Title: NON-ADHESIVE SLIDING STRUCTURE BALANCING MECHANICAL STRESS IN MOUNTING DEVICE

Abstract: A mounting device (100) for mounting electronic components, wherein the mounting device (100) comprises a carrier structure, in particular an electrically conductive structure (102), and a sliding structure (104) being at least partially embedded within the carrier structure, in particular the electrically conductive structure (102), and being made of a material which has non-adhesive properties on material of the carrier structure, in particular the electrically conductive structure (102), so that portions of the carrier structure, in particular the electrically conductive structure (102), are capable of sliding on the sliding structure (104) to thereby at least partially equilibrate mechanical stress within the mounting device (100).
Non-adhesive sliding structure balancing mechanical stress in mounting device

The invention relates to a mounting device, and a method of manufacturing a mounting device.

In the context of growing product functionalities of mounting devices equipped with one or more electronic components and increasing miniaturization of such electronic components as well as a rising number of electronic components to be mounted on mounting devices such as printed circuit boards, increasingly more powerful array-like components or packages having several electronic components are being employed, which have a plurality of contacts or connections, with ever smaller spacing between these contacts. Removal of heat generated by such electronic components and the mounting device itself during operation becomes an increasing issue. Furthermore, thermal expansion being different for different materials in a mounting device such as a printed circuit board results in mechanical stress within the mounting device, so that this undesired effect becomes an increasing issue in view of the increasing demands concerning a temperature range within which mounting devices have to operate.

DE 103 93 851 B4 discloses a semiconductor element heat dissipation element comprising a semiconductor element, an electrically conductive substrate, and a diamond-like carbon layer which is arranged between the semiconductor element and the diamond-like carbon layer. A further intermediate layer may be provided between the diamond-like carbon layer and the electrically conductive substrate to improve the adhesive properties of the diamond-like carbon layer.

US 2006/0 084 297 A1 discloses an anisotropically conductive sheet for the inspection of circuit boards. The anisotropically conductive sheet comprises an electrically insulating sheet body with magnetic electrically conductive particles arranged within the sheet body. A diamond-like carbon film is formed on the surface of the sheet body to prevent the circuit board to be inspected from adhering to the sheet body.
It is an object of the invention to provide a mounting device which can operate over a broad temperature range without the danger of a damage of the mounting device.

In order to achieve the object defined above, a mounting device, and a method of manufacturing a mounting device according to the independent claims are provided.

According to an exemplary embodiment of the invention, a mounting device for mounting electronic components is provided, wherein the mounting device comprises a carrier structure (in particular an electrically conductive structure), and a sliding structure being at least partially embedded within the carrier structure (in particular the electrically conductive structure) and being made of a material which has non-adhesive properties on material of the carrier structure (in particular the electrically conductive structure), so that portions of the carrier structure (in particular the electrically conductive structure) are capable of sliding on the sliding structure thereby at least partially equilibrate mechanical stress within the mounting device.

According to another exemplary embodiment of the invention, a method of manufacturing a mounting device for mounting electronic components is provided, wherein the method comprises providing a carrier structure (in particular an electrically conductive structure), and embedding a sliding structure at least partially within the carrier structure (in particular the electrically conductive structure) and making the sliding structure of a material which has non-adhesive properties on material of the carrier structure (in particular the electrically conductive structure), so that portions of the carrier structure (in particular the electrically conductive structure) are capable of sliding on the sliding structure (in particular relative to one another) to thereby at least partially equilibrate mechanical stress within the mounting device.

In the context of the present application, the term "sliding structure" may particularly denote a physical medium at least partly in direct contact with the carrier structure (in particular the electrically conductive structure) and being made of such a material that the sliding structure does not strongly adhere to or form a strong bond with the carrier structure (in particular the electrically conductive structure). In other words, an interface between the
carrier structure (in particular the electrically conductive structure) and the sliding structure may be characterized by a relatively loose contact rather than by a strong bond, although small to moderate physical and/or chemically adhesion forces may still be present at the interface. Thus, in the presence of (for instance mechanically induced and/or thermally induced) forces (such as shear forces) acting on the carrier structure (in particular the electrically conductive structure) and/or the sliding structure, low friction sliding along the interface between the carrier structure (in particular the electrically conductive structure) and the sliding structure can take place to thereby balance out mechanical stress and therefore transfer the mounting device back into a low tension or tension free state. In particular, the interface may be the section of the mounting device which is designed to lose adhesion first in the presence of sufficiently strong external forces (in particular external forces above a predefined threshold value). In other words, regardless of a bond type at the interface, the sliding structure can be configured as a zone (such as a layer) at which the connection to the carrier structure (in particular to the electrically conductive structure) is adjusted in such a way that only small rolling friction and/or small sliding friction exists, and also static friction can be adjusted to be so small that quality influencing micro-vibrations are suppressed during a thermal expansion procedure.

According to an exemplary embodiment, a carrier structure such as an electrically conductive structure of the mounting device is intentionally brought in direct contact with a material constituting a sliding structure, wherein the latter material may be designed to not adhere or bond with the surface of the carrier structure (in particular the electrically conductive structure). Hence, one or more mechanical weak points can be introduced into the design of the mounting device to thereby precisely define one or more spatial regions at which a sliding motion may take place between different sections of the mounting device in a predictable way. In case of any mechanical tensions, which may in particular arise from different thermal expansion coefficients between different materials of the mounting device (in particular material of the carrier structure embodied as electrically conductive structure and a further material, such as material of an electrically insulating core) and optionally also from external mechanical impact, the mounting device may
respond to such mechanical load in a self-sufficient and force equilibrating way to thereby increase the lifetime of the mounting device and its constituents. Thus, a mounting device is provided which can operate over a broad temperature range without the danger of a damage of the mounting device resulting from (particularly thermally induced) intrinsic mechanical stress within the mounting device.

In the following, further exemplary embodiments of the mounting device and the method will be explained.

In preferred embodiments, the carrier structure may be an electrically conductive structure, but may also be an electrically insulating structure. It is preferred that the carrier structure is an electrically conductive structure, because many electrically conductive structures such as copper have a weak adhesion on many sliding materials such as diamond like carbon. However, exemplary embodiments may additionally or alternatively also provide a sliding structure at an interface to an electrically insulating structure, such as of resin, resin soaked glass fibers, or FR4. The following description focuses on configurations of the carrier structure as electrically conductive structure. However, it should be emphasized that each of these embodiments may also be applied to a scenario in which the carrier structure is made of an electrically insulating material.

In an embodiment, the sliding structure may be configured as an only partial sliding structure (such as an only partial sliding layer), i.e. one or more isolated islands of material capable of promoting sliding in the presence of mechanical load. With such an only partial sliding structure, it is possible for a designer of the mounting board to specifically equip individual sections of the mounting device with local sliding structures. For instance, sections of the mounting device having a locally increased density of chip contacts may be rendered specifically stiff, thereby improving the quality of the entire mounting device.

In an embodiment, the sliding structure and the electrically conductive structure are locally fixed to one another exclusively at at least one fixing structure (while being not fixedly connected for the rest). The at least one fixing structure may in particular form part of the electrically conductive
structure. The one or more fixing structures may spatially confine or constrict at least a section of the sliding structure so that, in spite of the lack of adhesion of the sliding structure on the electrically conductive structure, complete separation or delamination of sliding structure and electrically conductive structure from one another is rendered impossible. This is highly advantageous, since it efficiently protects structural integrity of the mounting device. The one or more fixing structures may pin portions of the sliding structure or the entire sliding structure in place.

In an embodiment, the sliding structure comprises a layer having at least one through hole filled with material of the electrically conductive structure. In particular, a two-dimensional pattern of through holes (for instance arranged in rows and columns in a rectangular sliding material layer) may be provided, each of the through holes being filled with material of the electrically conductive structure. At least part of the fixing structures may be embodied as a respective via. Such a via may form part of the electrically conductive structure. It is however also possible that the at least one fixing structure is made of a material being separate from the electrically conductive structure, for instance from electrically insulating material.

In an embodiment, a number of the through holes per main surface area of the electrically conductive structure is in a range between 0.1 through holes/cm² and 10 through holes/cm². The number, density, size, and/or position of the one or more fixing structures can be advantageously selected so as to obtain a proper trade-off between the freedom of different sections of the mounting device to mutually slide for equilibrating mechanical load, and a sufficient rigidity and stability of the entire mounting device. In an embodiment, the number of fixing structures per square centimetre main surface of the mounting device can be less than or equal to one, for instance may be in a range between 0.1 and 1. The number of fixing structures of an entire mounting device can be less than 100, in particular less than 10. When the at least one fixing structure is embodied as a via or a cylindrical post, it may for instance have a diameter in a range between 30 pm and 120 pm.

In an embodiment, the sliding structure comprises or consists of a thermally conductive and electrically insulating material. This has the effect that the sliding structure also provides a significant contribution to the removal
of heat from the mounting device generated, for instance due to ohmic losses
or the like, during operation of the mounting device when carrying one or
more electronic components mounted thereon.

In an embodiment, the thermal conductivity of the thermally conductive
and electrically insulating sliding structure is higher than 2 W/mK, particularly
higher than 50 W/mK, more particularly higher than 400 W/mK. Such values
of the thermal conductivity are significantly better than the thermal conductivi-
ty of conventionally used electrically insulating materials (for instance FR4:
\(~0,3\ W/mK\) of mounting devices such as printed circuit boards, which there-
fore significantly improves the heat removal from the mounting device during
operation of the mounting device with electronic components (such as pack-
aged semiconductor chips, etc.) mounted thereon.

In an embodiment, the sliding structure has a smaller thermal expansion
coefficient than the electrically conductive structure (in case of anisotropic
thermal expansion coefficients, this feature shall refer to an average value). In
a further embodiment, the sliding structure has a smaller thermal expansion
coefficient than an electrically insulating structure of the mounting device (in
case of anisotropic thermal expansion coefficients, this feature shall refer to an
average value). Such a selection of the materials may result advantageously in
a heat spreading over the mounting device. In particular, the coefficient of
thermal expansion (CTE) of the material of the sliding structure may be
smaller than both thermal expansion coefficients of the material of the electri-
cally conductive structure and of optional material of an electrically insulating
structure mentioned below in further detail. When these conditions are ful-
filled, thermally induced mechanical tensions within the mounting device can
be at least partially compensated. Hence, the sliding structure may fulfill
multiple tasks in such an embodiment, i.e. enabling equilibration of mechanical
load by sliding, compensating effects due to high and in particular different
thermal expansion coefficients of constituents of the mounting device, and
optionally contributing to the removal of heat.

In an embodiment, material of the electrically conductive structure has
a smaller thermal expansion coefficient than material of the electrically
insulating structure. When the CTE value (for instance an average CTE value
over the various spatial directions) of the electrically conductive material is in
between the CTE values of the electrically insulating structure and the sliding
structure, differences between the CTE values of the electrically insulating
structure and the electrically conductive structure can be at least partially
equilibrated or compensated by the sliding structure so as to reduce mechan-
cal stress. This particularly holds in a geometry in which the sliding structure is
embedded in an interior of the electrically conductive structure and the
electrically insulating structure is configured as material attached to an outside
(for instance the main surfaces) of the electrically conductive structure.

In an embodiment, the mounting device further comprises an electrical-
insulating structure at least partially in contact with the electrically conduc-
tive structure. For instance, the electrically insulating structure comprises or
consists of resin, in particular comprises resin soaked glass fibres. In particu-
lar, the electrically insulating structure may be prepreg material (such as a
prepreg sheet or prepreg islands). Such prepreg material may form at least
partially an electrically insulating structure of a glass fiber reinforced epoxy-
based resin and may be shaped as a for instance patterned plate or sheet.
Prepreg may be denoted as a glass fiber mat soaked by resin material and
may be used for an interference fit assembly for the manufacture of mounting
devices such as printed circuit boards.

Exemplary embodiments of the mounting device are however not lim-
ited to such prepreg or FR4 materials. It is for instance also possible to
implement a sliding structure for designing flexiprints. For instance, it is
possible to implement a sliding structure (such as a sliding layer) in a mount-
ing device having a polyimide carrier, and a meander structure of electrically
conductive material such as copper. In particular, a sliding structure according
to an exemplary embodiment can be implemented in a flexible printed circuit
board, in order to obtain a better cyclic stability and smaller back driving
forces in view of an improved sliding capability.

In an embodiment, the electrically insulating structure is at least partial-
ly in contact with the sliding structure. More particularly, the sliding structure
may be made of a material which has adhesive properties on material of the
electrically insulating structure. For instance, the sliding structure may be
made of diamond like carbon, and the electrically insulating structure of FR4.
While direct, non-adhesive contact between the sliding structure and the
electrically conductive structure may ensure for a sliding equilibration motion between different sections of the mounting device, direct, adhesive contact between the sliding structure and the electrically insulating structure ensures that the mounting device remains stable as a whole.

In an embodiment, the electrically insulating structure is formed on at least one of two opposing main surfaces of the electrically conductive structure. In other words, the electrically conductive structure with the embedded sliding structure may be interposed between two electrically insulating bodies (such as sheets).

In an embodiment, the electrically conductive structure comprises or consists of copper. Copper is highly appropriate due to its high electrical and thermal conductivity and a desired poor adhesion in relation to sliding structure material such as diamond-like carbon. However, alternative materials are possible for the electrically conductive structure, such as an aluminum or nickel.

In an embodiment, the sliding structure comprises one of the group consisting of diamond-like carbon (DLC), a nitride (in particular a metal nitride such as aluminum nitride, etc.), and an oxide (in particular a metal oxide such as aluminum oxide, zinc oxide, etc.).

In the context of the present application, the term "diamond-like carbon" (DLC) may be denoted as a mixture of different forms of amorphous and/or crystalline carbon materials which may have both graphitic and diamond-like characteristics. DLC may contain adjustable (for instance by selecting a certain DLC production method and/or by correspondingly adjusting process parameters of a selected production method) amounts of sp² hybridized carbon atoms and/or sp³ hybridized carbon atoms. By mixing these polytypes in various ways at the nanoscale level of structure, a DLC structure as thermally conductive and electrically insulating sliding structure can be made that at the same time is amorphous, flexible, and yet of sp³ bonded diamond type.

Specifically the mentioned materials of the sliding structure are capable of being deposited on the electrically conductive structure (for instance of copper), without formation of a strong chemical bond, by physical vapor deposition (PVD), chemical vapor deposition (CVD), or plasma enhanced
chemical vapor deposition (PECVD), and simultaneously provide thermally conductive and electrically insulating properties.

In an embodiment, the electrically conductive structure comprises two layers, wherein the sliding structure is sandwiched between the two layers. For instance, a layer of material of the sliding structure may be deposited on a first electrically conductive foil (such as a copper foil), before a second electrically conductive foil (for instance a further copper foil) can be attached on top of the deposited material of the sliding structure. The embedding of the material of the sliding structure between two electrically conductive structures prevents the non-adhesive material of the sliding structure from being located on an exposed surface of the mounting device which would result in a removal of the sliding structure already in the presence of very small forces, for instance when being touched by hand.

In an embodiment, a thickness of the sliding structure perpendicular to opposing main surfaces of the mounting device is in a range between 100 nm and 1 pn. Therefore, the sliding structure may have very small physical dimensions and will increase the volume and mass of the manufactured mounting device only to a very minor extent. Therefore, a highly compact and lightweight mounting device may be obtained which however has integrated a very efficient protection mechanism against thermally induced damages.

In an embodiment, the mounting device is shaped as a plate, wherein the sliding structure is arranged to allow for an equilibrating sliding motion between different layers of the plate-shaped mounting device. Such an embodiment is shown in Figure 1 and Figure 2. Thus, the sliding structure or part thereof may be positioned so that its boundary plane(s) with regard to adjacent portions of the electrically conductive structure allows for a horizontal sliding when a main surface of the mounting device is positioned on a ground.

In an embodiment, the mounting device is shaped as a plate, wherein the sliding structure is arranged to allow for an equilibrating sliding motion between different portions of the plate-shaped mounting device (in particular of the electrically conductive structure thereof) in a direction normal to main surfaces of the plate. Such an embodiment is shown in Figure 3. Thus, the sliding structure or part thereof may be positioned so that its boundaries with
regard to adjacent portions of the electrically conductive structure slide vertically when main surfaces of the mounting device are aligned horizontally.

It should be said that combinations between the two previously described embodiments are possible, i.e. a configuration of the sliding structure allowing for an equilibration motion within a plane parallel to a main surface of the mounting device and simultaneously an equilibration motion perpendicular to such a plane.

The sliding structure may be configured to at least partially equilibrate thermally induced mechanical stress within the mounting device induced by different values of the thermal conductivity and/or induced by different values of the thermal expansion coefficient of different materials (in particular of the electrically conductive material and the electrically insulating material) of the mounting device.

In an embodiment, the mounting device is configured as one of the group consisting of a circuit board (in particular a printed circuit board), a substrate, and an interposer.

In the context of the present application, a "circuit board" may denote a particularly plate shaped body which has an electrically insulating core and electrically conductive structures on at least one surface of the circuit board. Such a circuit board may serve as a basis for mounting electronic members thereon and/or therein and serves both as a mechanical support platform and an electrically wiring arrangement.

In the context of the present application, a "printed circuit board" (PCB) may denote a board of an electrically insulating core (in particular made of a compound of glass fibers and resin) covered with electrically conductive material and conventionally serving for mounting thereon one or more electronic members (such as packaged electronic chips, sockets, etc.) to be electrically coupled by the electrically conductive material. More specifically, a PCB may mechanically support and electrically connect electronic components using conductive tracks, pads and other features etched from metal structures such as copper sheets laminated onto an electrically non-conductive substrate. PCBs can be single sided (i.e. may have only one of its main surfaces covered by a, in particular patterned, metal layer), double sided (i.e. may have both of its two opposing main surfaces covered by a, in particular patterned, metal
layer) or of multi-layer type (i.e. having also one or more, in particular patterned, metal layers in its interior). Conductors on different layers may be connected to one another with holes filled with electrically conductive material, which may be denoted as vias. The corresponding holes (which may be through holes or blind holes) may be formed for instance mechanically by boring, or by laser drilling. PCBs may also contain one or more electronic components, such as capacitors, resistors or active devices, embedded in the electrically insulating core.

In the context of the present application, an "interposer" may denote an electrical interface device routing between one connection to another. A purpose of an interposer may be to spread a connection to a wider pitch or to reroute a connection to a different connection. One example of an interposer is an electrical interface between an electronic chip (such as an integrated circuit die) to a ball grid array (BGA).

In the context of the present application, a "substrate" may denote a physical body, for instance comprising a ceramic material, onto which electronic components are to be mounted. Such substrates may comprise one or more amorphous materials, such as for instance glass.

In an embodiment, embedding the sliding structure in the electrically conductive structure comprises forming a layer of the material of the sliding structure on a foil of the electrically conductive structure, attaching a further foil of the electrically conductive structure on the layer of the sliding structure, forming one or more bores extending through the further foil and the layer of the sliding structure, and filling the one or more bores with electrically conductive material. This procedure has the advantage that the material of the sliding structure, which does not adhere on its electrically conductive support in form of the first foil, can be rapidly covered by the further foil before further processing to manufacture at least one fixing structure by filling the bores. Forming the bores can be performed by laser drilling, by mechanical drilling, or by an etching and lithography procedure.

In an alternative embodiment, embedding the sliding structure in the electrically conductive structure comprises arranging a mask over a foil of the electrically conductive structure, applying material of the sliding structure selectively onto surface portions of the foil being uncovered by the mask,
removing the mask, and attaching a further foil of the electrically conductive structure on the foil with the formed sliding structure. No additional effort for hole formation occurs with such a manufacturing method.

In an embodiment, forming the sliding structure comprises one of the group consisting of physical vapor deposition (PVD), chemical vapour deposition (CVD), and plasma enhanced chemical vapour deposition (PECVD). Thus, the sliding structure may be formed by deposition on an underlying substrate.

In an embodiment, the method further comprises providing an electrically insulating structure, forming the electrically conductive structure as a patterned structure on at least one of two opposing main surfaces of the electrically insulating structure, and subsequently forming the sliding structure in direct contact with both the electrically conductive structure and the electrically insulating structure. This procedure ensures that the material of the sliding structure comes into direct contact with the electrically insulating structure where it properly adheres. At the same time, it can be ensured that the material of the sliding structure remains fixed only in the holes of the patterned electrically conductive structure, since it does not adhere to the material of the electrically conductive structure and can therefore be removed easily (for instance by brushing) from the uppermost top surface of the patterned electrically conductive structure.

The aspects defined above and further aspects of the invention are apparent from the examples of embodiment to be described hereinafter and are explained with reference to these examples of embodiment.

The invention will be described in more detail hereinafter with reference to examples of embodiment but to which the invention is not limited.

Figure 1 illustrates a cross-sectional view of a mounting device according to an exemplary embodiment of the invention.

Figure 2 illustrates a cross-sectional view of a mounting device according to another exemplary embodiment of the invention.

Figure 3 illustrates a cross-sectional view of a mounting device according to yet another exemplary embodiment of the invention.

Figure 4 illustrates a phase diagram indicating contributions of \( \text{sp}^2 \) hybridized carbon, \( \text{sp}^3 \) hybridized carbon and hydrogen of a sliding structure.
of a mounting device according to an exemplary embodiment of the invention, wherein mechanical and thermal properties of the mounting device may be adjusted by configuring a manufacturing procedure in accordance with a desired section of the phase diagram.

Figure 5 illustrates a cross-sectional view of a mounting device embodied as a printed circuit board according to an exemplary embodiment of the invention.

Figure 6 to Figure 8 show cross-sectional views of structures obtained during carrying out a method of manufacturing a mounting device according to an exemplary embodiment of the invention.

Figure 9 and Figure 10 show cross-sectional views of structures obtained during carrying out a method of manufacturing a mounting device according to another exemplary embodiment of the invention.

Figure 11 and Figure 12 show cross-sectional views of structures obtained during carrying out a method of manufacturing a mounting device according to still another exemplary embodiment of the invention.

The illustrations in the drawings are schematic. In different drawings, similar or identical elements are provided with the same reference signs.

Before exemplary embodiments will be described in further detail referring to the figures, some general considerations of the present inventors will be presented based on which exemplary embodiments have been developed.

According to one aspect of an exemplary embodiment, a sliding structure (such as a sliding layer, in particular a patterned sliding layer) can be formed within a thick metal portion (such as thick copper) of a mounting device and can be fixed to only individual and spatially limited fixation positions of the metal portion so as to enable slidability between portions of the mounting device relative to one another and on the poorly adhesive sliding structure. At the same time it is possible to maintain structural order within the mounting device as a result of the one or more predictably positioned fixation points, in accordance with a stapler or bostitch principle.

Prints may comprise an electrically insulating structure as carrier on which at least one electrically conductive structure (such as a copper layer) can be applied. The thicknesses of such layers of electrically insulating struc-
tures can be at least 35 prn and may comprise glass fiber mats soaked in epoxy resin (such as FR4, wherein FR denotes flame resistant). The electrically conductive structure can be embodied as electric paths or tracks which may have a height appropriate for signal transmission, for instance a standard height of approximately 18 prn. However, the height may be larger for high stability applications, or may be smaller for instance in view of continued miniaturization. Copper layers and tracks simultaneously serve for distributing and conducting dissipated heat from electronic components mounted on and/or in the mounting device. For the latter purpose, the layer thickness may be also higher.

When such circuit boards are in operation, heat is generated which results in material specific thermal expansion within the circuit board. For instance, FR4 material has a coefficient of thermal expansion (CTE) of approximately 14 to 17 ppm per degree Celsius in x and y direction, and even about 70 ppm per degree Celsius in z direction (wherein the xy plane defines the main surfaces of the circuit board, and the z direction corresponds to the thickness of the circuit board). The CTE of copper is approximately 16 ppm per degree Celsius in x, y and z direction. Hence, there is a difference of about 54 ppm per degree Celsius between copper and FR4 material in z direction. In particular when the circuit boards are relatively thin, the described effect can result in a warpage problem, originating from different materials with different values of CTE. Additionally, crack formation or fissuring may occur within tracks of the electrically conductive structure as a result of thermally induced load, which may disturb a failure free conduction of electric signal by the mounting device. When using thicker copper layers, the mentioned difference in the thermal expansion as compared to an electrically insulating structure of the mounting device becomes even more pronounced.

In order to overcome the above-mentioned technical challenges by exemplary embodiments of the invention, a printed material may be employed which uses intentionally the poor adhesion, more particular even repulsion, of diamond like carbon (DLC) and similar materials on copper and similar materials. By the implementation of one or more sliding structures (such as sliding layers) of a non-adhesive material (more precisely non-adhesive on the electrically conductive structure, in particular on copper), it is possible to at
least partially compensate for the differences of the thermal expansion. For instance, DLC is repulsed by copper and has a CTE of about 9 ppm per degree Celsius. As an example, a boundary layer between copper and DLC may be used as sliding layer for equilibrating structural tensions upon exertion of thermal loads, wherein the copper can slidingly move on the DLC layer with its higher CTE value. Furthermore, DLC has the advantage of a higher thermal conductivity as compared to FR4 material and functions simultaneously as electric insulator.

The manufacture of a corresponding mounting device can be performed by depositing (for instance by sputtering, or using plasma enhanced chemical vapor deposition) material for the sliding structure (such as DLC) on a sufficiently thick electrically conductive structure (such as a copper layer with a thickness of at least 18 pm). The material for the sliding structure may be covered by another part of the electrically conductive structure, for instance by a further metal foil. In order to prevent an undesired complete delamination between the electrically conductive structure and the sliding structure it is possible to form a desired number of bores or holes in defined sections of the electrically conductive structure and the deposited sliding structure material. Subsequently, it is possible to fill these holes with electrically conductive material, thereby forming filled vias, through connections or interlayer connections. The latter serve as stapler locally fixing sections of the sliding structure material between portions of the electrically conductive structure (for instance between two copper layers). Optionally, further lamination and formation of any desired multilayer composition can be subsequently carried out.

Hence, an embodiment of the invention in particular relates to one DLC layer between two full-area copper layers, wherein the DLC layer is fixed to the copper layers by filled vias.

According to another aspect of an exemplary embodiment, one or more electrically insulating elasticity (or sliding) layers with an increased value of the thermal conductivity may be implemented in a mounting device for at least partially compensating different thermal expansion coefficients of different materials within the mounting device.

By the formation of one or more elasticity (or sliding) layers of a material having poor or no adhesion to material of the electrically conductive
structure is possible to at least partially compensate the different CTE values of material of the electrically conductive structure (such as copper) and material of an electrically insulating structure (such as FR4). Particularly advantageous in this respect is the use of DLC for the elasticity layer(s) which has both an appropriate CTE value (of about 9 ppm per degree Celsius) and lack of adhesion on copper. In the event of thermal loads, the boundary layer between copper and DLC acts as the above-mentioned sliding structure. Furthermore, DLC has the advantage to be thermally conductive and electrically isolating, so that no limitations with regard to the printed circuit board design need to be considered.

A corresponding mounting device may be manufactured by depositing material for the sliding structure (for instance a DLC layer) partially on material of the electrically conductive structure (such as copper), and partially on material of an electrically insulating structure (such as FR4). Such a deposition may be performed by sputtering or plasma enhanced chemical vapor deposition, for instance after a stripping procedure. Due to the non-adhesion between the sliding structure material and material of the electrically conductive structure (in particular in combination with a material selection providing a proper adhesion between the sliding structure material and material of the electrically insulating structure) the portion of the sliding structure material deposited on material of the electrically conductive structure may be very simply removed selectively therefrom (for instance by brushing or the like). In contrast to this, the material of the sliding structure adhering properly well on the material of the electrically insulating structure (such as FR4) may remain part of the mounting device to be manufactured. Subsequently, it is optionally possible to perform further lamination procedures.

Hence, using a material with a very small value of the CTE for the sliding structure (for instance using a material for the sliding structure having a CTE value of not more than 10 ppm per degree Celsius), it is possible to at least partially compensate the significantly different CTE values of the electrically conductive structure and of the electrically insulating structure. Simultaneously, the non-adhesion between the sliding structure material and the material of the electrically conductive material may be used for enabling elastic sliding in an interior of the mounting device. Advantages can also be
obtained in view of a possible higher thermal conductivity of material of the sliding structure as compared to FR4 material as conventionally used alone for forming electrically insulating structures of mounting devices.

**Figure 1** illustrates a mounting device 100 according to an exemplary embodiment of the invention.

The mounting device 100 serves for mounting one or more electronic components (not shown, for instance packaged electronic chips, active or passive electronic components, etc.) thereon. The mounting device 100 comprises an electrically conductive structure 102 which is here made of copper. A sliding structure 104, which may be preferably made of diamond like carbon (DLC), is embedded within the electrically conductive structure 102 (more precisely between two copper foils bonded to one another, see for instance **Figure 6** to **Figure 8**). The sliding structure 104, in the shown embodiment a patterned layer, is made of a material which has non-adhesive properties on material of the electrically conductive structure 102. The described embodiment makes use of the fact that DLC does not adhere on, but does even repel, copper material. In view of the shown embedded configuration of the sliding structure 104 within the electrically conductive structure 102 in combination with multiple fixation structures 108 embodied as post shaped copper sections of the electrically conductive structure 102, portions of the electrically conductive structure 102 above and below the patterned layer constituting the sliding structure 104 are capable of sliding on the sliding structure 104 in the presence of mechanical stress. When such mechanical stress is thermally induced, such a sliding motion results in an equilibration or balancing of mechanical stress within the mounting device 100. A number of the fixation structures 108 per main surface area of the electrically conductive structure 102 may be in an order of magnitude of 0,5 fixation structures 108/cm² to obtain both sufficient flexibility for thermal equilibration motion and sufficient stability as required for many modern electronic applications. The arrangement of the fixation structures 108 may be a two-dimensional distribution, for instance in a matrix like pattern (i.e. in rows and columns).

Advantageously, the DLC material constituting the sliding structure 104 is thermally conductive (so as to contribute to the heat removal during
operation of the mounting device 100) and electrically insulating (so that the presence of the sliding structure 104 does not impose any limitations to a circuit designer when designing the mounting device 100).

Moreover, the sliding structure 104 of DLC has a smaller thermal expansion coefficient than both the copper material constituting the electrically conductive structure 102 as well as prepreg material of an electrically insulating structure 106 (which is here embodied as two electrically conductive sheets covering two opposing main surfaces of the electrically conductive structure 102). Thus, the small CTE of DLC in combination with the significantly higher CTE values of copper and prepreg results in the suppression of mechanical stress when the mounting device 100 is subject to high temperatures.

A thickness, A1 and A2, of any of the copper foils of the electrically conductive structure 102 may be in a range between 1 pm and 100 pm, for instance in a range between 2 pm and 35 pm. A thickness, B, of the sliding structure 104 perpendicular to opposing main surfaces of the mounting device 100 may be in a range between 100 nm and 1 pm. A respective thickness, C1 and C2, of any of the prepreg sheets of the electrically insulating structure 106 may be in a range between 10 pm and 500 pm.

The mounting device 100 is shaped as a plate. The sliding structure 104 is arranged to allow for an equilibrating sliding motion between different layers of the plate-shaped mounting device 100, more precisely between the upper copper foil and the lower copper foil (indicated schematically by arrows 110).

**Figure 2** illustrates a mounting device 100 according to another exemplary embodiment of the invention.

In addition to the mounting device 100 shown in Figure 1, the mounting device 100 shown in Figure 2 shows the electrically insulating structure 106 of Figure 1 after patterning. Subsequently, additional electrically conductive material and electrically insulating material, either as continuous sheets or as patterned structures, are deposited and/or pressed onto the shown layer sequence to thereby establish more sophisticated electronic wiring functions. The mounting device 100 of Figure 2 is particularly suitable to be used as printed circuit board (PCB).

**Figure 3** illustrates a mounting device 100 according to yet another
exemplary embodiment of the invention.

In contrast to the embodiments of Figure 1 and Figure 2, Figure 3 illustrates a mounting device 100 in which the electrically insulating structure 106 is partially in contact with the sliding structure 104, and partially in contact with the electrically conductive structure 102. The sliding structure 104 is made of a material (such as DLC) which has adhesive properties on material of the electrically insulating structure 106 (such as prepreg/FR4).

Also according to Figure 3, the mounting device 100 is shaped as a plate. The sliding structure 104 is arranged to allow for an equilibrating sliding motion between different portions of the mounting device 100 (in particular different portions of the electrically conductive structure 102) in a direction normal to main surfaces of the plate, as indicated schematically by arrow 300. This also contributes to the equilibration of thermally induced mechanical stress in an interior of the mounting device 100.

Since the value of the CTE of both the copper material of the electrically conductive structure 102 and the FR4/prepreg material of the electrically insulating structure 106 is larger than the value of the CTE of the DLC material of the sliding structure 104, thermally induced stress is further suppressed.

With regard to the illustration of the sliding structure 104 with individual sections having the island-like configuration of Figure 3, it should be said that, particularly when the electrically conductive structure 102 and/or the electrically insulating structure 106 exceed(s) certain thicknesses, it might happen that not the entire volume of the gaps in between the electrically conductive structure 102 and the electrically insulating structure 106 is fully filled with the material of the sliding structure 104 (for instance when the latter is made of DLC, which has a high stability particularly at low thickness values of for instance below 1 μm). In contrast to this, it may also happen that these gap volumes are only partially filled with material of the sliding structure 104. However, the general functional principle, as described, will not be changed by this fact.

Figure 4 illustrates a phase diagram 400 indicating contributions of sp² hybridized carbon, sp³ hybridized carbon und hydrogen of a sliding structure 104 of a mounting device 100 according to an exemplary embodiment of the invention, wherein mechanical and thermal properties of the mounting device
100 may be adjusted by configuring a manufacturing procedure in accordance with a desired section of the phase diagram.

According to the phase diagram 400, the sliding structure 104 of diamond like carbon (DLC) is a hydrogen (H) comprising amorphous carbon coating with a mixture of sp² and sp³ hybridized carbon. Preferably, the portion of sp² hybridized carbon is in a range between 40 and 60 weight percent of the thermally conductive and electrically insulating structure 106, the portion of sp³ hybridized carbon is in a range between 25 and 40 weight percent of the thermally conductive and electrically insulating structure 106, and the percentage of hydrogen is above 10 weight percent (preferably not above 40 weight percent). When the sliding structure 104 is formed by sputtering/physical vapor deposition (PVD), the percentage of sp² hybridized carbon is high. When however plasma enhanced chemical vapor deposition (PECVD) is used for forming the sliding structure 104, a higher hydrogen percentage is obtained. With a high percentage of sp² hybridized and sp³ hybridized carbon, a high thermal conductivity of the sliding structure 104 may be obtained. With a high hydrogen percentage, a mechanically stable sliding structure 104 is obtained. By a selection of the manufacturing procedure (for instance also adjustment of the precise process parameters and/or, if desired, a combination of the above-mentioned manufacturing procedures), the mechanical and thermal properties of the sliding structure 104 may be precisely set. A particularly appropriate composition in terms of the mechanical and thermal properties is shown in Figure 4 with an area denoted with reference numeral 402.

**Figure 5** illustrates a mounting device 100, embodied as a printed circuit board, according to another exemplary embodiment of the invention.

The mounting device 100 comprises an electrically insulating structure 106 as dielectric core with patterned metal islands forming part of electrically conductive structure 102 on both opposing main surfaces of the electrically insulating structure 106. Figure 5 furthermore shows through holes through the electrically insulating structure 106 filled with vias 500. The vias 500 may comprise a post-shaped central portion forming part of the electrically conductive structure 102 (for instance made of copper) covered with a hollow sliding structure 104 (for instance made of DLC). Beyond this, a patterned copper
layer with an embedded patterned DLC layer as sliding structure 104 is embedded within the electrically insulating structure 106.

With the mounting device 100 shown in Figure 5, a combination of horizontal and vertical equilibration sliding motions is possible.

Figure 6 to Figure 8 show cross-sectional views of structures obtained during carrying out a method of manufacturing a mounting device 100 according to an exemplary embodiment of the invention.

In order to obtain a structure 600 shown in Figure 6, a DLC layer is deposited by sputtering or chemical vapor deposition on a lower copper foil constituting the lower portion of electrically conductive structure 102. Subsequently, an upper copper foil constituting the upper portion of the electrically conductive structure 102 is pressed together with the layer sequence of the lower copper foil and the continuous DLC layer.

In order to obtain a structure 700 shown in Figure 7, holes 702 are formed in the structure 600 by a laser drilling procedure. The holes 702 penetrate through the entire upper copper foil, the entire DLC layer, and a part of the lower copper foil.

In order to obtain a mounting device 100 shown in Figure 8, copper material is filled into the holes 702. This can be done by a galvanic deposition (such as electroplating) or by filling the holes 702 with copper paste. Thereby, the fixation structures 108 are formed and the holes 702 are closed.

Figure 9 and Figure 10 show cross-sectional views of structures obtained during carrying out a method of manufacturing a mounting device 100 according to another exemplary embodiment of the invention.

In order to obtain a structure 900 shown in Figure 9, a mask 902 or screen is positioned so as to partially cover a foil of the electrically conductive structure 102. Subsequently, DLC material for forming the sliding structure 104 is deposited selectively onto surface portions of the foil being uncovered by the mask 902 (see arrows in Figure 9). As can be taken from Figure 9, also top surface portions of the mask 902 are thereby covered with DLC material.

In order to obtain a mounting device 100 shown in Figure 10, the mask 902 is removed. Furthermore, a further foil of the electrically conductive structure 102 is attached to the foil with the formed sliding structure 104 so that the two foils sandwich the sliding structure 104.
Figure 11 and Figure 12 show cross-sectional views of structures obtained during carrying out a method of manufacturing a mounting device 100 according to still another exemplary embodiment of the invention.

The starting point of Figure 11 is an electrically insulating structure 106, for instance a prepreg sheet. A copper layer of electrically conductive structure 102 is deposited on or attached to the electrically insulating structure 106 and is patterned (for instance by printing or photolithographically). Subsequently, a DLC layer is deposited, by sputtering or CVD, on the exposed surface portions of the electrically insulating structure 106 and of the electrically conductive structure 102. DLC material properly adheres to the prepreg material, but does not adhere to the copper material. Hence, simply brushing over structure 1100 shown in Figure 11 (not shown) will remove the DLC material selectively from the exposed portions of the electrically conductive structure 102.

In order to obtain mounting device 100 shown in Figure 12, the structure 1100 can be further processed, for instance by attaching one or more further structures of electrically conductive and/or electrically insulating material, see reference numeral 1200 as a mere example.

It should be noted that the term "comprising" does not exclude other elements or steps and the "a" or "an" does not exclude a plurality. Also elements described in association with different embodiments may be combined.

It should also be noted that reference signs in the claims shall not be construed as limiting the scope of the claims.

Implementation of the invention is not limited to the preferred embodiments shown in the figures and described above. Instead, a multiplicity of variants are possible which use the solutions shown and the principle according to the invention even in the case of fundamentally different embodiments.
Claims:

1. A circuit board (100) for mounting electronic components, wherein the circuit board (100) comprises:
   a carrier structure, in particular an electrically conductive structure (102);
   a sliding structure (104) being at least partially embedded within the carrier structure, in particular the electrically conductive structure (102), and being made of a material which has non-adhesive properties on material of the carrier structure, in particular the electrically conductive structure (102), so that portions of the carrier structure, in particular the electrically conductive structure (102), are capable of sliding on the sliding structure (104) to thereby at least partially equilibrate mechanical stress within the circuit board (100).

2. The circuit board (100) according to claim 1, wherein the sliding structure (104) and the carrier structure, in particular the electrically conductive structure (102), are locally fixed to one another by at least one fixing structure (108), the at least one fixing structure (108) in particular forming part of the carrier structure, in particular the electrically conductive structure (102).

3. The circuit board (100) according to claim 1 or 2, wherein the sliding structure (104) comprises or consists of a thermally conductive and electrically insulating material.

4. The circuit board (100) according to claim 3, wherein the thermal conductivity of the thermally conductive and electrically insulating structure (106) is higher than 2 W/mK, particularly higher than 50 W/mK, more particularly higher than 400 W/mK.

5. The circuit board (100) according to any of claims 1 to 4, wherein material of the sliding structure (104) has a smaller thermal expansion coefficient than material of the carrier structure, in particular the electrically conductive structure (102).
6. The circuit board (100) according to any of claims 1 to 5, further comprising an electrically insulating structure (106) at least partially in contact with the electrically conductive structure (102).

7. The circuit board (100) according to claim 6, wherein the electrically insulating structure (106) is at least partially in contact with the sliding structure (104).

8. The circuit board (100) according to claim 7, wherein the sliding structure (104) is made of a material which has adhesive properties on material of the electrically insulating structure (106).

9. The circuit board (100) according to any of claims 6 to 8, wherein material of the sliding structure (104) has a smaller thermal expansion coefficient than material of the electrically insulating structure (106).

10. The circuit board (100) according to any of claims 6 to 9, wherein material of the electrically conductive structure (102) has a smaller thermal expansion coefficient than material of the electrically insulating structure (106).

11. The circuit board (100) according to any of claims 6 to 10, wherein the electrically insulating structure (106) comprises or consists of resin, in particular comprises resin soaked glass fibres.

12. The circuit board (100) according to any of claims 1 to 11, wherein the electrically conductive structure (102) comprises or consists of copper.

13. The circuit board (100) according to any of claims 1 to 12, wherein the sliding structure (104) comprises or consists of diamond-like carbon, a nitride, and an oxide.

14. The circuit board (100) according to any of claims 1 to 13, wherein the carrier structure, in particular the electrically conductive structure (102),
comprises two layers, wherein the sliding structure (104) is sandwiched between the two layers.

15. The circuit board (100) according to any of claims 1 to 14, wherein the sliding structure (104) comprises a layer having at least one through hole, in particular a two-dimensional pattern of through holes, each of the at least one through hole being filled with material of the carrier structure, in particular the electrically conductive structure (102).

16. The circuit board (100) according to claim 15, wherein a number of the through holes per main surface area of the carrier structure, in particular the electrically conductive structure (102), is in a range between 0.1 through holes/cm$^2$ and 10 through holes/cm$^2$.

17. The circuit board (100) according to any of claims 1 to 16, wherein a thickness of the sliding structure (104) perpendicular to opposing main surfaces of the circuit board (100) is in a range between 100 nm and 1 pm.

18. The circuit board (100) according to any of claims 1 to 17, shaped as a plate, wherein the sliding structure (104) is arranged to allow for an equilibrating sliding motion between different layers of the plate-shaped circuit board (100).

19. The circuit board (100) according to any of claims 1 to 18, shaped as a plate, wherein the sliding structure (104) is arranged to allow for an equilibrating sliding motion between different portions of the plate-shaped circuit board (100) in a direction normal to main surfaces of the plate.

20. The circuit board (100) according to any of claims 1 to 19, wherein the sliding structure (104) is configured to at least partially equilibrate thermally induced mechanical stress within the circuit board (100) induced by different values of the thermal conductivity and/or induced by different values of the thermal expansion coefficient of different materials of the circuit board (100).
21. The circuit board (100) according to any of claims 1 to 20, configured as one of the group consisting of a printed circuit board, a substrate, and an interposer.

22. A method of manufacturing a circuit board (100) for mounting electronic components, wherein the method comprises:
   - providing a carrier structure, in particular an electrically conductive structure (102);
   - embedding a sliding structure (104) at least partially within the carrier structure, in particular the electrically conductive structure (102), and making the sliding structure (104) of a material which has non-adhesive properties on material of the carrier structure in particular the electrically conductive structure (102), so that portions of the carrier structure, in particular the electrically conductive structure (102), are capable of sliding on the sliding structure (104) to thereby at least partially equilibrate mechanical stress within the circuit board (100).

23. The method according to claim 22, wherein embedding the sliding structure (104) in the carrier structure, in particular the electrically conductive structure (102), comprises:
   - forming a layer of the material of the sliding structure (104) on a foil of the carrier structure, in particular the electrically conductive structure (102);
   - attaching a further foil of the carrier structure, in particular the electrically conductive structure (102), on the layer of the sliding structure (104);
   - forming one or more bores extending through the further foil and the layer of the sliding structure (104);
   - filling the one or more bores with material, in particular electrically conductive material.

24. The method according to claim 22, wherein embedding the sliding structure (104) in the carrier structure, in particular the electrically conductive structure (102), comprises:
   - arranging a mask (902) over a foil of the carrier structure, in particular the electrically conductive structure (102);
applying material of the sliding structure (104) selectively onto surface portions of the foil being uncovered by the mask (902);
removing the mask (902);
attaching a further foil of the carrier structure, in particular the electrically conductive structure (102), on the foil covered with the sliding structure (104).

25. The method according to any of claims 22 to 24, wherein forming the sliding structure (104) comprises one of the group consisting of physical vapour deposition, chemical vapour deposition, and plasma enhanced chemical vapour deposition.

26. The method according to any of claims 22 to 25, further comprising:
providing an electrically insulating structure (106);
forming the electrically conductive structure (102) as a patterned structure on at least one of two opposing main surfaces of the electrically insulating structure (106);
subsequently forming the sliding structure (104) in direct contact with both the electrically conductive structure (102) and the electrically insulating structure (106).
**INTERNATIONAL SEARCH REPORT**

### Observations where certain claims were found unsearable

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. 
   - **Claims Nos.:**
     - because they relate to subject matter not required to be searched by this Authority, namely:

2. **Claims Nos.:** 2-21, 23-26
   - because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
     - see FURTHER INFORMATION sheet PCT/ISA/210

3. 
   - **Claims Nos.:**
     - because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

### Observations where unity of invention is lacking

This International Searching Authority found multiple inventions in this international application, as follows:

1. 
   - **As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.**

2. 
   - **As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.**

3. 
   - **As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:**

4. 
   - **No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:**

**Remark on Protest**

- The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

- The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

- No protest accompanied the payment of additional search fees.
**INTERNATIONAL SEARCH REPORT**

**A. CLASSIFICATION OF SUBJECT MATTER**

INV. H05K1/02 H05K1/05 H05K3/44

ADD. According to International Patent Classification (IPC) and both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

H05K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic database consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>US 2014/003011 AI (KATO NOBORU [JP] ET AL) 2 January 2014 (2014-01-02) paragraph [0065]; figure 1</td>
<td>1, 12, 18, 20-22</td>
</tr>
<tr>
<td>X</td>
<td>US 6 320 136 Bl (SAKAMOTO AKIRA [JP]) 20 November 2001 (2001-11-20)</td>
<td>1, 3, 4, 6-12, 14, 18-22, 26</td>
</tr>
<tr>
<td>A</td>
<td>col umn 5, l ines 32-48; f igures 5-8 col umn 6, l ines 14-38</td>
<td>5, 13</td>
</tr>
<tr>
<td>A</td>
<td>US 2011/204408 AI (MCKENZIE JAMES STUART [GB] ET AL) 25 August 2011 (2011-08-25) paragraphs [0053], [0054], [0059], [0063], [0067], [0068]; figure 5</td>
<td>1, 14, 15, 22</td>
</tr>
</tbody>
</table>

- See patent family annex.

Further documents are listed in the continuation of Box C.

- Special categories of cited documents:
  - "X" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
  - "X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
  - "Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
  - "A" document member of the same patent family

Date of the actual completion of the international search: 29 October 2015

Date of mailing of the international search report: 05/11/2015

Name and mailing address of the ISA:
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040
Fax: (+31-70) 340-3016

Authorized officer:
Degroote, Bart

Form PCT/ISA/210 (second sheet) (April 2005)
<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patent document cited in search report</td>
<td>Publication date</td>
<td>Patent family member(s)</td>
</tr>
<tr>
<td>----------------------------------------</td>
<td>----------------</td>
<td>-------------------------</td>
</tr>
<tr>
<td>US 2014003011 AI</td>
<td>02-01-2014</td>
<td>CN 103416112 A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>US 2014003011 AI</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WO 2012120995 A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>US 6320136 BI</td>
</tr>
<tr>
<td></td>
<td></td>
<td>EP 2193696 Al</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GB 2455489 A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>US 2011204408 Al</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WO 2009024801 Al</td>
</tr>
<tr>
<td>EP 0520243 A2</td>
<td>30-12-1992</td>
<td>NONE</td>
</tr>
<tr>
<td>US 2008144291 AI</td>
<td>19-06-2008</td>
<td>TW 200836596 A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>US 2008144291 Al</td>
</tr>
<tr>
<td></td>
<td></td>
<td>EP 1817945 Al</td>
</tr>
<tr>
<td></td>
<td></td>
<td>JP 2008522387 A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>US 2008118706 Al</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WO 2006056149 Al</td>
</tr>
</tbody>
</table>
Claims Nos.: 2-21, 23-26 (altogether)

It appears that the claims are not supported by the description as required by Article 6 PCT, as the scope is broader than justified by the description on and drawings. In the description on all types of embodiments can be distinguished,

i) Embodiments having the feature that the sliding structure is a layer sandwiched between two electrically conductive layers of the carrier structure, wherein the sliding layer has through-holes thereon, the through-holes being filled with electrically conductive materials (see embodiments in Fig. 1, 2, 5 and Fig. 6-10 for manufacturing).

ii) Embodiments having the feature that the carrier structure comprises an electrically conductive layer sandwiched between two electrically isolating layers, wherein the electrically conductive layer has through-holes thereon, the through-holes being filled with the materials of the sliding structure (see embodiment in Fig. 3 and Fig. 11 and 12 for manufacturing).

Even though claim 1 in combination with the features of claims 14 and 15 partly covers the first type of embodiments, there is no feature that specifies that the sliding structure is sandwiched between two electrically conductive layers. For this reason, the claims are broader than justified by the description on and drawings.

Even though claim 1 in combination with the features of claims 6, 7 and 14 also covers the second type of embodiments, there is no feature that specifies that the carrier structure comprises an electrically conductive layer sandwiched between two electrically isolating layers. For this reason, the claims are broader than justified by the description on and drawings.

In view of the above, the international search was directed to the invention as defined by the claims, as interpreted with due regard to the description on and drawings and with particular emphasis on the invention concept towards which the claims are directed (PCT/GL/ISPE/4 15/22). For this reason, the subject of the international search mainly covered subject-matter defined by:

i) claim 1 in combination with the features of claims 14 and 15 and the additional feature that the sliding structure is sandwiched between two electrically conductive layers.

ii) claim 1 in combination with the features of claims 6, 7 and 14 and the additional feature that the carrier structure comprises an electrically conductive layer sandwiched between two electrically isolating layers.

No meaningful search appears to be possible with respect to claim 1 combined with features of other dependent claims. Any of the features covered by other dependent claims are considered as further additional features to the subject-matter covered by i) and ii).

The same reasoning applies to claim 22, which in combination with the features of claims 23-25 corresponds to subject-matter covered by i) and in combination with the
features of claim 26 corresponds to the subject-matter covered by ii).
For this reason, claims 2-21 and 23-26 are only partially searched.

The applicant's attention is drawn to the fact that claims relating to inventions in respect of which no international search report has been established need not be the subject of an international preliminary examination (Rule 66.1(e) PCT). The applicant is advised that the EPO policy when acting as an International Preliminary Examining Authority is normally not to carry out a preliminary examination on matter which has not been searched. This is the case irrespective of whether or not the claims are amended following receipt of the search report or during any Chapter II procedure. If the application proceeds into the regional phase before the EPO, the applicant is reminded that a search may be carried out during examination before the EPO (see EPO Guidelines C-IV, 7.2), should the problems which led to the Article 17(2) declaration be overcome.