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(54) ## PRINTED CIRCUIT BOARD WITH ANTENNA STRUCTURE AND METHOD FOR ITS PRODUCTION

(57) The invention relates to a method for producing an intermediate printed circuit board product (80) with an antenna structure (5), comprising the following steps:
- Providing a ground layer (10) comprising optionally a release layer (20) that is removably positioned (22) on an antenna subarea (12) of an exterior side (11) of the ground layer (10);
- Attaching a dielectric insulating layer (30) on the exterior side (11) of the ground layer (10) that is if applicable partly covered by the release layer (20);
- Attaching a conducting layer (40) on an exterior side (31) of the dielectric insulating layer (30);
- Laminating of the layers (10, 20, 30,40) to receive a first semi-finished product (50);
- Manufacturing of an antenna cavity (60) throughout the conducting layer (40) and the dielectric insulating layer (30) with a ground-plane area (62) that is if applicable made up of the release layer (20);
- Attaching a compound signal layer (70) on the conducting layer (40) covering the antenna cavity (60);
- Laminating of the layers (50, 70) to receive the intermediate product (80).

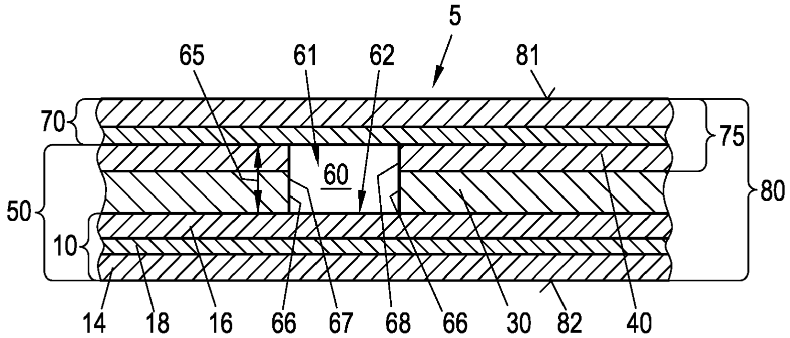

Fig. 6

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Description

[0001] The present invention relates to methods for producing an intermediate printed circuit board product with an antenna structure for high-frequency applications. The present invention also relates to an intermediate printed circuit board product as well as a printed circuit board with an antenna structure.

[0002] The selection of laminates for the fabrication of printed circuit boards (PCB's) typically available to designers is significantly reduced once operational frequencies increase to 500 MHz and above.

[0003] Disadvantageously standard laminate materials that are regularly used for low cost fabrication of printed circuit boards like FR-4-based laminates have comparably high relative permittivities with dielectric constants DC in the range approximately between 4,3 and 5,4. FR-4 (or FR4) is a grade designation assigned to glass-reinforced epoxy laminate sheets, tubes, rods and printed circuit boards (PCB). FR-4 denominates a composite material composed of woven fiberglass cloth with an epoxy resin binder that is flame resistant.

[0004] Due to high relative permittivities and dielectric constants, respectively, these basic laminates cannot be used for high-frequency applications like high-speed antennas and/or digital applications working at frequencies of 500 MHz and above, particularly for high-frequency applications at high frequencies of 40 GHz and above. For these high-frequency applications so-called RF laminates (RF short for Radio Frequency) are required with low dielectric loss as well as conductor loss for improved insertion loss and signal integrity while maintaining all other desirable attributes of the standard laminates. Such RF laminates like PTFE (PolyTetraFluoroEthylene, Teflon®)-based materials or hydrocarbon ceramic laminates are designed to offer superior high frequency performance but are very expensive. Also the process efforts and process costs in PCB manufacturing are very high when these RF laminates are applied.

[0005] In telecommunication, there are several types of microstrip antennas that are also known as printed antennas. The most common of which is the microstrip patch antenna or patch antenna, respectively. A patch antenna that is also known as a rectangular microstrip antenna is a type of radio antenna with a low profile, which can be mounted on a flat surface. Commonly it consists of a flat rectangular sheet or patch of metal or a conductive material, mounted over a larger sheet of metal called a ground plane. The assembly is usually contained inside a housing like a plastic radome, which protects the antenna structure from damage. Patch antennas are simple to fabricate and easy to modify and customize. They are the original type of microstrip antenna wherein the two metal sheets together form a resonant piece of microstrip transmission line with a length of approximately one-half wavelength of the radio waves. The radiation mechanism arises from discontinuities at each truncated edge of the microstrip transmission line. The radiation at the edges causes the antenna to act slightly larger electrically than its physical dimensions, so in order for the antenna to be resonant, a length of microstrip transmission line slightly shorter than one-half a wavelength at the frequency is used. A patch antenna is usually constructed on a dielectric substrate, using the same materials and lithography processes used to make printed circuit boards. For example the documents EP 1 501 155 A1, JP 2002-151911 A, JP 1996-111609 A and WO 2008/102950 A1 show different embodiments of these antennas.

[0006] The document US 5,444,453 A discloses a microstrip antenna structure having an air gap between a radiator patch that is affixed on an inside of a thin substrate layer and a ground plane. The radiator patch made of a conductive material is attached the thin substrate layer made of a dielectric material forming a radiator layer. To maintain a substantially uniform air gap between the radiator patch and the ground plane several support posts of a predetermined thickness as well as of the same, dimple shape have to be arranged between the radiator layer and the ground layer. Thus the disadvantages of dielectric basic materials with a low dielectric constant like PTFE (Teflon®) that are frequently used in microstrip antenna systems can be overcome as air with a very low dielectric constant DC of 1,0 is arranged between the radiator layer and the ground layer.

[0007] Disadvantageously the method of US 5,444,453 A for producing such a microstrip antenna structure is expensive as well as labour-intensive as a rigid radiator layer including a substrate layer with radiator patches affixed thereto has to be provided and connected with a ground plane layer via a plurality of support posts that have to be arranged between the two layers to ensure the constant air gap width. The support posts have to be formed for example by punching the bottom face of the ground plane with a die thereby deforming the ground plane and resulting in a plurality of protrusions of ground plane material.

[0008] Thus an object of the present invention is to provide an improved method to construct an antenna structure for high speed or respective high frequency applications that can be realized with laminate materials like FR-4-based laminates which are used in standard PCB production and which have the benefit of high uptime as well as low raw material costs.

[0009] Another, more specific object of the present invention is to provide an improved construction method for the aforementioned antenna structures wherein - compared with a default PCB production process - no additional process steps or auxiliary tools for process equipment are required.

[0010] A further object of the present invention is to provide a method for producing an intermediate printed circuit board product or a printed circuit board with an antenna structure, wherein the antenna or microstrip antenna structure and the digital application are arranged within the same printed circuit board, preferably within the same layers of the PCB, to avoid additional physical connectors like cables between an antenna area and a digital application area.

[0011] Another aim of the present invention is to avoid the need to use expensive RF laminates like PTFE-based materials or hydrocarbon ceramic laminates to achieve superior high frequency performance for high-frequency applications when producing an intermediate printed circuit board product or a printed circuit board, respectively.

[0012] A further, even more specific aim of the present invention is to decouple required Radio Frequency (RF) properties of the antenna structure from the material properties of the laminates used to build up the antenna structure.

[0013] The afore-mentioned objects are solved within the present invention by providing a method for producing an intermediate printed circuit board product with an antenna structure with the features of claim 1 - or alternatively - with the features of claim 2. Other advantageous embodiments of the invention are presented in the dependent method claims.

[0014] A first method for producing an intermediate printed circuit board product with an antenna structure according to the invention comprises the following steps:

- Providing a ground layer;
- Optionally attaching a release layer with a release layer shape on one exterior side of the ground layer wherein the release layer is removably positioned on an antenna subarea of the exterior side of the ground layer;
- Attaching a dielectric insulating layer on one exterior side of the ground layer that is if applicable partly covered by the release layer wherein the release layer is arranged between the ground layer and the dielectric insulating layer;
- Attaching a conducting layer on an exterior side of the dielectric insulating layer opposite to the ground layer wherein the dielectric insulating layer is arranged between the conducting layer and the ground layer;
- Laminating of the ground layer, dielectric insulating layer, conducting layer and if applicable the release layer to receive a first semi-finished product;
- Manufacturing of an antenna cavity within the first semi-finished product starting on its exterior side that is made up of the conducting layer and extending throughout the conducting layer as well as the dielectric insulating layer with a cavity height equal to the sum of the conducting layer height and the dielectric insulating layer height, wherein if applicable a cavity projection area corresponds to the release layer shape and is positioned on the antenna subarea covered by the release layer and wherein a ground-plane area of the cavity is made up of the release layer;
- Optionally coating of the side walls within the antenna cavity;
- Attaching a compound signal layer on the exterior side made up of the conducting layer of the first semi-finished product, wherein the compound signal layer covers the antenna cavity;
- Laminating of the first semi-finished product and the compound signal layer to receive an intermediate printed circuit board product.

[0015] Advantageously with the aforesaid inventive production method an antenna cavity of an antenna structure can be integrated within an intermediate printed circuit board product made of standardized laminate stack materials. The antenna cavity within the PCB is filled with air that shows best conditions for low insertion and transmission losses due to its low dielectric constant DC of 1,0. Thus the stacked-up layers made of standard laminate material like FR-4 laminate sheets and/or conducting layers exemplarily made of Copper that cover the antenna cavity on its both opposite sides contribute only with a small share to the total relative permittivity of the printed circuit board.

[0016] To the best advantage the respective relative permittivities of the dielectric laminates applied have comparably minor relevance or no relevance, respectively, in order to achieve superior high frequency performance of the antenna structure for high-frequency applications. Thus the properties of the dielectric laminate material can be selected and optimized according to individual target parameters of the respective application, for example to optimize heat management targets of the dielectric material or for economic targets to use cheap and readily available materials. With the inventive production method material selection of dielectric materials is no longer a compromise between Radio Frequency (RF) and other applications but can be optimized for any other purpose which is a major advantage of the invention that enhances flexibility of the respective production method decisively.

[0017] Manufacturing of the antenna cavity within the first semi-finished product can be made for example via a laser cutting-, punching-, etching- and/or deep routing process. Depending on the precision that is required to obtain an antenna cavity with exact outlines, usage of a release layer that is attached on the ground layer and that defines the shape of the antenna subarea, can be of advantage. Thus a cavity projection area that corresponds to the release layer shape can be obtained, wherein the ground-plane area of the cavity is covered by the release layer. After manufacturing the antenna cavity it can be opened like a plug by peeling off the release layer. This manufacturing feature is also known as 2.5D technology developed by the applicant.

[0018] Advantageously the depth of the antenna cavity is flexible and can be adapted according to individual requirements. In order to meet a very low dissipation factor (DF) which is a measure of loss-rate of energy of a mode of mechanical, electrical, or electromechanical oscillation in a dissipative system, the depth of the antenna cavity can be adjusted in relation the inductance of a patch antenna. Also the antenna design area can be adjusted in relation to the depth of the cavity which is another advantage of the invention.

[0019] For the sake of completeness it is mentioned that in principle different materials can be used as electrically insulating material. Mainly reinforced or unreinforced resins or epoxy resins, respectively, like FR-4 or FR-5 laminate sheets, are used. Alternatively or in addition also insulating materials made of Teflon®, polyamide, polyimide, cyanate ester and/or Bismaleimide-Triazine (BT) resin, as well as glasses or glass-like carrier materials like multilayer glass, or also ceramics can be used as insulating materials.

[0020] In an alternative embodiment of the invention a method for producing an intermediate printed circuit board product with an antenna structure can be indicated comprising the following steps:

- Providing a ground layer;
- Attaching a dielectric insulating layer on one exterior side of the ground layer, wherein the dielectric insulating layer has a recess extending throughout the dielectric insulating layer height of the dielectric insulating layer, and wherein the recess is positioned on an antenna subarea of the exterior side of the ground layer;
- Attaching a conducting layer on an exterior side of the dielectric insulating layer opposite to the ground layer, wherein the dielectric insulating layer is arranged between the conducting layer and the ground layer, and wherein further on the conducting layer has a recess extending throughout the conducting layer height of the conducting layer that recess is positioned coextensive with the recess of the dielectric insulating layer;
- Laminating of the ground layer, dielectric insulating layer and conducting layer to receive a first semi-finished product;
- Receiving an antenna cavity within the first semi-finished product starting on its exterior side that is made up of the recess of the conducting layer as well as the coextensive recess of the dielectric insulating layer, the antenna cavity comprising a cavity height equal to the sum of the conducting layer height and the dielectric insulating layer height, wherein a cavity projection area of the antenna cavity is positioned on the antenna subarea;
- Optionally coating of the side walls within the antenna cavity;
- Attaching a compound signal layer on the exterior side made up of the conducting layer of the first semi-finished product, wherein the compound signal layer covers the antenna cavity;
- Laminating of the first semi-finished product and the compound signal layer to receive an intermediate printed circuit board product.

[0021] The aforesaid alternative method for producing an intermediate printed circuit board provides the advantage that the antenna cavity can be pre-formed via recesses within the dielectric insulating layer as well as within the conducting layer. Advantageously in this case so called "no-flow" or "low-flow", respectively, materials are used as insulating layer and/or conducting layer. Low-flow prepregs are prepregs which are modified to reduce or limit their resin flow during lamination and hardening. Thus cut-out areas or recesses, respectively, can be realised within these materials that cannot tolerate resin flowing in. Where appropriate manufacturing of the recesses within the layers can be made for example via a laser cutting-, punching-, etching- and/or deep routing process.

[0022] Particularly advantageous for a method according to the invention the compound signal layer can comprise a dielectric no-flow prepreg layer and a conducting metal layer that is directly attached to the dielectric no-flow prepreg layer wherein the dielectric no-flow prepreg layer is attached to the conducting layer of the first semi-finished product. In this advantageous embodiment the compound signal layer comprising two layers is provided in advance before attaching it on the exterior side made up of the conducting layer of the first semi-finished product to cover the antenna cavity.

[0023] In a further practical embodiment of the inventive method the ground layer can be made of a laminated compound layer comprising at least two conducting metal layers laminated with an insulating layer in between the at least two conducting metal layers. Usage of a pre-laminated compound layer as ground layer improves production handling and reduces production costs.

[0024] Usefully in an embodiment of a production method according to the invention the antenna cavity can have a vent through-hole arranged between the ground-plane area of the cavity and an exterior side of the intermediate printed circuit board product. In this embodiment the vent through-hole ensures that a pressure compensation can take place between the inside pressure within the antenna cavity and the surrounding pressure outside of the PCB.

[0025] In a preferred realisation of the inventive method the antenna cavity can be surrounded with shielding vias that are arranged within the laminated ground layer and/or laminated dielectric insulating layer and/or conducting layer and/or compound signal layer at a distance in regard to the antenna cavity. Shielding vias act as electric screen to shield the antenna structure and the antenna cavity, respectively, from electric and electrostatic discharges within the PCB.

[0026] In a further preferred embodiment of the inventive method the antenna structure can comprise an antenna design area on an exterior side of the compound signal layer.

[0027] Advantageously in another preferred embodiment of the inventive method a digital processing area with a digital structure can be arranged within the laminated ground layer and/or laminated dielectric insulating layer and/or conducting layer and/or compound signal layer at a distance in regard to the antenna cavity. Thus an antenna structure and a digital structure for digital processing are arranged within the same printed circuit board, preferably within the same layers of the printed circuit board. Advantageously no additional physical connectors like cables are required for processing of digital applications.

[0028] Particularly convenient is a method according to the invention wherein the digital structure can comprise an air gap passing through the intermediate printed circuit board product from a first exterior side of the intermediate printed circuit board product to an opposite second exterior side. Thus within the air gap any digital installations can be implemented.

[0029] Advantageously side walls within the air gap can be covered with a coating. A metallic coating within the air gap can shield the digital structure from electric and electrostatic discharges within the PCB.

[0030] The aforesaid varieties of methods according to the invention can also be used to receive a printed circuit. Advantageously for this purpose solder masks are affixed on both exterior sides of one intermediate printed circuit board product or on both exterior sides of at least two previously interconnected and stacked-up intermediate printed circuit board products, wherein structured solder layers are applied within recesses of the solder masks, and wherein the solder masks are removed and optionally the outer surfaces are finished to receive a printed circuit board.

[0031] In case two or more intermediate printed circuit board products are stacked-up to receive a multi-layered printed circuit board, it is obvious for the skilled person that if any vent through-hole is arranged between the ground-plane area of the antenna cavity and an exterior side of a first intermediate printed circuit board product, it may be necessary to extend the vent through-hole also throughout the interconnected further intermediate printed circuit board products right up to an outer surface of the printed circuit board.

[0032] The same may be true if any digital processing area is realised that comprises a digital structure. Thus in case several intermediate printed circuit board products are stacked-up it may be necessary to extend also an air gap passing through a first intermediate printed circuit board product into one or more interconnected further intermediate printed circuit board products accordingly.

[0033] In a further preferred embodiment of the inventive method at least one electronic component is embedded within the layers of the intermediate printed circuit board product.

[0034] Each active electronic component like for example an electronic chip, especially a flip chip, or each passive electronic component like a capacitor, a resistor, an inductance or any magnetic element like a magnetic ferrite core can be understood as electronic component according to the invention that can be embedded within the intermediate printed circuit board product. Further examples for embedded electronic components are data storage devices like a dynamic random access memory (DRAM), filters that can be configured for example as highpass filter, low-pass filter or band-pass filter or that can be used as frequency filters. Also an integrated circuit (IC) like a so-called logic IC, any signal processing component like a microprocessor, any performance management component, any opto-electronic device, any voltage converter like a DC/DC-converter or AC/DC-converter, any electromechanical converter like a lead-zirconium titanate (PZT)-sensor and/or -actor, as well as any sender unit or receiving unit for electromagnetic waves like a RFID-chip or -transponder, any cryptographic component, capacity, inductivity or switch like a transistor-based switch are comprised alone or combined with the aforementioned or together with other functional electronic components by the aforesaid term of an electronic component to be embedded. Furthermore the electronic component can also comprise a microelectromechanical system (short MEMS), a battery, an accumulator, a camera or an antenna.

[0035] The afore-mentioned tasks are also solved within the present invention by providing an intermediate printed circuit board product with an antenna structure with the features of the characterising part of claim 13. Other advantageous embodiments of the invention are also presented in the dependent product claims.

[0036] According to the invention an intermediate printed circuit board structure with an antenna structure features an antenna cavity that is arranged within a first semi-finished product comprising at least a ground layer, a dielectric insulating layer which is attached to the ground layer and a conducting layer which is attached to the dielectric insulating layer opposite to the ground layer in a way that the dielectric insulating layer is arranged between the conducting layer and the ground layer, whereby the ground layer, dielectric insulating layer and conducting layer are laminated, and wherein the antenna cavity touches the ground layer alongside a ground-plane area and extends throughout the conducting layer as well as the dielectric insulating layer with a cavity height equal to the sum of the conducting layer height and the dielectric insulating layer height, wherein a compound signal layer is attached on the conducting layer of the first semi-finished product covering the antenna cavity, and the first semi-finished product and the compound signal layer are laminated.

[0037] Advantageously an intermediate printed circuit board product according to the invention that comprises an antenna structure is built up of laminated semi-finished products that are themselves built up by standardized laminate stack materials and/or by conducting layers. The antenna cavity within the intermediate printed circuit board or later PCB, respectively, is filled with air that shows best conditions for low insertion and transmission losses due to its low dielectric constant DC of

1,0. The stacked-up layers made of standard laminate material like FR-4 laminate sheets and/or by conducting layers exemplarily made of Copper that cover the antenna cavity on its both opposite sides contribute only with a small share to the total relative permittivity of the printed circuit board. Thus the printed circuit board can be produced at low production costs with standard PCB manufacturing equipment due to the usage of standard stack-up materials that are regularly applied in PCB production. Due to the fact that air is within the antenna cavity the overall permittivity of the PCB can be kept low and thus the efficiency of high speed transmission can be improved although applied standard materials show relatively high dielectric constants and high permittivity, respectively.

[0038] Also of advantage is that the antenna cavity within the first semi-finished product can be manufactured for example via a laser cutting-, punching-, etching- and/or deep routing process.

[0039] In a further practical embodiment of the invention an intermediate printed circuit board product can comprise a compound signal layer with a dielectric no-flow prepreg layer and a conducting metal layer directly attached to the dielectric no-flow prepreg layer wherein the dielectric no-flow prepreg layer is attached to the conducting layer of the first semi-finished product. In this advantageous embodiment the compound signal layer comprising two layers is provided in advance before attaching it on the exterior side made up of the conducting layer of the first semi-finished product to cover the antenna cavity.

[0040] In another embodiment of an intermediate printed circuit board product according to the invention, the antenna cavity can be surrounded with shielding vias that are arranged within the ground layer and/or dielectric insulating layer and/or conducting layer and/or compound signal layer at a distance of the antenna cavity. Shielding vias act as electric screen to shield the antenna structure and the antenna cavity, respectively.

[0041] Usefully an intermediate printed circuit board product according to the invention can comprise a digital processing area with a digital structure that is arranged within the laminated ground layer and/or laminated dielectric insulating layer and/or conducting layer and/or compound signal layer at a distance of the antenna cavity. Thus an antenna structure and a digital structure for digital processing are arranged within the same printed circuit board, preferably within the same layers of the printed circuit board.

[0042] In a further advantageous embodiment of an intermediate printed circuit board product according to the invention the digital structure can comprise an air gap passing through the intermediate printed circuit board product from a first exterior side of the intermediate product to an opposite second exterior side. Thus within the air gap several different digital installations can be implemented.

[0043] Usefully an intermediate printed circuit board product can have an antenna cavity with a vent through-hole starting from the ground-plane area of the antenna cavity and passing throughout the laminated ground layer to enhance pressure compensation between the inside pressure within the antenna cavity and the surrounding pressure outside of the intermediate printed circuit board product or a PCB, respectively.

[0044] In a further embodiment of the invention the intermediate printed circuit board product can comprise at least one electronic component that is embedded within the layers of the intermediate printed circuit board product. As aforesaid the term electronic component comprises both active and passive electronic components to be embedded.

[0045] In a further development of the invention a printed circuit board with an antenna structure can be indicated comprising at least one intermediate printed circuit board product wherein structured solder layers are applied on both exterior sides of one intermediate printed circuit board product or on both exterior sides of at least two previously interconnected and stacked-up intermediate printed circuit board products. Optionally the outer surfaces are finished before to receive the printed circuit board. The aforesaid advantages of an intermediate printed circuit board product apply equivalently also for a printed circuit board according to the invention.

[0046] Other objects, advantages, and novel features of the present invention will become more apparent from the following detailed description when taken in conjunction with the accompanying schematic drawings:

- **Fig. 1** is a sectional view along a vertical plane illustrating a preferred embodiment of a printed circuit board with an antenna structure as well as with a digital structure according to the present invention.
- **Fig. 2** is a sectional view along a vertical plane illustrating the several production steps to produce a printed circuit board according to an alternative inventive production method.
- **Fig. 3A** or **Fig. 3B** to **Fig. 6** each show in succession different production steps details of the manufacture of an intermediate printed circuit board product with an antenna structure, wherein **Fig. 3A** and **Fig. 4A** refer to a first alternative manufacturing method and **Fig. 3B** and **Fig. 4B** refer to a second alternative method of manufacture;
- **Fig. 3A** shows in a sectional view along a vertical plane a ground layer comprising a release layer that is removable positioned on an antenna subarea of an exterior side of the ground layer;
- **Fig. 4A** illustrates in an isometric and partly sectional view the step of attaching a dielectric insulating layer and a conducting layer on the exterior side of the ground layer that is partly covered by the release layer before laminating the layers to receive a first semi-finished product;
- **Fig. 3B** shows in a sectional view along a vertical plane a ground layer without release layer;

- **Fig. 4B** illustrates in an isometric and partly sectional view the step of attaching a dielectric insulating layer and a conducting layer on the exterior side of the ground layer before laminating the layers to receive a first semi-finished product, wherein recesses within the dielectric insulating layer and the conducting layer are stacked in a coextensive way to form an antenna cavity;
- **Fig. 5** shows in an isometric and partly sectional view the laminated first semi-finished product with an antenna cavity;
- **Fig. 6** illustrates in a sectional view along a vertical plane the intermediate printed circuit board product wherein the antenna cavity is covered by a compound signal layer;
- **Fig. 7** shows in a top view a detail of an antenna structure of another embodiment of an intermediate printed circuit board according to the invention;
- Fig. **8** depicts a sectional view according to sectional plane A-A as marked in Fig. 7.

[0047] With reference to **Fig. 1,** a preferred embodiment of a printed circuit board 1 with an antenna structure 5 is shown, wherein the antenna structure 5 comprises an antenna design area 6 as well as an antenna cavity 60. When producing the printed circuit board 1 according to the invention firstly a ground layer 10 with an exterior side 11 of the ground layer 10 is provided. The ground layer 10 comprises a first conducting metal layer 14, a second conducting metal layer 16 and an insulating layer 18, that is arranged and laminated between the conducting metal layers 14,16. On the exterior side 11 of the ground layer within an antenna subarea 12 a release layer 20 is positioned, as can be seen in **Fig. 3A.**

[0048] **Fig. 2** illustrates the several production steps to produce a printed circuit board 1 according to an alternative inventive method without usage of a release layer.

[0049] Reference is made now to **Fig. 3A** that shows the ground layer 10 in more detail. On the exterior side 11 of the ground layer within an antenna subarea 12 a release layer 20 is positioned. The position 22 of the release layer 20 on the exterior ground layer side 11 as well as the release layer shape 25 of the release layer 20 corresponds with the position and shape of the antenna cavity 60.

[0050] Back to **Fig. 1** furthermore a dielectric insulating layer 30 with an exterior side 31 of the dielectric insulating layer 30 and a dielectric insulating layer height 35 is attached on the ground layer 10 in a way that on the exterior side 11 of the ground layer 10 that is partly covered by the release layer 20 the release layer 20 is arranged between the ground layer 10 and the dielectric insulating layer 30. Also a conducting layer 40 with a conducting layer height 45 is attached on the dielectric insulating layer 30 in a way that the dielectric insulating layer 30 is arranged between the conducting layer 40 and the ground layer 10.

[0051] After laminating of the ground layer 10, the release layer 20, the dielectric insulating layer 30 and the conducting layer 40 a first semi-finished product 50 is received, as is illustrated in **Fig. 4A** just before lamination. The first semi-finished product 50 comprises an exterior side 51 of first semi-finished product 50 that is formed by the conducting layer. **Fig. 3A** and **Fig. 4A** refer to a first alternative manufacturing method using an optional release layer 20 to obtain later on an antenna cavity with preferably exact outlines.

[0052] **Fig. 3B** and **Fig. 4B** refer to a second alternative method of manufacture without using a release layer. In **Fig. 3B** a ground layer 10 without release layer is shown. **Fig. 4B** illustrates in an isometric and partly sectional view the step of attaching a dielectric insulating layer 30 and a conducting layer 40 on the exterior side 11 of the ground layer 10 before laminating the layers 10, 30, 40 to receive a first semi-finished product 50, wherein recesses 39, 49 within the dielectric insulating layer 30 and the conducting layer 40 are stacked in a coextensive way to form an antenna cavity.

[0053] Ensuing from the first embodiment of the production method as depicted in Fig. 4A, within the first semi-finished product 50 and starting on its exterior side 51 that is made up of the conducting layer 40 an antenna cavity 60 is manufactured for example via a laser cutting and/or deep routing process throughout the conducting layer 40 as well as the dielectric insulating layer 30 with a cavity height 65 equal to the sum of the conducting layer height 45 and the dielectric insulating layer height 35. A cavity projection area 65 of the antenna cavity 60 corresponds to the release layer shape 25 and the release layer position 22 as of the release layer 20 on the antenna subarea 12. A ground-plane area 62 of the antenna cavity 60 is made up of the release layer 20. Due to the release layer 20 the cut-out and/or shaped-out material of the conducting layer 40 and dielectric insulating layer 30 can easily be taken out of the cavity projection area 61 to form the antenna cavity 60. Optionally the antenna cavity 60 can be coated with a metal coating 66 on its side walls 67, 68 as is shown in **Fig. 5.**

[0054] Alternatively according to the second embodiment of the production method as shown in **Fig. 4B,** the first semi-finished product 50 as shown in **Fig. 5** can be easily derived by laminating the respective layers 10, 30, 40.

[0055] Optionally a vent through-hole 69 can be drilled between the ground-plane area 62 of the antenna cavity 60 and an outer surface 99 of the printed circuit board 1. This vent through-hole 69 is manufactured as non-plated through hole and enhances pressure compensation between the interior of the antenna cavity 60 and the surrounding of the PCB 1 and is depicted in **Fig.** 1 and **Fig. 2,** respectively.

[0056] Afterwards a compound signal layer 70 with an exterior side 71 of the signal layer 70 is attached on the exterior side 51 of the first semi-finished product 50 that is made up of the conducting layer 40. Thus the compound signal layer 70 covers the antenna cavity 60. After lamination of the compound signal layer 70 with the conducting layer 40 a compound antenna layer 75 is received comprising a dielectric no-flow prepreg layer 76 and a conducting metal layer 78 forming the compound signal layer 70 as well as the conducting layer 40.

[0057] After laminating the first semi-finished product 50 and the compound signal layer 70 an intermediate printed circuit board product 80 is received that is shown in more detail also in **Fig. 6.**

[0058] To receive a printed circuit board 1, afterwards solder masks 91, 92 are affixed on both exterior sides 81, 82 of the intermediate printed circuit board product 80 to apply structured solder layers 90 within recesses 95 of the solder masks 91, 92. After removing of the solder masks 91, 92 and optionally finishing the outer surfaces 99 a printed circuit board 1 with an antenna structure 5 is received as is illustrated in **Fig. 1** and **Fig. 2.** In both **Fig. 1** and **Fig. 2** the antenna structure 5 and a digital processing area 105 each are marked by dotted lines.

[0059] In **Fig. 2** an aerial view of the antenna design area 6 on an exterior side 71 of the signal layer 70 is illustrated as an insert surrounded by dotted lines. A micro-via structure is shown within the antenna design area 6.

[0060] Furthermore - as each shown in **Fig. 1** and **Fig. 2 -** a digital structure 100 within a digital processing area 105 is arranged within the same printed circuit board 1, especially within the same laminated ground layer 10, laminated dielectric insulating layer 30, conducting layer 40 as well as compound signal layer 70 at a distance 125 in regard to the antenna cavity 60. The digital structure 100 comprises an air gap 120 passing through the intermediate printed circuit board product 80 from a first exterior side 81 of the intermediate printed circuit board product 80 to an opposite second exterior side 82. As shown exemplarily in **Fig. 1** and **Fig. 2,** the side walls 121 within the air gap 120 are covered with a coating 66. Additionally the antenna cavity 60 is surrounded by several shielding vias 110 that are arranged here within the laminated ground layer 10, the dielectric insulating layer 30, the conducting layer 40 as well as the compound signal layer 70 each at a distance 115 in regard to the antenna cavity 60.

[0061] While in **Fig. 3A** or **Fig. 3B** to **Fig. 6** only details of the manufacture of an intermediate printed circuit board product 80 with its antenna structure 5 are shown, this intermediate printed circuit board product 80 may also comprise at least one digital processing area 105 to host digital structures 100 and/or at least one embedded electronic component that are not explicitly shown in Figures 3A or 3B to 6 due to enhanced clearness of the respective figures.

[0062] **Fig. 7** shows in a top view a detail of an antenna structure 5 of another embodiment of an intermediate printed circuit board 1 according to the invention. **Fig. 8** depicts a sectional view according to sectional plane A-A as marked in **Fig. 7.** The antenna design area 6 has here a complex, tree-like shape. The respective antenna cavity 60 has an enlarged shape comparable to that of the antenna design area 6. The antenna cavity 60 is made for example via a laser cutting process wherein the applicants' 2.5D technology is applied.

LIST OF ABBREVIATIONS

[0063]

1	printed circuit board
5	antenna structure
6	antenna design area
10	ground layer
11	exterior side of ground layer
12	antenna subarea
14	(first) conducting metal layer
16	(second) conducting metal layer
18	insulating layer
20	release layer
22	position of release layer on exterior ground layer side
25	release layer shape
30	dielectric insulating layer
31	exterior side of dielectric insulating layer
35	dielectric insulating layer height
39	recess within dielectric insulating layer
40	conducting layer
45	conducting layer height
49	recess within conducting layer
50	(first) semi-finished product
51	exterior side of first semi-finished product
60	antenna cavity
61	cavity projection area
62	ground-plane area of antenna cavity
65	cavity height
66	coating
67	side wall within antenna cavity
68	side wall within antenna cavity
69	vent through-hole
70	compound signal layer
71	exterior side of signal layer
75	compound antenna layer
76	dielectric no-flow prepreg layer
78	conducting metal layer
80	intermediate printed circuit board product
81	(first) exterior side of intermediate printed circuit board product
82	(second) exterior side of intermediate printed circuit board product
90	solder layer
91	solder mask on (first) exterior side of intermediate printed circuit board product
92	solder mask on (second) exterior side of intermediate printed circuit board product
95	recess within solder mask
99	outer surface of printed circuit board
100	digital structure

105 digital processing area
110 shielding via
115 distance between shielding via and antenna cavity
120 air gap
121 side wall of air gap
125 distance between antenna cavity and digital structure

Claims

1. A method for producing an intermediate printed circuit board product (80) with an antenna structure (5), comprising the following steps:

- Providing a ground layer (10);
- Optionally attaching a release layer (20) with a release layer shape (25) on one exterior side (11) of the ground layer (10), wherein the release layer (20) is removably positioned (22) on an antenna subarea (12) of the exterior side (11) of the ground layer (10);
- Attaching a dielectric insulating layer (30) on one exterior side (11) of the ground layer (10) that is if applicable partly covered by the release layer (20) wherein the release layer (20) is arranged between the ground layer (10) and the dielectric insulating layer (30);
- Attaching a conducting layer (40) on an exterior side (31) of the dielectric insulating layer (30) opposite to the ground layer (10) wherein the dielectric insulating layer (30) is arranged between the conducting layer (40) and the ground layer (10);
- Laminating of the ground layer (10), dielectric insulating layer (30), conducting layer (40) and if applicable the release layer (20), to receive a first semi-finished product (50);
- Manufacturing of an antenna cavity (60) within the first semi-finished product (50) starting on its exterior side (51) that is made up of the conducting layer (40) and extending throughout the conducting layer (40) as well as the dielectric insulating layer (30) with a cavity height (65) equal to the sum of the conducting layer height (45) and the dielectric insulating layer height (35), wherein if applicable a cavity projection area (65) corresponds to the release layer shape (25) and is positioned (22) on the antenna subarea (12) covered by the release layer (20) and wherein a ground-plane area (62) of the cavity (60) is made up of the release layer (20);
- Optionally coating (66) of the side walls (67, 68) within the antenna cavity (60);
- Attaching a compound signal layer (70) on the exterior side (51) made up of the conducting layer (40) of the first semi-finished product (50), wherein the compound signal layer (70) covers the antenna cavity (60);
- Laminating of the first semi-finished product (50) and the compound signal layer (70) to receive an intermediate printed circuit board product (80).

2. A method for producing an intermediate printed circuit board product (80) with an antenna structure (5), comprising the following steps:

- Providing a ground layer (10);
- Attaching a dielectric insulating layer (30) on one exterior side (11) of the ground layer (10), wherein the dielectric insulating layer (30) has a recess (39) extending throughout the dielectric insulating layer height (35) of the dielectric insulating layer (30), and wherein the recess (39) is positioned on an antenna subarea (12) of the exterior side (11) of the ground layer (10);
- Attaching a conducting layer (40) on an exterior side (31) of the dielectric insulating layer (30) opposite to the ground layer (10), wherein the dielectric insulating layer (30) is arranged between the conducting layer (40) and the ground layer (10), and wherein further on the conducting layer (40) has a recess (49) extending throughout the conducting layer height (45) of the conducting layer (40) that recess (49) is positioned coextensive with the recess (39) of the dielectric insulating layer (30);
- Laminating of the ground layer (10), dielectric insulating layer (30) and conducting layer (40) to receive a first semi-finished product (50);
- Receiving an antenna cavity (60) within the first semi-finished product (50) starting on its exterior side (51) that is made up of the recess (49) of the conducting layer (40) as well as the coextensive recess (39) of the dielectric insulating layer (30), the antenna cavity (60) comprising a cavity height (65) equal to the sum of the conducting layer height (45) and the dielectric insulating layer height (35), wherein a cavity projection area (65) of the antenna cavity (60) is positioned (22) on the antenna subarea (12);
- Optionally coating (66) of the side walls (67, 68) within the antenna cavity (60);
- Attaching a compound signal layer (70) on the exterior side (51) made up of the conducting layer (40) of the first semi-finished product (50), wherein the compound signal layer (70) covers the antenna cavity (60);
- Laminating of the first semi-finished product (50) and the compound signal layer (70) to receive an intermediate printed circuit board product (80).

3. The method according to claim 1 or 2, **characterized**

in that the compound signal layer (70) comprises a dielectric no-flow prepreg layer (76) and a conducting metal layer (78) directly attached to the dielectric no-flow prepreg layer (76) wherein the dielectric no-flow prepreg layer (76) is attached to the conducting layer (40) of the first semi-finished product (50).

4. The method according to any of claims 1 to 3, **characterized in that** the ground layer (10) is made of a laminated compound layer comprising at least two conducting metal layers (14, 16) laminated with an insulating layer (18) in between the at least two conducting metal layers (14,16).

5. The method according to any of claims 1 to 4, **characterized in that** the antenna cavity (60) has a vent through-hole (69) arranged between the ground-plane area (62) of the cavity (60) and an exterior side (82) of the intermediate printed circuit board product (80).

6. The method according to any of claims 1 to 5, **characterized in that** the antenna cavity (60) is surrounded with shielding vias (110) that are arranged within the laminated ground layer (10) and/or laminated dielectric insulating layer (30) and/or conducting layer (40) and/or compound signal layer (70) at a distance (115) in regard to the antenna cavity (60).

7. The method according to any of claims 1 to 6, **characterized in that** the antenna structure (5) comprises an antenna design area (6) on an exterior side (71) of the compound signal layer (70).

8. The method according to any of claims 1 to 7, **characterized in that** a digital processing area (105) with a digital structure (100) is arranged within the laminated ground layer (10) and/or laminated dielectric insulating layer (30) and/or conducting layer (40) and/or compound signal layer (70) at a distance (125) in regard to the antenna cavity (60).

9. The method according to claim 8, **characterized in that** the digital structure (100) comprises an air gap (120) passing through the intermediate printed circuit board product (80) from a first exterior side (81) of the intermediate printed circuit board product (80) to an opposite second exterior side (82).

10. The method according to claim 9, **characterized in that** side walls (121) within the air gap (120) are covered with a coating (66).

11. The method according to any of claims 1 to 10, **characterized in that** solder masks (91, 92) are affixed on both exterior sides (81, 82) of one intermediate printed circuit board product (80) or on both exterior sides (81, 82) of at least two previously interconnected and stacked-up intermediate printed circuit board products (80), wherein structured solder layers (90) are applied within recesses (95) of the solder masks (91, 92), and wherein the solder masks (91,92) are removed and optionally the outer surfaces (99) are finished to receive a printed circuit board (1).

12. The method according to any of claims 1 to 11, **characterized in that** at least one electronic component is embedded within the layers (10, 30, 40, 50, 70) of the intermediate printed circuit board product (80).

13. An intermediate printed circuit board product (80) with an antenna structure (5), **characterized in that** an antenna cavity (60) is arranged within a first semi-finished product (50) comprising at least a ground layer (10), a dielectric insulating layer (30) which is attached to the ground layer (10) and a conducting layer (40) which is attached to the dielectric insulating layer (30) opposite to the ground layer (10) in a way that the dielectric insulating layer (30) is arranged between the conducting layer (40) and the ground layer (10), whereby the ground layer (10), dielectric insulating layer (30) and conducting layer (40) are laminated, and wherein the antenna cavity (60) touches the ground layer (10) alongside a ground-plane area (62) and extends throughout the conducting layer (40) as well as the dielectric insulating layer (30) with a cavity height (65) equal to the sum of the conducting layer height (45) and the dielectric insulating layer height (35), wherein a compound signal layer (70) is attached on the conducting layer (40) of the first semi-finished product (50) covering the antenna cavity (60), and the first semi-finished product (50) and the compound signal layer (70) are laminated.

14. The intermediate printed circuit board product (80) according to claim 13, **characterized in that** the compound signal layer (70) comprises a dielectric no-flow prepreg layer (76) and a conducting metal layer (78) directly attached to the dielectric no-flow prepreg layer (76) wherein the dielectric no-flow prepreg layer (76) is attached to the conducting layer (40) of the first semi-finished product (50).

15. The intermediate printed circuit board product (80) according to claim 13 or 14, **characterized in that** the antenna cavity (60) is surrounded with shielding vias (110) that are arranged within the ground layer (10) and/or dielectric insulating layer (30) and/or conducting layer (40) and/or compound signal layer (70) at a distance (115) of the antenna cavity (60).

16. The intermediate printed circuit board product (80) according to any of claims 13 to 15, **characterized in that** a digital processing area (105) with a digital structure (100) is arranged within the laminated

ground layer (10) and/or laminated dielectric insulating layer (30) and/or conducting layer (40) and/or compound signal layer (70) at a distance (125) of to the antenna cavity (60).

17. The intermediate printed circuit board product (80) according to claim 16, **characterized in that** the digital structure (100) comprises an air gap (120) passing through the intermediate printed circuit board product (80) from a first exterior side (81) of the intermediate product (80) to an opposite second exterior side (82).

18. The intermediate printed circuit board product (80) according to any of claims 13 to 17, **characterized in that** the antenna cavity (60) has a vent throughhole (69) starting from the ground-plane area (62) and passing throughout the laminated ground layer (10).

19. The intermediate printed circuit board product (80) according to any of claims 13 to 18, **characterized in that** at least one electronic component is embedded within the layers (10, 30, 40, 50, 70) of the intermediate printed circuit board product (80).

20. A printed circuit board (1) with an antenna structure (5) comprising at least one intermediate printed circuit board product (80) according to any of claims 13 to 19, **characterized in that** structured solder layers (90) are applied on both exterior sides (81, 82) of one intermediate printed circuit board product (80) or on both exterior sides (81, 82) of at least two previously interconnected and stacked-up intermediate printed circuit board products (80), wherein optionally outer surfaces (99) of the printed circuit board (1) are finished.

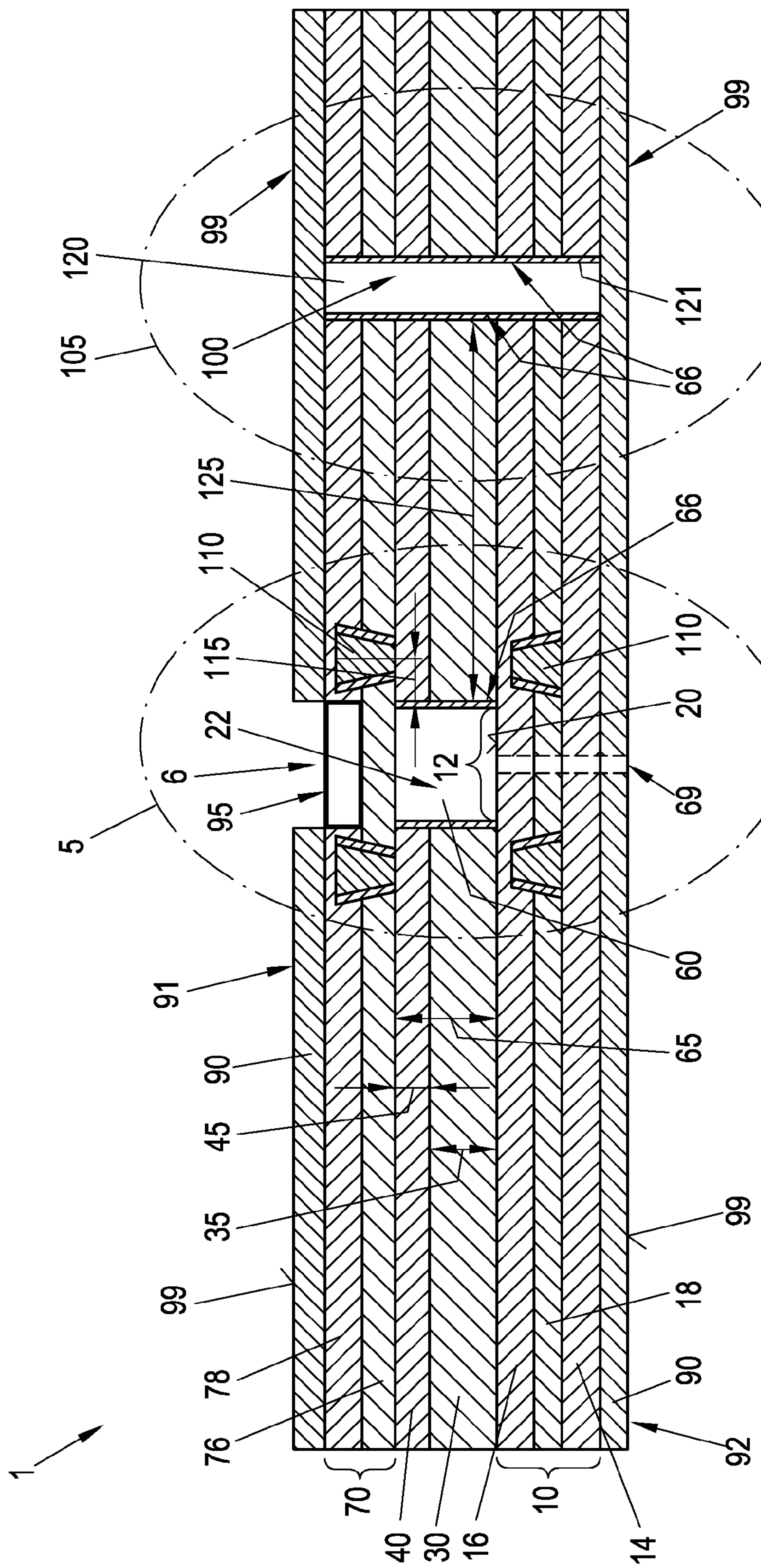

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Fig. 1

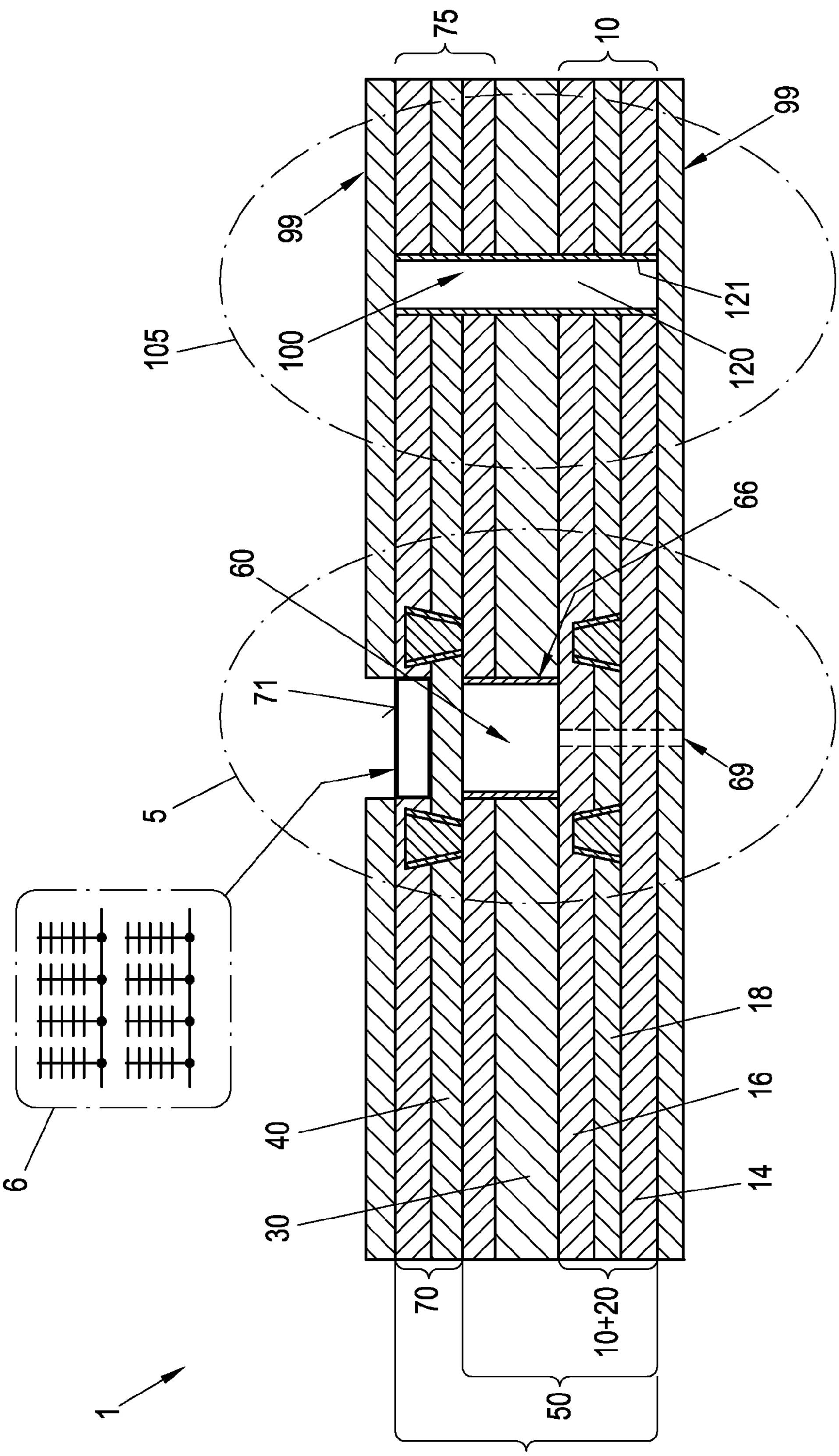
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Fig. 2

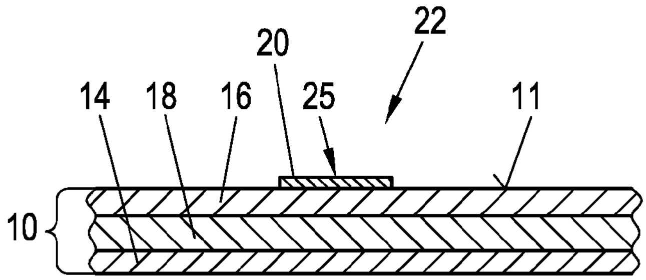

Fig. 3A

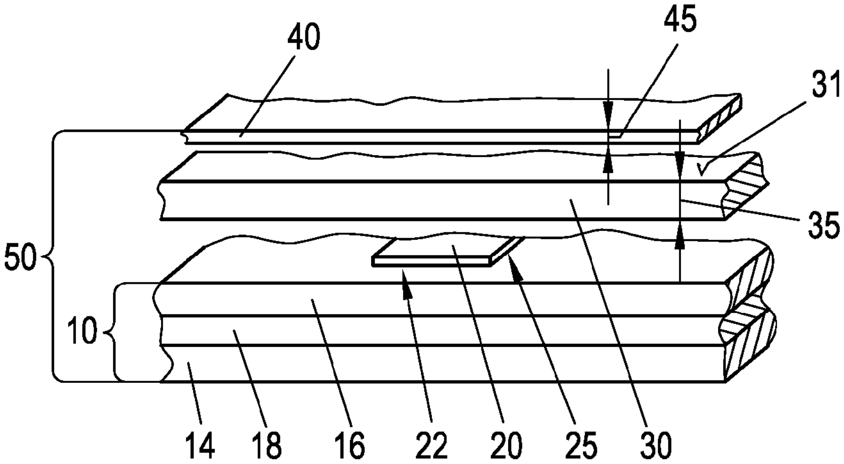

Fig. 4A

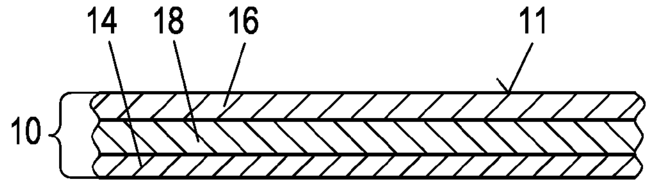

Fig. 3B

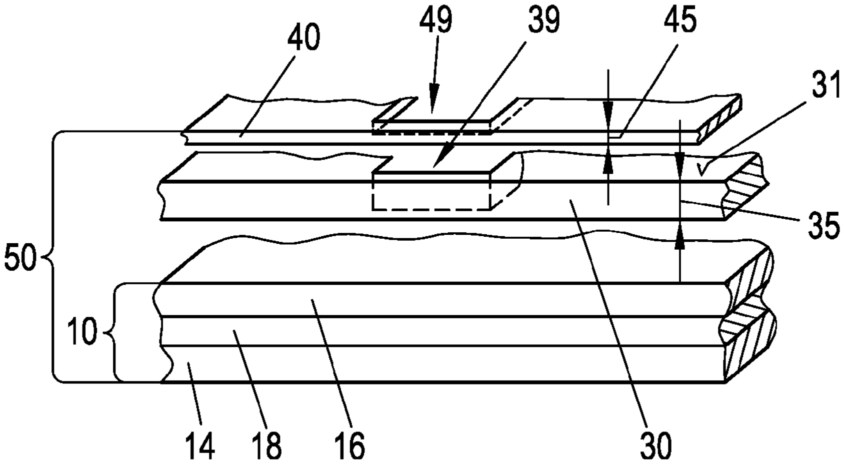

Fig. 4B

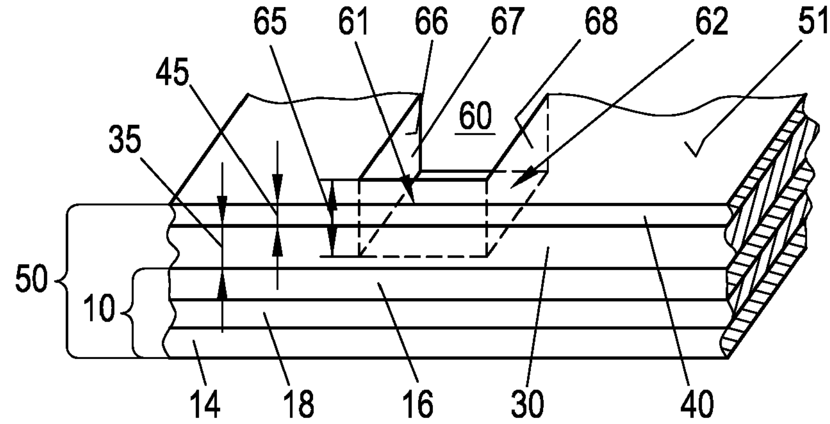
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Fig. 5

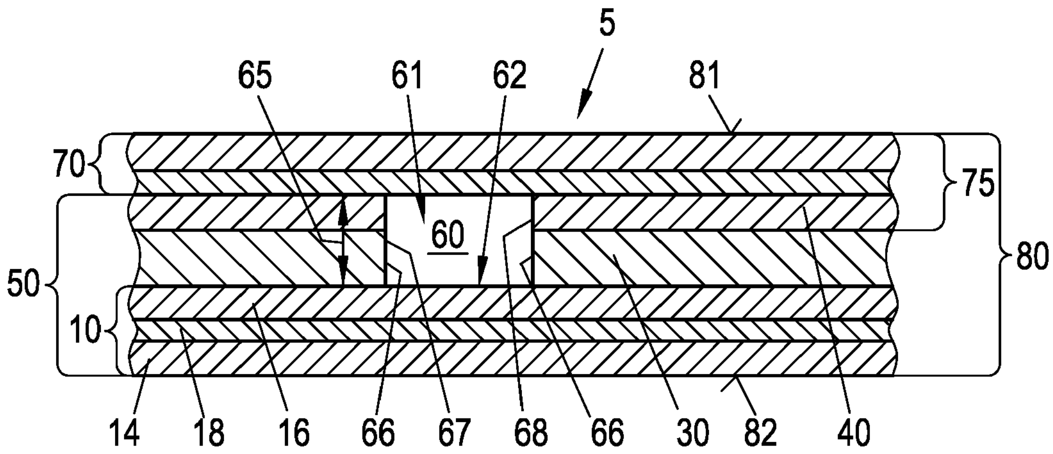
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Fig. 6

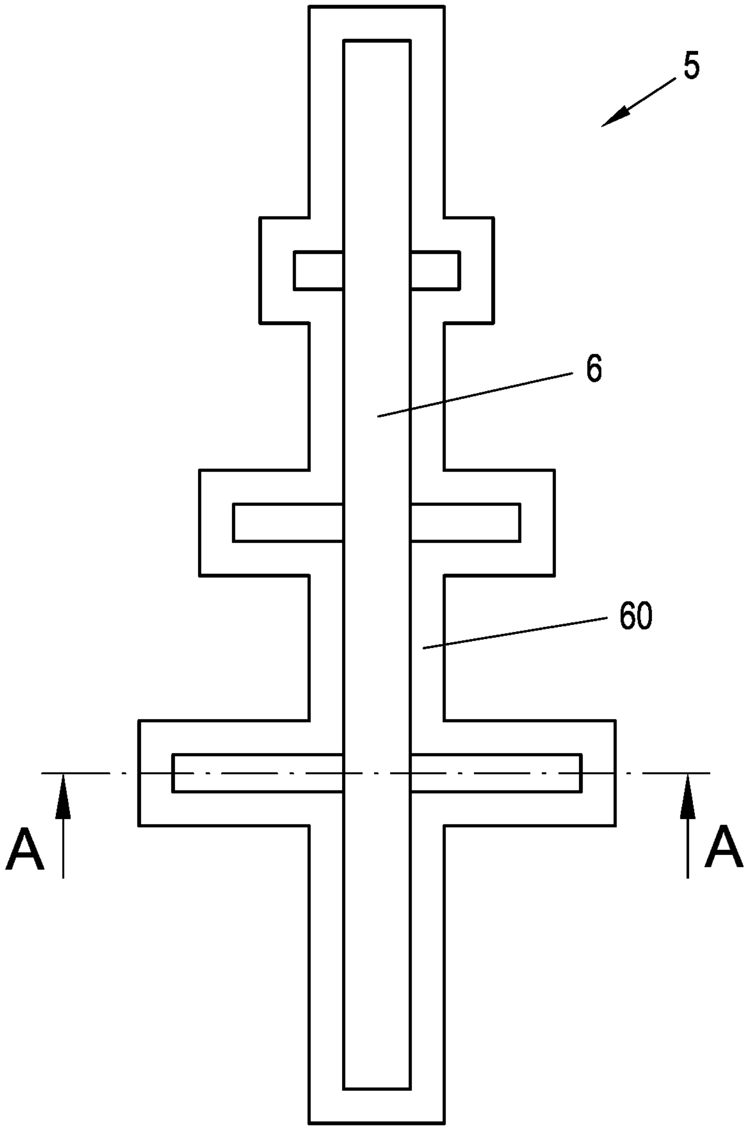

Fig. 7

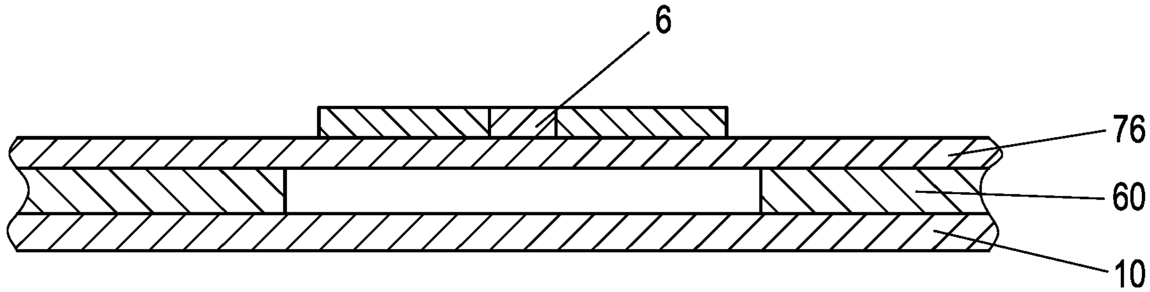

Fig. 8

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EUROPEAN SEARCH REPORT

Application Number
EP 16 15 7837

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 2012/212384 A1 (KAM DONG G [US] ET AL) 23 August 2012 (2012-08-23)	2-20	INV. H05K3/46 H01Q1/38
Y	* paragraphs [0029] - [0039]; figure 1 *	1,3-12	

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TECHNICAL FIELDS SEARCHED (IPC)

H05K
H01Q

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	24 August 2016	Degroote, Bart

CATEGORY OF CITED DOCUMENTS

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24-08-2016

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