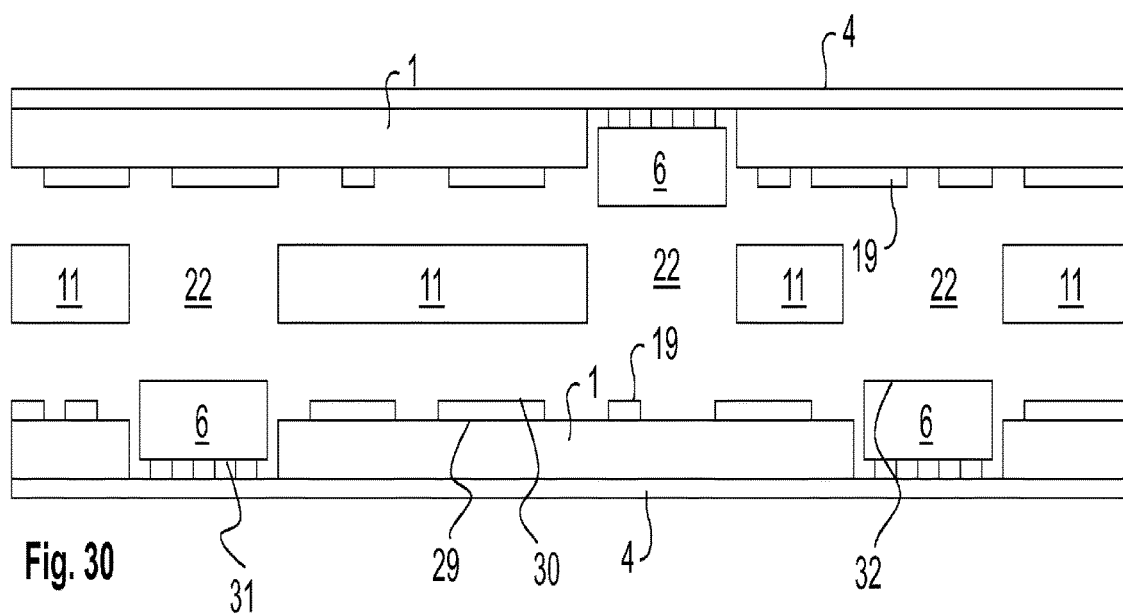
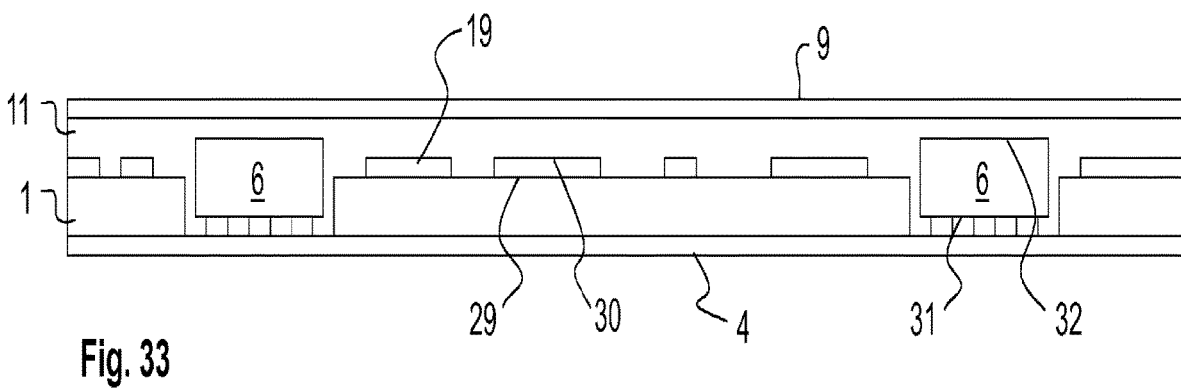
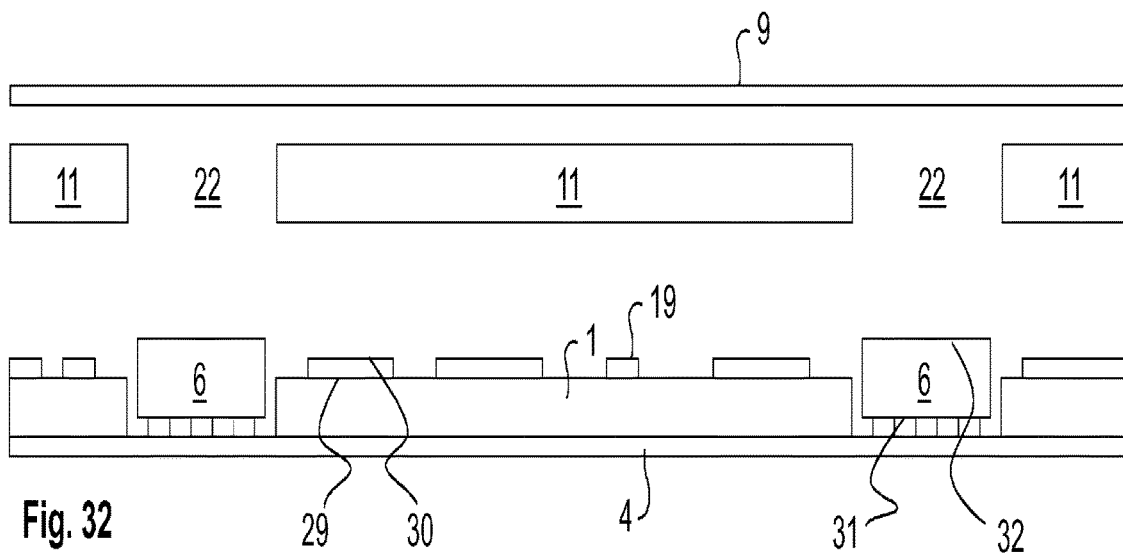
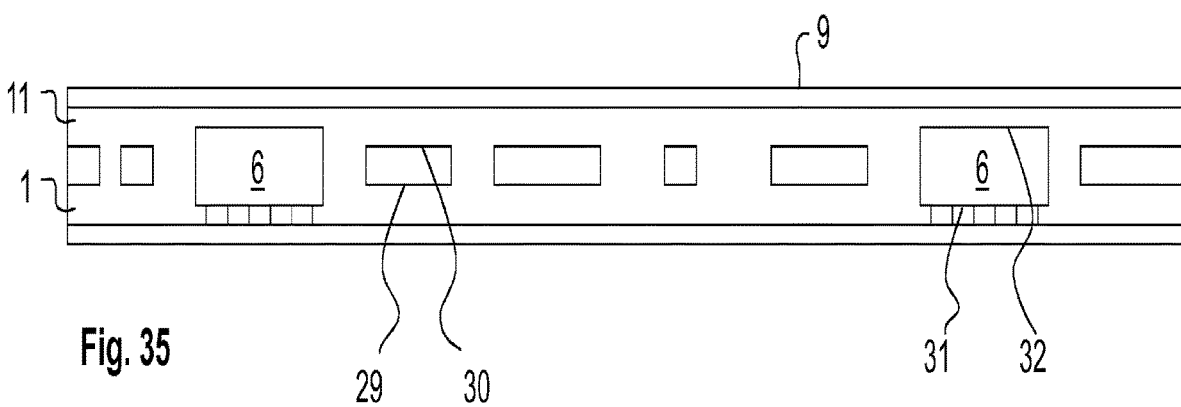
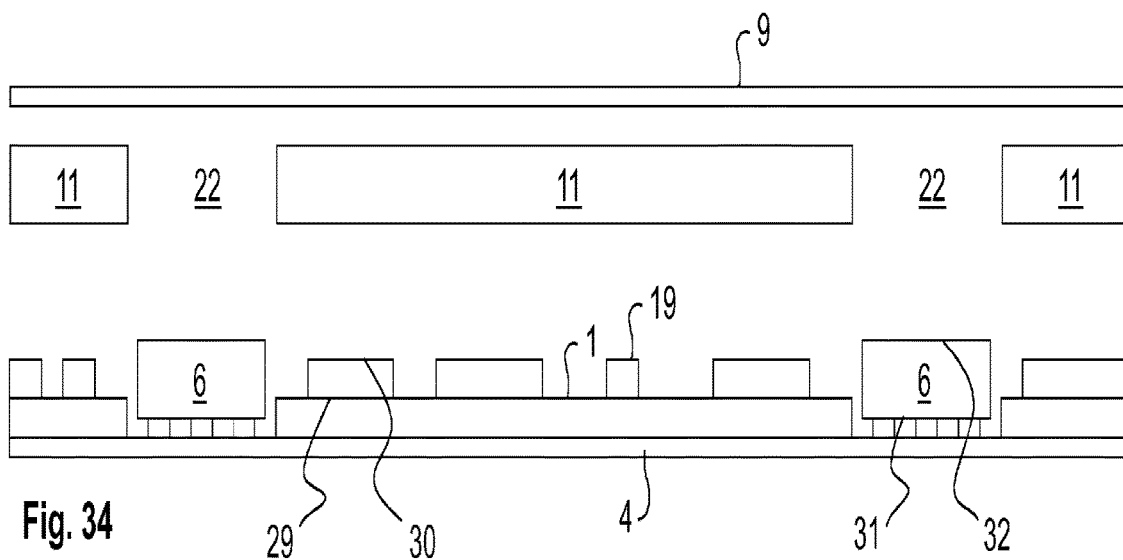


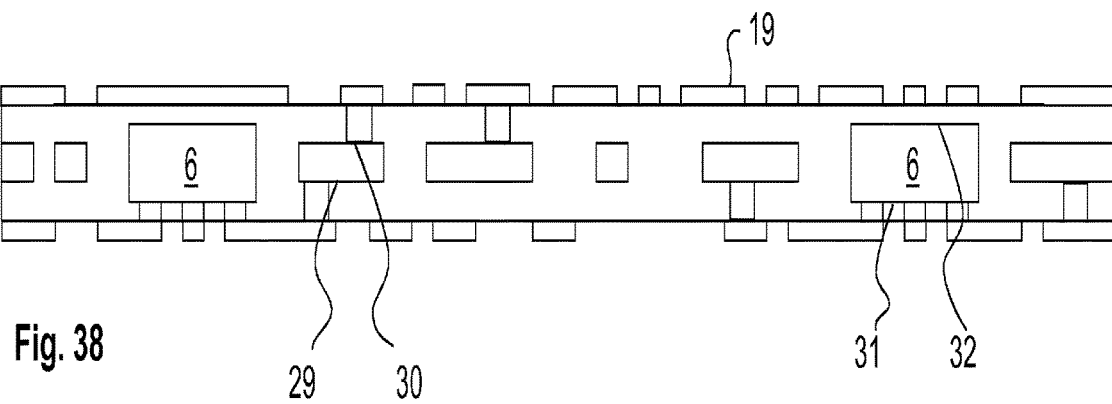
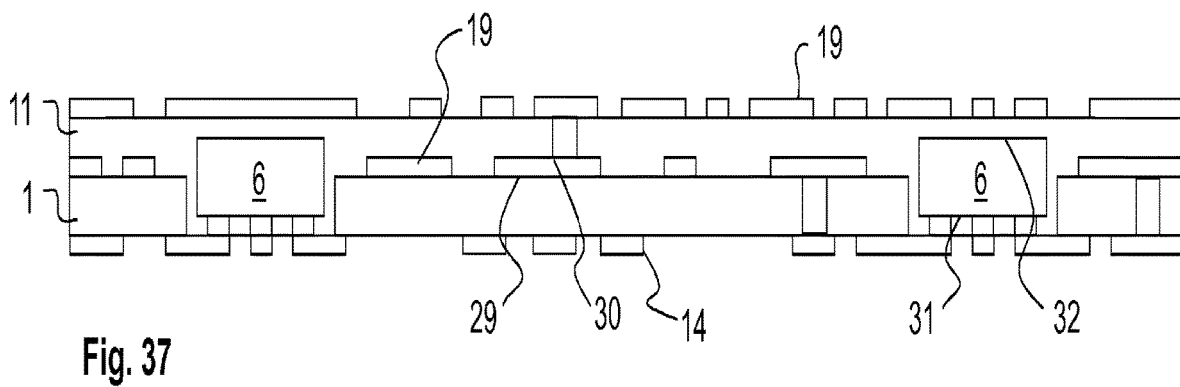
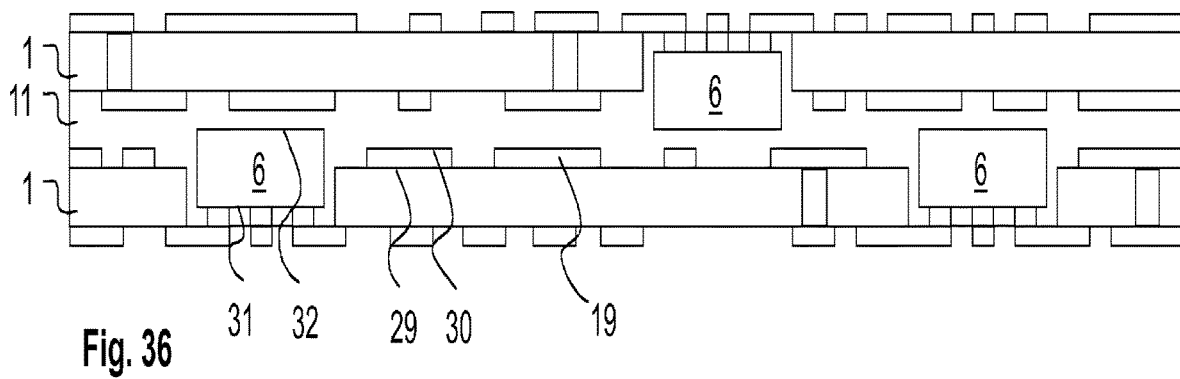
Fig. 27











1

METHOD FOR MANUFACTURING AN ELECTRONIC MODULE AND ELECTRONIC MODULE

RELATED APPLICATIONS

This application is a Continuation of U.S. patent application Ser. No. 16/788,701, filed on Feb. 12, 2020, which is a Continuation of U.S. patent application Ser. No. 14/580,257, filed on Dec. 23, 2014, which is a Continuation-in-Part of U.S. patent application Ser. No. 10/572,340, filed on Sep. 15, 2004. The subject matter of which is incorporated by reference herein in its entirety.

FIELD OF THE INVENTION

Aspects of the present invention relate to an electronic module.

Further aspects of the present invention relate to a method for manufacturing an electronic module.

In particular, embodiments of the invention relate to an electronic module, in which one or more components are embedded in an installation base. The electronic module being manufactured can be a module like a circuit board, which includes several components, which are connected to each other electrically, through conducting structures manufactured in the module. Embodiments of the invention relate to an electronic module, which contains microcircuits, to which several contact terminals are connected. In addition to, or in place of microcircuits, other components too, for example, passive components, can, of course, be embedded in the installation base. Thus, the intention is to embed in the electronic module such components as are typically attached in an unpackaged form to the circuit board (to the surface of the circuit board). Another important group of components are components that are typically packaged for connection to a circuit board. The electronic modules to which the invention relates can, of course, also include other types of components.

BACKGROUND OF THE INVENTION

The installation base can be of a type similar to the bases that are generally used in the electronics industry as installation bases for electrical components. The task of the base is to provide components with a mechanical attachment base and the necessary electrical connections to both components that are on the base and those that are outside the base. The installation base can be a circuit board, in which case the construction and method to which the invention relates are closely related to the manufacturing technology of circuit boards. The installation base may also be some other base, for example, a base used in the packaging of a component or components, or a base for an entire functional module.

The manufacturing techniques used for circuit boards differ from those used for microcircuits in, among other things, the fact that the installation base in microcircuit manufacturing techniques, i.e. the substrate, is of a semiconductor material, whereas the base material of an installation base for circuit boards is some form of insulating material. The manufacturing techniques for microcircuits are also typically considerably more expensive than the manufacturing techniques for circuit boards.

The constructions and manufacturing techniques for the cases and packages of components, and particularly semiconductor components differ from the construction and manufacture of circuit boards, in that component packaging

2

is primarily intended to form a casing around the component, which will protect the component mechanically and facilitate the handling of the component. On the surface of the component, there are connector parts, typically protrusions, which allow the packaged component to be easily set in the correct position on the circuit board and the desired connections to be made to it. In addition, inside the component case, there are conductors, which connect the connector parts outside the case to connection zones on the surface of the actual component, and through which the component can be connected as desired to its surroundings.

However, component cases manufactured using conventional technology demand a considerable amount of space. As electronic devices have grown smaller, there has been a trend to eliminate component cases, which take up space, are not essential, and create unnecessary costs. Various constructions and methods have been developed to solve this problem, with the aid of which components can be placed inside the circuit-board structure.

US patent publication 4 246 595 discloses one solution, in which recesses are formed in the installation base for the components. The bottoms of the recesses are bordered by a two-layered insulation layer, in which holes are made for the connections of the component. The layer of the insulation layer that lies against the components is made of an adhesive. After this, the components are embedded in the recesses with their connection zones facing the bottom of the recess, electrical contacts being formed to the components through the holes in the insulation layer. If it is wished to make the structure mechanically durable, the component must also be attached to an installation base, so that the method is quite complicated. It is extremely difficult to use a complicated method, which demands several different materials and process stages, to profitably manufacture cheap products.

JP application publication 2001-53 447 discloses a second solution, in which a recess is made for the component in an installation base. The component is placed in the recess, with the component's contact areas facing towards the surface of the installation base. Next, an insulation layer is made on the surface of the installation base and over the component. Contact openings for the component are made in the insulation layer and electrical contacts are made to the component, through the contact openings. In this method, considerable accuracy is demanded in manufacturing the recess and setting the component in the recess, so that the component will be correctly positioned, to ensure the success of the feed-throughs, relative to the width and thickness of the installation board.

International patent application publication WO 03/065778 discloses a method, in which at least one conductive pattern is made in the base, as are through-holes for semiconductor components. After this, the semiconductor components are placed in the holes, aligned relatively to the conductive pattern. The semiconductor components are attached to the structure of the base and one or more conductive-pattern layers are manufactured in the base, in such a way that at least one conductive pattern forms an electrical contact with the contact areas on the surface of the semiconductor component.

International patent application publication WO 03/065779 discloses a method, in which through-holes are made in the base for semiconductor components, in such a way that the holes extend between the first and second surfaces of the base. After the manufacture of the holes, a polymer film is spread over the second surface of the base structure, in such a way that the polymer film also covers the

through-holes made for the semiconductor components, on the second side of the base structure. Before the hardening of the polymer film, or after its partial hardening, the semiconductor components are placed in the holes made in the base, from the direction of the first surface of the base. The semiconductor components are pressed against the polymer film so that they adhere to the polymer film. After this, the final hardening of the polymer film is performed and additional conductive-pattern layers are manufactured, in such a way that at least one conductive pattern forms an electrical contact with the contact areas on the surface of the semiconductor components.

SUMMARY OF THE INVENTION

It is an object of certain embodiments of the invention to provide an electronic module. It is another object of certain embodiments of the invention to create a simple and reliable method with low manufacturing costs, for embedding components in an installation base.

Embodiments of the invention are based on commencing manufacture from an insulating board, which is surfaced on at least one side with a conductive layer. After this, a recess or opening is made in the insulation, which opens onto one surface of the board, but does not penetrate the conductive layer on the opposite surface of the board. A component is attached to the recess or opening and electrical contacts are formed between the conductive layer and the contact areas, or contact protrusions of the component. After the attachment of the component, conductive patterns are formed from this conductive layer, which become part of the circuit-board structure, or other electronic module. An additional conductive pattern is embedded in the insulating-material of the module. According to one example, there is an electronic module, comprising a first conductive pattern layer and a first insulating-material layer on at least one surface of the first conductive pattern layer, at least one opening in the first insulating-material layer that extends through the first insulating-material layer, a component having a contact surface with contact terminals, the component being arranged at least partially within the opening with its contact terminals electrically coupled to the first conductive pattern layer, a second insulating-material layer provided on the first insulating-material layer, and a conductive pattern embedded between the first and second insulating material layers.

Considerable advantages are gained with the aid of embodiments of the invention. This is because embodiments of the invention can be used to design a simple and reliable method with low manufacturing costs, which can be used to manufacture electronic modules containing embedded components. The conductively surfaced insulating board used as the basic material is one of the basic raw materials of the circuit-board industry and boards of this kind are available cheaply and reliably. In the method, the use of the raw material is extremely efficient, as the conductively surfaced insulating board is exploited to manufacture the conductive patterns of the electronic module. Even circuits that are embedded inside the insulating board can be connected electrically to this conductive-pattern layer. An additional conductive pattern can be embedded in the insulating material of the board which can be connected electrically to the conductive-pattern layer. The embedded conductive pattern can be totally separated from the environment by means of the insulating-material layers.

According to certain embodiments of the invention, at least one neutral bending axis of the electronic module can be in the middle of or inside the embedded conductive

pattern. Such a location of an embedded conductive pattern in the electronic module can minimize the risk of breaking an embedded conductive pattern due to bending of the structure during manufacturing steps of the electronic module at a later stage or due to unintentional bending of the module as such after manufacture. This can improve reliability and lifetime of the embedded conductive pattern and the module as such.

The invention has embodiments, according to which relatively few process stages are required in the manufacturing process. Embodiments with fewer processing stages correspondingly also need less process equipment and various manufacturing methods. With the aid of such embodiments, in many cases it is also possible to reduce the manufacturing costs, compared to more complicated processes.

The number of the conductive-pattern layers of the electronic module in addition to the at least one embedded conductive pattern can also be selected according to the embodiments. There can be, for example, one or two conductive-pattern layers. In addition, additional conductive-pattern layers can also be manufactured on top of them, in the manner known in the circuit-board industry. There can thus be a total of, for example, three, four, or five conductive-pattern layers in a module. In the very simplest embodiments, there is only a single conductive-pattern layer, and, indeed, any conductive layer. In some embodiments, each of the conductive layers contained in an electronic module can be utilized to form conductive patterns.

There are also embodiments of the invention, in which conductive patterns can be manufactured at the locations of the components. This will increase the wiring capability of the structure, which, in turn, will permit the components to be placed closer together. The wiring capability can also be improved by placing some of the components 'upside-down', so that the active surfaces of components will face both surfaces of the board.

BRIEF DESCRIPTION OF THE FIGURES

For a more complete understanding of particular embodiments of the present invention and their advantages, reference is now made to the following descriptions, taken in conjunction with the accompanying drawings. In the drawings:

FIGS. 1-17 show a series of cross-sections of an example of a manufacturing method of an electronic module.

FIGS. 18-27 show a series of cross-sections of another example of a manufacturing method of an electronic module.

FIGS. 28 and 29 show two intermediate stages of the manufacture of an electronic module.

FIGS. 30 and 31 show two intermediate stages of the manufacture of an electronic module in manufacturing methods according to certain embodiments of the present invention.

FIGS. 32 and 33 show two intermediate stages of the manufacture of an electronic module in manufacturing methods according to certain embodiments of the present invention.

FIGS. 34 and 35 show two intermediate stages of the manufacture of an electronic module in manufacturing methods according to certain embodiments of the present invention.

5

FIGS. 36, 37 and 38 show examples of patterned conductive layers from the conductive layers of FIGS. 31, 33 and 35 respectively.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS OF THE INVENTION

In the methods of the examples, manufacturing is started by manufacturing an installation base of insulating material, which has a conductive layer on at least one surface. Typically, a commercially available sheet 1 of insulating material, both surfaces 1a, 1b of which are surfaced with a conductive layer 4, is selected as the installation base. The insulating material 1 can be, for example, glass-fibre-reinforced epoxy (e.g., FR4). The conductive material 4 is, for its part, usually copper.

The installation base is typically selected in such a way that the thickness of the insulating material layer 1 is greater than the thickness of the components 6 to be later attached to the base, although this is not essential. Recesses or openings 2, the size of which is selected according to the size of the components 6 being installed, are manufactured by a suitable method in the insulating-material layer 1. The recesses or openings 2 are manufactured in such a way that the conductive layer 4 on the surface of the insulating material layer 1 closes one or other end of the recess or opening 2. This is achieved, for example, by removing the conductive material 4 on the first surface of the installation base around the recess or opening 2. In connection with the removal of the conductive material 4, other patterns can also be formed in the conductive-pattern layer 4, for example, the patterns of the conductors of the circuit that will be formed. After this, the making of recesses or openings 2 is continued using a suitable selective method, which affects the insulating material 1 but not the conductive layer 4. The recess or opening 2 thus manufactured should extend through the entire insulating material layer 1, while the conductive layer 4 at the other end of the recess or opening 2 remains undamaged. Recesses or openings 2 can be made in a corresponding manner from the directions of both surfaces.

Suitable alignment marks are also required to align the components 6, for the creation of which several different methods are available. One possible method is the making of small through-holes in the vicinity of the installation holes 2 of the components 6.

The components 6 are aligned in their installation holes 2 with the aid of the alignment holes or other alignment marks and the components are attached to the conductive layer 4. The components 6 can be attached to the conductive layer 4 using a method that permits the formation of an electrical contact between the conductive layer 4 and the contact areas of the component. Such methods are, for example, the ultrasonic bonding method, the thermo-compression method, and gluing with an electrically conductive adhesive. Alternatively, it is possible to use a method, in which an electrical contact is formed between the conductive layer 4 and the contact areas of the component. Such a method, is, for example, gluing with an insulating adhesive. In the following, the procedure of the process is described in greater detail, in connection with the attachment methods referred to above.

The term ultrasonic methods refers to a method, in which two pieces containing metal are pressed together and vibration energy is brought to the attachment area at an ultrasound frequency. The ultrasound and the pressure created between the surfaces being attached cause the pieces being attached to bond metallurgically to each other. Methods and devices

6

for creating ultrasound joints (ultrasonic bonding) are commercially available. Ultrasonic bonding has the advantage that a high temperature is not required to form the joint.

The term thermo-compression method refers to a method, in which two pieces containing metal are pressed against each other and thermal energy is applied to the joint area. The thermal energy and the pressure created between the surfaces being attached cause the pieces being attached to bond metallurgically to each other. Methods and devices for making thermo-compressed joints (thermo-compression bonding) are also commercially available.

The term adhesive refers to a material, by means of which the components can be attached to the conductive layer. One property of the adhesive is that the adhesive can be spread on the surface of the conductive layer, and/or of the component in a relatively fluid form, or otherwise in a form that will conform to the shape of the surface. Another property of the adhesive is that, after spreading, the adhesive hardens, or can be hardened, at least partly, so that the adhesive will be able to hold the component in place (relative to the conductive layer), at least until the component is secured to the structure in some other manner. A third property of the adhesive is its adhesive ability, i.e. its ability to stick to the surface being glued.

The term gluing refers to the attachment of the component and conductive layer to each other with the aid of an adhesive. Thus, in gluing, an adhesive is brought between the component and the conductive layer and the component is placed in a suitable position relative to the conductive layer, in which the adhesive is in contact with the component and the conductive layer and at least partly fills the space between the component and the conductive layer. After this, the adhesive is allowed (at least partly) to harden, or the adhesive is actively hardened (at least partly), so that the component sticks to the conductive layer with the aid of the adhesive. In some embodiments, the contact protrusions of the component may, during gluing, extend through the adhesive layer to make contact with the conductive layer.

The components 6 can thus be attached to the surface of the conductive layer 4 with the aid of an electrically conductive adhesive. Electrically conductive adhesives suitable for this purpose are generally available in two basic types: isotropically conductive adhesives and anisotropically conductive adhesives. An isotropically conductive adhesive conducts in all directions, whereas an anisotropically conductive adhesive has a conductive direction and a direction diametrically opposite to this, in which the conductivity of the adhesive is extremely low. An anisotropically conductive adhesive can be formed, for example, from an isolating adhesive, into which suitable conductor particles are mixed. If an anisotropically conductive glue is used, the glue can be dosed over the component's entire surface that is being glued. When using an isotropically conductive glue, dosing should be performed by area, so that short-circuits are not created between the contact areas.

After the attachment of the components, the space remaining in the installation recess or opening 2 is typically filled with a filler 8. After this, the conductive layer 4 can be patterned, so that conductive patterns 14 are formed, at least some of which are connected to the contact areas of some of the components 6. After this, the process can be continued by manufacturing additional conductive-pattern layers and manufacturing the necessary through-holes.

Manufacturing exploiting the ultrasonic method and the thermo-compression method are disclosed in greater detail in the same applicant's Finnish patent application FI20030292, filed on 26 Feb. 2003.

7

Manufacturing exploiting conductive glues are, in turn, disclosed in greater detail in the same applicant's Finnish patent application FI20031201, filed on 26 Aug. 2003.

Thus, instead of attachment methods forming an electrical contact, it is also possible to use methods, in which an electrical contact is not formed. Such a joint can be made, for example, by gluing the component **6** to the surface of the conductive layer **4** with the aid of an insulating adhesive. After gluing, the installation recess or opening **2** can be filled with a filler **8** and the feed-throughs made, through which electrical contacts can be formed between the contact areas of the components **6** and the conductive layer **4**. Holes **17** for the feed-throughs are made in the conductive layer **4**, at the contact areas of the components **6**. The holes **17** are made in such a way that they also break through the adhesive layer that has remained on top of the contact areas, or the contact protrusions. The holes **17** thus extend as far as the material of the contact protrusions or other contact areas of the components **6**. The holes **17** can be made, for example, by drilling with a laser device, or by using some other suitable method. After this, conductive material is brought to the holes **17**, in such a way that an electrical contact is formed between the component **6** and the conductive layer **4**.

After this, the conductive layer **4** can be patterned, so that conductive patterns **14** are formed, at least some of which are connected to some of the contact areas of the components **6**. After this, the process can be continued by manufacturing additional conductive-pattern layers and manufacturing the necessary feed-throughs.

Manufacturing processes exploiting an insulating adhesive are disclosed in greater detail in the same applicant's Finnish patent application FI20030493, filed on 1 Apr. 2003.

The manufacturing processes according to the embodiments of the invention can be implemented using manufacturing methods that are generally known to one versed in the art of manufacturing circuit boards.

In the following, the stages of the method shown in FIGS. 1-17 are examined in greater detail.

Stage A (FIG. 1):

In stage A, a sheet of suitable insulating material **1**, from which the body of the installation base is formed, is selected for the electronic-module manufacturing process. In the example using single insulating-material layer, the insulating-material layer **1** should preferably be thicker than the component being installed. It will then be possible to embed the component entirely inside the installation base and the electronic module will be smooth on both sides. Thicker special components, the rear surface of which will protrude beyond the insulating-material layer **1**, can, of course, also be embedded in the installation base. This is the preferred procedure particularly in such examples, in which several insulating-material layers are used, which are joined together during the process. In that case, the components can be embedded entirely in the structure, if the total thickness of the insulating-material layer exceeds the thickness of the component. On account of the durability of the structure, it is preferable for the components in the finished electronic module to be located entirely inside the installation base.

The insulating-material layer **1** can be, for example, a polymer base, such as a sheet of glass-fibre reinforced epoxy FR4. Other materials suitable for the insulating-material layer **1** are PI (polyimide), FR5, aramid, polytetrafluoroethylene, Teflon®, LCP (liquid crystal polymer), and a pre-hardened binder layer, i.e. prepreg.

Prepeg refers to one of the basic materials of the circuit-board industry, which is generally a glass-fibre-reinforced insulating mat saturated with B-stage resin. A pre-hardened

8

binder layer is typically used as a binding insulating material, when manufacturing multi-layer circuit-boards. Its B-stage resin is cross-bridged in a controlled manner with the aid of temperature and pressure, for example, by pressing or laminating, so that the resin hardens and becomes C-stage. In the controlled hardening cycle, during the rise in temperature, the resin softens and its viscosity diminishes. Forced by the pressure, the fluid resin fills the holes and openings in its boundary surface. When using a pre-hardened binder layer, this property is exploited to fill the empty space remaining around the components. In this way, it is possible to further simplify the electronic-module manufacturing methods described in the examples, as the installation recesses or openings for the components need not be filled with a separate filler.

The insulating-material layer **1** is surfaced on both sides **1a**, **1b**, with a conductive layer **4**, for example, a metal layer. The manufacturer of the electronic module can also select a ready surfaced insulating sheet as the basic material.

Stage B (FIG. 2):

In stage B, conductive patterns **14** are formed from the conductive layer **4**, using some suitable method. The removal of the conductive material can be performed, for example, using vaporization with a laser, or some selective etching method, which are widely used and well known in the circuit-board industry. The conductive pattern **14** is made in such a way that the surface of the insulating-material layer **1** is exposed at the installation recesses or openings **2** made for the components **6**, or the side of the surface **1a** or **1b**. Correspondingly, the conductive material layer **14** on the opposite surface **1a** or **1b** of the insulating-material layer **1** is left intact.

Stage C (FIG. 3):

In stage C, suitably sized and shaped recesses or openings **2** are made in the insulating-material layer **1**, for the embedding of the components. The recesses or openings **2** can be made as required, using, for example, some known method used in circuit-board manufacture. The recesses or openings **2** can be made, for example, using CO₂. The recesses or openings **2** are made from the direction of the second surfaces **1b** and extend through the entire insulating-material layer **1**, as far as the surface **1a** of the conductive material layer **14** on the opposite surface of the layer.

Stage D (FIG. 4):

In stage D, the blank of the electronic module is turned the other way round.

Stage E (FIG. 5):

In stage E, additional installation recesses or openings **2** in the insulating-material layer **1** are made for components in the direction of the first surface **1a**. Otherwise, the recesses or openings **2** can be made in the same way as in stage C.

Stage F (FIG. 6):

In stage F, an adhesive layer **5** is spread on the bottom of the installation recesses or openings **2**, on top of the conductive layer **14**. The thickness of the adhesive layer **5** is selected so that the adhesive suitably fills the space between the component **6** and the conductive layer **14**, when the component **6** is later pressed onto the adhesive layer **5**. If the component **6** includes contact protrusions **7**, it would be good for the thickness of the adhesive layer **5** to be greater, for example about 1.5-10 times, the height of the contact protrusions, so that the space between the component **6** and the conductive layer **4** will be well filled. The surface area of the adhesive layer **5** formed for the component **6** can also

be slightly larger than the corresponding surface area of the component 6, which will also help to avoid the risk of inadequate filling.

Stage F can be modified in such a way that the adhesive layer 5 is spread on the attachment surfaces of the components 6, instead of on the attachment areas of the conductive layer 14. This can be carried out, for example, by dipping the component in adhesive, prior to setting it in place in electronic module. It is also possible to proceed by spreading the adhesive on both the attachment areas of the conductive layer 14 and on the attachment surfaces of the components 6.

The adhesive used in this example is thus an electrical insulator, so that the adhesive layer 5 itself does not form electrical contacts between the contact areas of the component 6.

Stage G (FIG. 7):

In stage G, the components 6 to be installed from the direction of the first surface 1a are set in place in the electronic module. This can be done, for example, by pressing the components 6 into the adhesive layer 5, with the aid of an assembly machine.

Stage H (FIG. 8):

In stage H, the blank of the electronic module is turned the other way round (see stage D).

Stage I (FIG. 8):

In stage I, an adhesive layer 5 is spread on the bottom of the installation recesses or openings 2 opening onto the second surface 1b. Stage I is performed correspondingly to stage F, but from the direction of the opposite surface of the electronic module.

The work stages (e.g., stage F and I) made from opposite sides of the electronic module can, in principle, also be performed simultaneously or consecutively without turning the blank, if the manufacturing equipment being used permits the work stages to be made from two directions.

Stage J (FIG. 9):

In stage J, the components 6 to be installed from the direction of the second surface 1b are set in place, correspondingly to stage G of the electronic module.

Stage K (FIG. 10):

In stage K, the space remaining between the components 6 and the installation base is filled entirely with a filler 8, which is, for example, some suitable polymer. If the insulating material 1 is a pre-hardened binder layer (prepreg), this stage can be omitted.

Stage L (FIG. 11):

In stage L, holes 17 are manufactured for the electrical contacts of the components 6. The holes 17 are made through the conductive layer 14 and the adhesive layer 5, in such a way that the material of the contact protrusions, or the corresponding contact areas of the components 6 is exposed. The holes 17 can be made, for example, by drilling with the aid of a laser. A sufficient number of holes 17 is made at the contact areas of the components 6. If, in the process, it is intended to form direct contacts to the components 6 not only through the conductive layer 14, but also through some other conductive layer, the holes 17 need not necessarily be made at contact area participating in such a contact. Typically, in order to form a reliable contact between the contact areas of a component 6 and, for example, a conductive layer 24, a hole 28 is made in two parts; first a hole 17 is made between the component 6 and the conductive layer 14 and then a hole 27 is made directly on top of this.

Stage M (FIG. 12):

In stage M, holes 11 are made in the module for the feed-throughs. The holes 11 can be made, for example, mechanically by drilling.

Stage N (FIG. 13):

In stage N, conductive material 15 is grown into the holes 17 made in stage L and into the through-holes 11 made in stage M. In the example process, the conductive material 15 is also grown elsewhere on top of the base, so that the thickness of the conductive layers 14 also increases.

The conductive material 15 being grown can be, for example, copper, or some other sufficiently electrically conductive material. In the selection of the conductive material 15, attention must be paid to the ability of the material to form an electrical contact with the material of the contact protrusions 7 or other contact areas of the component 6. In one example process, the conductive material 15 is mainly copper. Copper metallization can be made by surfacing the holes 11 and 17 with a thin layer of chemical copper and after this the surfacing can be continued using an electrochemical copper-growing method. Chemical copper is used, for example, because it will also form a surface on top of adhesive and will act as an electrical conductor in electrochemical surfacing. The growth of the metal can thus be performed using a wet-chemical method, so that the growth is cheap.

Stage N is intended to form an electrical contact between the components 6 and the conductive layer 14. In stage N, it is not essential to increase the thickness of the conductive layer 14, instead the process can be equally well designed in such a way that, in stage I, the holes 17 and 11 are only filled with a suitable material. The conductive layer 15 can be manufactured, for example, by filling the holes 17 and 11 with an electrically conductive paste, or by using some other metallization method suitable for micro-feed-throughs.

In the later figures, the conductive layer 15 is shown merged with the conductive layer 14.

Stage O (FIG. 14):

In stage O, the conductive layers 14 are patterned in such a way that conductive patterns 14 are formed on both surfaces of the sheet 1. The patterning can be performed, for example, in the manner described in stage B.

After stage O, the electronic module contains a component 6 or several components 6, as well as conductive patterns 14, with the aid of which the component or components 6 can be connected to an external circuit or to each other. The preconditions then exist for manufacturing an operational totality. The process can thus be designed in such a way that the electronic module is ready after stage O and FIG. 14 indeed shows one possible electronic module. If desired, the process can also be continued after stage O, for example, by covering the electronic module with a protective substance, or by manufacturing additional conductive-pattern layers on the first and/or second surface.

Stage P (FIG. 15):

In stage P, an insulating-material layer 21 is made on both surfaces of the sheet 1 as well as a conductive layer 24 on top of the insulating-material layer 21. Stage P can be performed, for example, by pressing suitable RCF foils onto both surfaces of the sheet 1. The RCF foil then includes both an insulating-material layer 21 and a conductive layer 24. When the RCF foils are pressed onto the sheet 1 with the aid of heat and pressure, the polymer of the layer 21 forms a unified and tight insulating-material layer between the conductive layer 14 and 24. By means of this procedure, the conductive layer 24 too becomes quite flat and smooth.

11

Stage Q (FIG. 16):

In stage Q, holes 27 are made for forming feed-throughs between the conductive layer 14 and 24. The holes can be made, for example, as in stage L using a laser. In some examples, it is also possible to make holes 28, with the aid of which a straight feed-through can be formed with the conductive layer 24 and the contact protrusion or contact area of the component 6.

Stage R (FIG. 17):

In stage R, conductive material 15 is grown in the holes 27 (and the holes 28) while at the same time the thickness of the conductive layer 24 can also be increased. Stage R can be performed correspondingly to Stage N.

After stage R, the process can be continued by patterning the conductive layers 24 and possibly by manufacturing additional conductive layers on either or both of the surfaces. Separate components can also be connected to the conductive layer on the surface of the electronic module, in the conventional manner of circuit-board technology.

The following will deal, with the aid of FIGS. 18-27, with some possible modifications of the manufacturing process.

Stage A2 (FIG. 18):

In stage A2, as in stage A, a suitable insulating-material sheet 1, from which the body of the installation base is formed, is selected for the manufacturing process of the electronic module. In the example process, the insulating-material layer 1 is surfaced from the first surface 1a with a conductive layer 4, for example, a metal layer.

Stage B2 (FIG. 19):

In stage B2, as in stage C, suitably sized and shaped recesses or openings 2 are manufactured in the insulating-material layer 1, for the components to be embedded in the sheet. The recesses or openings 2 are made from the direction of the second surface 1b and extend through the entire insulating-material layer 1 as far as the surface of the conductive-material layer 4 on the opposite surface of the layer.

Stage C2 (FIG. 20):

In stage C2, the components 6 to be installed from the direction of the second surface 1b are set in place in the recesses or openings 2 and connected to the conductive layer 4. Electrical contacts are then also formed between the contact protrusions or contact areas of the components and the conductive layer 4. The connection of the components 6 can be made, for example, by gluing with an isotropically or anisotropically electrically conductive adhesive. The attachment can also be performed using some other applicable method, for example, the ultrasonic or thermo-compression method.

Stage D2 (FIG. 20):

In stage D2, the space remaining between the component 6 and the installation base is entirely filled with a filler 8, which is, for example, some suitable polymer.

Stage E2, (FIG. 21):

In stage E2, conductive patterns 14 are formed from the conductive layer 4, using some suitable method. The removal of the conductive material can be performed, for example, by vaporization with a laser, or using one of the selective etching methods, which are widely using and well known in the circuit-board industry.

Stage F2 (FIG. 22):

In stage F2, a conductive layer 9 is formed on the second surface 1b of the sheet 1. Stage F2 can be performed, for example, by laminating an RCF-foil onto the second surface 1b.

12

Stage G2 (FIG. 23):

In stage G2, recesses or openings 2 for components are made in the insulating-material layer 1, as in stage B2. Now the recesses openings 2 are manufactured from the direction of the first surface 1a and extend as far as the surface of the conductive-material layer 9.

Stage H2 (FIG. 24):

In stage H2, the components 6 to be installed from the direction of the first surface 1a are connected to the conductive layer 9. The stage can be performed as in stage C2.

Stage I2 (FIG. 20):

In stage I2, the space remaining between the components 6 and the installation base is entirely filled with a filler 8, which is, for example, some suitable polymer.

Stage J2 (FIG. 25):

In stage J2, conductive patterns 19 are formed from the conductive layer 9, using a suitable method.

Stage K2 (FIG. 26):

In stage K2, holes 27 are made to form feed-throughs between the conductive-pattern layers 14 and 19.

Stage L2 (FIG. 27):

In stage L2, conductive material is grown in the holes 27. Stage L2 can be performed correspondingly as stage N.

After stage L2, the electronic module includes two conductive-pattern layers and embedded components 6 connected to them. If several conductive layers are not required in the electronic module being manufactured, the module can, for example, be protected with a protective substance after stage L2. After stage L2, it is also possible, if wished, to manufacture additional conductive layers in the module, or to connect surface-assembled components to it. The modules can also be connected to each other to create a multi-layer structure.

The above descriptions are of -examples, in which the insulating-material layer 1 is formed from a single unified insulating-material sheet, for example, a glass-fibre-reinforced epoxy sheet, or a prepreg sheet. However, the insulating-material layer 1 can equally well be manufactured from more than one part. It is then also possible to proceed in such a way that the insulating-material layer 1 is formed of more than one insulating material. FIGS. 28-31 shows two such examples.

FIG. 28 shows an element, which includes a first insulating-material layer 1, with components 6 set in recesses or openings made in it. In addition, the element includes a conductive layer 4 on the surface of the insulating-material layer 1. The thickness of the first insulating-material layer 1 is preferably greater than the height of the components 6. An element like that shown in the figure can be manufactured, for example, by combining the sub-processes of the previous series of figures. In addition to the element, the figures also show a second insulating-material layer 11, in which recesses or openings 22 for components 6, as well as a second conductive layer 9 are also made.

In the above example, the second insulating-material layer 11 is prepreg. The first insulating-material layer 1 can then also be of some other insulating material, for example, a glass-fibre-reinforced epoxy sheet. After this, the layers are joined together, resulting in the element depicted in FIG. 29. As can be seen from FIG. 28, the resin contained in the prepreg fills the space between the component 6 and its surroundings. After this, the manufacture of the electronic module can be continued with the aid of the sub-processes described above.

In the following, stages of the manufacture of an electronic module in manufacturing methods according to certain embodiments of the present invention are examined in greater detail in FIGS. 30-35. Features of the manufacturing

13

methods described above can also be used in the manufacturing methods described below.

In FIGS. 30 and 31 two intermediate stages of the manufacture of an electronic module in manufacturing methods according to certain embodiments of the present invention are illustrated. FIG. 30 shows a first and a second element, both of which include a first insulating-material layer 1 and components 6 in recesses or openings manufactured in the insulating-material layer 1. In addition, the elements include conductive layers 4 on the first surfaces of the insulating-material layers 1 and conductive patterns 19 on the second surfaces of the insulating-material layers 1. The conductive patterns 19 are each located on the level of the respective components 6. In both elements, the thickness of the first insulating-material layer is greater than the height of the components 6. The second element is rotated relative to the first element in such a way that the conductive patterns 19 face each other and a second insulating-material layer 11, in which recesses 22 or openings are also made for components 6, is placed between the elements. After this, the elements are attached to each other, resulting in the module structure shown in FIG. 31. The structure of FIG. 31 is compact and thin, and, at this stage of the process, it already includes four conductive layers (layers 4, 4, 19, and 19). The conductive layers 19 are each located on the level of a respective component 6. The conductive layers 19 are embedded in insulating material of the structure. Feed throughs or so called via openings, which are not shown in FIGS. 30 and 31, are typically made in the first insulating material layers 1 and electrical contacts are subsequently formed between the conductive patterns 19 and the first conductive layers 4. High-quality electrical contacts can be made, for example, by forming a metallurgical connection by growing the conductor material chemically or by an electrochemical method. Another option is to grow a thin layer by a chemical method and continue the growing using a cheaper electrochemical method. Of course, any other suitable method can be used instead or in addition to the aforementioned methods. Thus, the possible methods include, for example, electrochemical plating, chemical deposition methods, sputtering and vaporization. The contact structure can include one, two or several layers of one, two or several metals. Possible metals include, but are not limited to, aluminum, copper, zinc, nickel, gold, titanium and iron, for instance. Also conducting adhesive, conductive paste or solder can be used, for instance.

In the embodiment shown in FIGS. 30 and 31 too, prepreg can be used as the second insulating-material layer 11. The first insulating-material layer 1 of both elements can then also be some other insulating material, for example, a glass-fibre-reinforced epoxy sheet. With the aid of the prepreg, excellent filling is achieved in the space between the elements, as shown in the example of FIG. 29. The modules shown in FIGS. 30 and 31 can be made, for example, with the aid of the sub-processes described above. The manufacture of the electronic module can also be continued in a corresponding manner as, for example, that of the elements shown in FIG. 10 or FIG. 24, making allowance for the selected connection techniques, the patterning requirement of the conductive layers 4, and other similar special requirements of the process.

In FIGS. 32 and 33 two intermediate stages of the manufacture of an electronic module in manufacturing methods according to certain embodiments of the present invention are illustrated. In FIG. 32 a first insulating-material layer 1 is provided on one surface of a first conductive layer 4. Subsequently, two openings are made in

14

the first insulating-material layer 1 that extend through the first insulating-material layer 1 as far as the first conductive layer 4. Two components 6 having a contact surface, i.e. a first surface 31 with contact areas or contact protrusions, are then placed in the openings with their contact surfaces facing the first conductive layer 4 and attached to the conductive layer 4. A portion of the first insulating-material layer 1 can be between at least a portion of the component and the conductor layer. Additionally, an insulating material which is either the same or different from the insulating material of the first insulating-material layer 1 can be between at least a portion of the component and the conductor layer. Vias, for example, can be formed in the insulating material between contact surface(s) of the component and the conductive layer.

A conductive pattern 19 can be made from conductor material on the first insulating-material layer 1. The conductive pattern 19 is located on the same level as the component 6. Further, a second insulating-material layer 11 is provided on the first insulating-material layer 1 and the conductive pattern 19 such that the components 6 and the conductive pattern 19 are embedded in the first and second insulating-material layers 1, 11. Additionally, a second or third conductive layer 9 can be provided on the second insulating-material layer 11.

The distance between a first surface 29 of the embedded conductive pattern 19 and the second conductive layer 9 in a direction perpendicular to the surface of the first conductive layer 4 is less than the distance between a first surface 31 of the component 6 and the second conductive layer 9. The first surface 29 of the embedded conductive pattern 19, the first surface 31 of the component 6, and the second conductive layer 9 are arranged substantially parallel to each other. The first surface 29 of the embedded conductive pattern 19 and the first surface 31 of the component 6 are facing towards the first conductive layer 4. The first conductive layer 4 is arranged substantially parallel to the second conductive layer 9. The distance between a second surface 30 of the embedded conductive pattern 19 and the first conductive layer 4 in a direction perpendicular to the surface of the first conductive layer 4 is also less than the distance between the second surface 32 of the component 6 and the first conductive layer 4. The second surface 30 of the embedded conductive pattern 19, the second surface 32 of the component 6, and the first conductive layer 4 are also arranged substantially parallel to each other. The second surface 30 of the embedded conductive pattern 19 and the second surface 32 of the component 6 are facing towards the second conductive layer 9. In other words, the embedded conductive pattern 19 is substantially located on the same level as the component 6, but the height of the embedded conductive pattern 19 is less than the height of the component 6. The height of the embedded conductive pattern 19 is defined as the distance between the first surface 29 of the embedded conductive pattern 19 and the second surface 30 of the embedded conductive pattern 19 in a direction perpendicular to the surface of the first conductive layer 4. The height of the component 6 is defined as the distance between the first surface 31 of the component 6 and the second surface 32 of the component 6 in a direction perpendicular to the surface of the first conductive layer 4.

According to certain embodiments, the second insulating-material layer 11 can be made of a different material than the first insulating-material layer 1. One example is that the first insulating-material layer 1 can be a glass-fibre reinforced epoxy sheet and the second insulating-material layer 11 can be prepreg. Other examples of materials of the first and/or

15

second insulating material are polyimide, polyimide based materials, epoxies with or without fillers (e.g. fillers which are ceramic particles), epoxy based materials, non-glass fiber containing materials or combinations thereof.

According to certain examples, the material of the first insulating material layer **1** and/or the material of the second insulating material layer **11** can be materially different before and after manufacturing. For example, a pre-final product can have a first insulating material layer **1** made from a polyimide film and the second insulating material layer **11** can be made from an unfilled epoxy. During a curing process of manufacturing after the first and second insulating material layers have been placed in contact with one another, the polyimide of the first insulating material layer **1** will generally hold its form but the unfilled epoxy of the second insulating material layer will flow. In a case where both materials of the first and second insulating material layers would be effected by a manufacturing step, a final product may have only one combined insulating material layer, or an additional insulating material layer which is a combination of at least a portion of both first and second initial insulating material layers.

The embedded conductive pattern **19** is made of conductor material such as, for example, copper, aluminum, zinc, nickel, gold, titanium or iron, a combination of two or more of the afore-mentioned metals, or any other suitable conductive material. Also the first and second conductive layers **4**, **9** are made of conductor material such as, for example, copper, aluminum, zinc, nickel, gold, titanium or iron, a combination of two or more of the afore-mentioned metals, or any other suitable conductive material.

After this, the layers are joined together, resulting in the element depicted in FIG. **33**. As can be seen from FIG. **32**, the resin contained in the prepreg fills the space between the component **6** and its surroundings. After this, the manufacture of the electronic module can be continued with the aid of the sub-processes described above.

In the final electronic module, e.g. after the manufacturing process, an embedded conductive pattern **19** is arranged such that it is separated from the environment. At least one of the first and second conductive layers **4**, **9** will be further formed as conductive pattern layers. Additionally, feed throughs are provided in the first or second insulating material layer and an electrical contact is formed between the embedded conductive pattern and the first or second conductive pattern layer.

In FIGS. **34** and **35** two intermediate stages of the manufacture of an electronic module in manufacturing methods according to certain embodiments of the present invention are illustrated. In FIG. **34** a first insulating-material layer **1** is provided on one surface of a first conductive layer **4**. Subsequently, at least one opening is made in the first insulating-material layer **1** that extends through the first insulating-material layer **1** as far as the first conductive layer **4**. At least one component **6** having a contact surface, i.e. a first surface **31** with contact areas or contact protrusions, is then placed in the opening with its contact surfaces facing the first conductive layer **4** and attached to the conductive layer **4**. A conductive pattern **19** is made from conductor material on the first insulating-material layer **1**. The conductive pattern **19** is located on the same level as the component **6**. Further, a second insulating-material layer **11** is provided on the first insulating-material layer **1** and the conductive pattern **19** such that the components **6** and the conductive pattern **19** are embedded in the

16

first and second insulating-material layers **1**, **11**. Additionally, a second conductive layer **9** is provided on the second insulating-material layer **11**.

After this, the layers can be joined together, resulting in an element as depicted in FIG. **35**. The first and second insulating-material layers **1**, **11** can be of the same material, though they may be different and/or have together formed one or more additional combined layers during a manufacturing process as discussed above. Further, the height of the embedded conductive pattern **19** is greater than in the previous embodiments. Additionally, the distance between a first surface **29** of the embedded conductive pattern **19** and the first conductive layer **4** in a direction perpendicular to the surface of the first conductive layer **4** substantially equals a distance between a second surface **30** of the embedded conductive pattern **19** and the second conductive layer **9**.

According to other embodiments, the distance between the second surface **30** of the embedded conductive pattern **19** and the first conductive layer **4** in a direction perpendicular to the surface of the first conductive layer **4** substantially equals or equals the distance between the second surface **32** of the component **6** and the first conductive layer **4**.

In further embodiments, the distance between the first surface **29** of the embedded conductive pattern **19** and the second conductive layer **9** in a direction perpendicular to the surface of the first conductive layer **4** substantially equals or equals the distance between the first surface **31** of the component **6** and the second conductive layer **9**.

In certain embodiments, the height of the embedded conductive pattern **19** substantially equals the height of the component **6**. In other certain embodiments, the height of the embedded conductive pattern **19** is greater or less than the height of the component **6**.

In case that the beam theory is applied to a cross-sectional portion of the electronic module, the neutral bending axis of the electronic module is located in the middle of the embedded conductive pattern **19** according to certain embodiments, thus minimizing the risk of breaking the embedded conductive pattern **19** due to bending of the structure during manufacturing steps of the electronic module at a later stage or due to unintentional bending of the module as such after manufacture. According to certain other embodiments, the neutral bending axis of the embedded conductive pattern **19** is located inside the embedded conductive pattern **19**. According to certain embodiments, the neutral bending axis is located inside of at least a portion of the embedded conductive pattern **19** or located totally outside of the embedded conductive pattern **19**.

In the final electronic module, i.e. after the manufacturing process, an embedded conductive pattern **19** is arranged such that it is separated from the environment. At least one of the first and second conductive layers **4**, **9** will be further formed as conductive pattern layers. Additionally, feed throughs are provided in the first or second insulating material layer and an electrical contact is formed between the embedded conductive pattern and the first or second conductive pattern layer.

The embodiments of the previous figure series show some possible processes, with the aid of which the invention can be exploited. The invention is not, however, restricted to only the processes disclosed above, but instead the invention also covers other different processes and their end products, taking into account the full scope and equivalence interpretation of the Claims. The invention is also not restricted to the constructions and methods described in the embodiments, it being obvious to one versed in the art that various

17

applications of our invention can be used to manufacture very many different electronic modules and circuit boards, which differ from the embodiments described above to even a great extent. The components and connections of the figures are thus presented only to illustrate the manufacturing process. Thus, a great many alterations can be made to the process of the embodiments given above, without, however, deviating from the basic idea according to the invention. The alterations can relate, for example, to the manufacturing techniques described in the different stages, or to the mutual sequence of the process stages.

In the processes described above, it is possible, for example, to use several techniques for attaching the components, for example, in such a way that the components to be attached from the direction of the first surface are attached using some first technique and the components to be attached from the direction of the second surface are attached using some second technique, which differs from the said first technique.

In the embodiments given above, electronic modules are manufactured, which include components embedded from a first and a second direction. Of course, within the scope of the invention, it is also possible to manufacture such simpler modules, which include only components embedded from one direction. With the aid of such simpler modules, it is also possible to manufacture a module including components embedded in two directions. The module can be manufactured, for example, in such a way that two modules are laminated together from their 'back' sides, so that the active surfaces contained in the sub-modules face the opposite outward surface of the module that has been laminated together. The embodiments according to the invention include at least one embedded conductive pattern. The embodiments according to the invention may include one or more embedded conductive patterns, e.g. in case that the components are embedded from a first and a second direction.

Although the present invention has been described in detail for the purpose of illustration, various changes and modifications can be made within the scope of the claims. In addition, it is to be understood that the present disclosure contemplates that, to the extent possible, one or more features of any embodiment may be combined with one or more features of any other embodiment.

It is to be understood that the embodiments of the invention disclosed are not limited to the particular structures, process steps, or materials disclosed herein, but are extended to equivalents thereof as would be recognized by those ordinarily skilled in the relevant arts. It should also be understood that terminology employed herein is used for the purpose of describing particular embodiments only and is not intended to be limiting.

The invention claimed is:

1. An electronic module, comprising:

a first conductive pattern layer, and a first insulating-material layer arranged on at least one surface of the first conductive pattern layer;

at least one opening in the first insulating-material layer that extends through the first insulating-material layer;

a component comprising contact terminals, the component being arranged at least partially within the at least one opening, the contact terminals electrically connected to the first conductive pattern layer;

18

a second insulating-material layer disposed on the first insulating-material layer; and

a second conductive pattern layer spaced apart from the first conductive pattern layer by at least the first and second insulating-material layers,

wherein the first conductive pattern layer and the second conductive pattern layer are each substantially planar.

2. The electronic module of claim 1, wherein the second insulating-material layer directly contacts the component.

3. The electronic module of claim 1, wherein the second conductive pattern layer is spaced apart from the first conductive pattern layer by the component.

4. The electronic module of claim 3, wherein the second conductive pattern layer is spaced apart from the component by the second insulating-material layer.

5. The electronic module of claim 4, wherein the second insulating-material layer is continuously disposed between the second conductive pattern layer and the component.

6. The electronic module of claim 1, wherein the first insulating-material layer is spaced apart from the component.

7. The electronic module of claim 1, wherein the first insulating-material layer comprises a different material than a material of the second insulating-material layer.

8. An electronic module, comprising:

a first conductive pattern layer, and a first insulating-material layer arranged on at least one surface of the first conductive pattern layer;

an opening in the first insulating-material layer that extends through the first insulating-material layer;

a component comprising contact terminals, the component being arranged at least partially within the opening, the contact terminals electrically connected to the first conductive pattern layer;

a second insulating-material layer disposed on the first insulating-material layer;

a third insulating-material layer disposed on the second insulating-material layer; and

a second conductive pattern layer spaced apart from the first conductive pattern layer by at least the first, second, and third insulating-material layers,

wherein the first conductive pattern layer and the second conductive pattern layer are each substantially planar.

9. The electronic module of claim 8, wherein the second insulating-material layer directly contacts the component.

10. The electronic module of claim 8, wherein the second conductive pattern layer is spaced apart from the first conductive pattern layer by the component.

11. The electronic module of claim 10, wherein the second conductive pattern layer is spaced apart from the component by the second and third insulating-material layers.

12. The electronic module of claim 11, wherein the second insulating-material layer is continuously disposed between the second conductive pattern layer and the component.

13. The electronic module of claim 8, wherein the first and third insulating-material layers are spaced apart from the component.

14. The electronic module of claim 8, wherein the first and third insulating-material layers comprise a first material, the second insulating-material layer comprises a second material, the first material being different than the second material.

* * * * *