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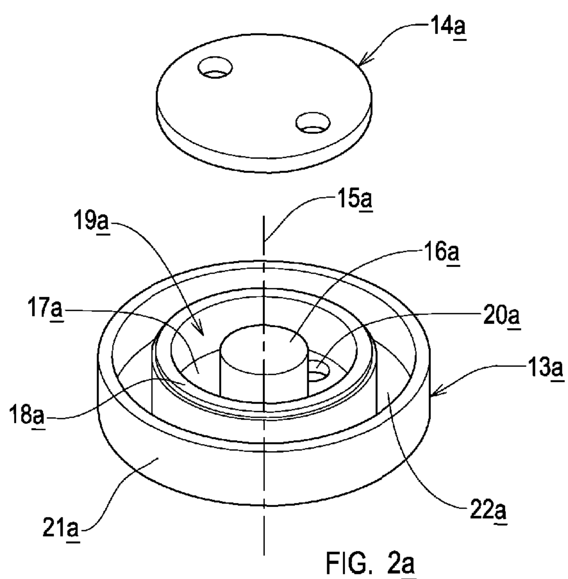

FIG. 2a

(57) Abstract: An electromagnetic arrangement comprises a ferrite core (9a). A primary transformer winding (6a) is connected in series with an inductor winding (23a). The primary transformer winding (6a) and the inductor winding (23a) are each wound around part of the main body (13a) of the core (9a). A secondary winding (10a) is attached to a separate ferrite plate (14a). The electromagnetic connector is configured to couple power in an electrical distribution system that operates with a high frequency alternating current.

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ELECTRICAL DEVICES

The inventions disclosed in this application relate to electrical devices and more particularly relate to LED lighting devices.

An Electromagnetic Arrangement

The present invention relates to an electromagnetic arrangement and more particularly relates to an electromagnetic arrangement for coupling power in a high frequency alternating current (HFAC) power distribution system which operates at a frequency of between 10kHz and 200kHz.

A mains powered LED lighting circuit incorporates a power supply unit to convert the mains supply voltage and current to suitable levels to power the LEDs in the lighting circuit. It is known to integrate a power supply unit into an LED lighting unit to produce a compact LED lighting device that can be powered directly by a mains supply. However, the problem with conventional integrated LED lighting devices of this kind is that the components of the power supply unit tend to fail well before the LEDs. When the lighting device stops working due to failure of the power supply unit, users are forced to replace the entire integrated device. This is wasteful and expensive because the fully functioning and expensive LEDs are disposed of unnecessarily as a result of the failure of the power supply unit.

A further problem with integrated LED lighting devices is that the integrated power supply is designed for use with a particular mains supply. It is not possible to use the lighting device with a mains supply having a different voltage than the one for which it has been designed. This means that different integrated LED lighting devices must be manufactured for different countries where the voltage of the mains supply is different. The different power supply requirements are confusing for the end user and provide complications for manufacturers and suppliers who distribute worldwide.

It has been proposed previously to provide a central LED power supply unit which is mains powered and which supplies power to LEDs which are remote from the LED power supply unit. However, there are still problems with this arrangement because the operating parameters of the power supply unit must still be fixed at the time of manufacture to match a particular mains supply voltage. A different central power supply unit must therefore be used in different countries where the mains supply voltage is different.

The present invention seeks to provide an improved electromagnetic arrangement.

An Electrical Device and a Method of Manufacturing an Electrical Device

The present invention relates to an electrical device and a method of manufacturing an electrical device and more particularly relates to an electrical device and a method of manufacturing an electrical device comprising a non-planar printed circuit board.

A conventional rigid printed circuit board is usually in the form of a rigid planar sheet that is cut to an appropriate shape for use in a device. Flexible printed circuit boards are used in low power devices, such as cameras and laptop computers, because flexible circuit boards can be deformed to fit a non-planar shape inside a device.

There is now a need for a non-planar circuit board that can be used in higher powered devices, such as LED lighting devices, that can operate at high temperatures of 40-80°C.

The present invention seeks to provide an improved electrical device and a method of manufacturing the same.

A Printed Circuit Board

The present invention relates to a printed circuit board and more particularly relates to a printed circuit board for use in an LED lighting device.

LED lighting device generates heat when in use. In order to maintain an appropriately low operating temperature, heat generated by LEDs in the device must be dissipated by a heatsink.

LED lighting devices often incorporate surface-mount LEDs which are mounted directly to an upper surface of a printed circuit board. The lower surface of the printed circuit board is usually mounted to a heatsink. To enable heat to be conducted from the LEDs to the heatsink it is known to provide thermal via holes in the printed circuit board which are filled with solder. The thermal via holes provide a thermal connection between the LED on the upper surface of the printed circuit board and the heatsink on the lower surface of the printed circuit board.

During assembly, solder flows from the top surface of the board and into the thermal via holes as the LEDs are mounted to the surface of the printed circuit board. The problem with forming conventional thermal via holes in this way is that solder tends to bulge out from the lower surface of the printed circuit board. This is particularly evident in large via holes. The solder bulging out from the lower surface of the printed circuit board means that the lower surface is no longer flat. When the heatsink is brought into contact with the lower surface of the printed circuit board, the heatsink rests unevenly on the bulging solder and is not flat against the surface of the printed circuit board. The uneven mounting of the heatsink to the printed circuit board impairs the performance of the heatsink and can prevent the heatsink from cooling the LEDs effectively.

The present invention seeks to provide an improved printed circuit board.

According to one aspect of the present invention, there is provided an electromagnetic arrangement comprising a first electromagnetic connector incorporating an inductor winding, a primary transformer winding which is connected electrically in series with the inductor winding, and a ferrite member, wherein the primary transformer winding is wound around a first part of the ferrite member and the inductor winding is wound around a second part of the ferrite member.

Preferably, the first and second parts of the ferrite member are formed integrally.

Conveniently, in a plane intersecting the ferrite member, the second part of the ferrite member at least partly surrounds the first part of the ferrite member.

Advantageously, the second part of the ferrite member is in the shape of a hollow cylinder.

Preferably, the ferrite member incorporates a base which connects the first part to the second part.

Conveniently, an electrical connection to the primary transformer winding extends through an aperture provided in the base.

Advantageously, an electrical connection to the inductor winding extends through a further aperture provided in the base.

Preferably, the ferrite member incorporates an outer wall which, in a plane intersecting the ferrite member, surrounds the first and second parts of the ferrite member.

Conveniently, the outer wall is in the shape of a hollow cylinder.

Advantageously, a top surface of the first electromagnetic connector is axi-symmetrical about an axis extending through the connector.

Preferably, the electromagnetic arrangement further comprises a second electromagnetic connector incorporating a secondary transformer winding which is air-wound with an aperture at its centre.

Conveniently, the aperture in the secondary transformer winding is configured to receive part of the first part of the ferrite member of the first electromagnetic connector.

Advantageously, the second electromagnetic connector incorporates a further ferrite member which incorporates an aperture through which an electrical connection to the secondary transformer winding extends.

Preferably, the further ferrite member is substantially disc-shaped.

According to another aspect of the present invention, there is provided a method of manufacturing an electrical device comprising providing a flexible printed circuit board having a first surface and a second surface, and forming a track arrangement on the printed circuit board, wherein the track arrangement comprises a first group of elongate tracks that are substantially aligned with one another and spaced apart from one another over a portion of the printed circuit board, and a second group of elongate tracks that are substantially aligned with one another and spaced apart from one another over a portion of the printed circuit board, and wherein the tracks in the first group are spaced apart from and at least partly interdigitated with the tracks in the second group to strengthen the flexible printed circuit board.

In one embodiment, the first and second groups of elongate tracks are formed on the first surface of the printed circuit board.

In another embodiment, the first group of elongate tracks is formed on the first surface of the printed circuit board and the second group of elongate tracks is formed on the second surface of the printed circuit board.

Conveniently, the method further comprises forming a further track arrangement on the printed circuit board, wherein the further track arrangement comprises a third group of elongate tracks that are substantially aligned with one another and spaced apart from one another over a portion of the printed circuit board, and a fourth group of elongate tracks that are substantially aligned with one another and spaced apart from one another over a portion of the printed circuit board, and wherein the tracks in the third group are spaced apart from and at least partly interdigitated with the tracks in the fourth group to strengthen the flexible printed circuit board.

In one embodiment, the third and fourth groups of elongate tracks are formed on the second surface of the printed circuit board.

In another embodiment, the third group of elongate tracks is formed on the first surface of the printed circuit board and the fourth group of elongate tracks is formed on the second surface of the printed circuit board.

Conveniently, the elongate tracks in the track arrangement are positioned to be at least partly offset relative to the elongate tracks in the further track arrangement in a plane parallel to the plane of the flexible printed circuit board.

Advantageously, the elongate tracks in each group are substantially straight and substantially parallel with the other tracks in the same group.

Preferably, the printed circuit board is elongate and the step of providing the printed circuit board comprises winding at least part of the printed circuit board to form a roll of printed circuit board.

Conveniently, the step of forming the or each track arrangement comprises unwinding a length of printed circuit board from the roll and etching the or each track arrangement on the unwound length of printed circuit board.

Advantageously, the method further comprises forming the or each track arrangement repeatedly at spaced apart positions along the length of the printed circuit board.

Preferably, the method further comprises forming at least one channel in a side edge of the printed circuit board.

Conveniently, the method comprises forming a plurality of channels at spaced apart positions along a side edge of the printed circuit board.

Advantageously, the method further comprises forming at least one further channel in a further side edge of the printed circuit board.

Preferably, the or each further channel is aligned with a channel in the other side edge of the printed circuit board.

Conveniently, the method further comprises forming at least one line of mechanical weakness in the printed circuit board between two side edges of the printed circuit board.

Advantageously, the method further comprises moving a length of the printed circuit board relative to a component mounting device, stopping the printed circuit board so that part of the printed circuit board is in position adjacent the component mounting device, and mounting a component to the first surface of the printed circuit board using the component mounting device.

Preferably, the step of mounting the component comprises applying heat to a portion of the second surface of the printed circuit board, applying solder to an adjacent portion of the first surface so that the solder is melted by heat conducted through the printed circuit board from the second surface, and mounting the component to the first surface using the solder.

Conveniently, the method further comprises forming at least one thermal via hole in the printed circuit board to facilitate heat applied on one surface of the printed circuit board being conducted to the other surface of the printed circuit board.

Advantageously, the method further comprises mounting a plurality of components to the printed circuit board.

Preferably, the method comprises mounting a plurality of components to the printed circuit board at spaced apart positions along the length of the printed circuit board.

Conveniently, the or each component is a light emitting diode.

Advantageously, the method further comprises plastically deforming the printed circuit board at one or more spaced apart positions.

Preferably, the method comprises deforming the printed circuit board plastically at the portion of the printed circuit board where heat is applied by the component mounting device.

Conveniently, the method comprises plastically deforming the printed circuit board at the same time as applying heat to the printed circuit board.

Advantageously, the printed circuit board is of epoxy and fibreglass.

Preferably, the printed circuit board is FR-4 printed circuit board.

Conveniently, the method is an in-line manufacturing process.

According to another aspect of the present invention, there is provided an electrical device comprising a flexible printed circuit board having a first surface and a second surface, a track arrangement being provided on the printed circuit board, wherein the track arrangement comprises a first group of elongate tracks that are substantially aligned with one another and spaced apart from one another over a portion of the printed circuit board, and a second group of elongate tracks that are substantially aligned with one another and spaced apart from one another over a portion of the printed circuit board, and wherein the tracks in the first group are spaced apart from and at least partly interdigitated with the tracks in the second group to strengthen the flexible printed circuit board.

In one embodiment, the first and second groups of elongate tracks are provided on the first surface of the printed circuit board.

In another embodiment, the first group of elongate tracks is provided on the first surface of the printed circuit board and the second group of elongate tracks is provided on the second surface of the printed circuit board.

Advantageously, the printed circuit board is provided with a further track arrangement which comprises a third group of elongate tracks that are substantially aligned with one another and spaced apart from one another over a portion of the printed circuit board, and a fourth group of elongate tracks that are substantially aligned with one another and spaced apart from one another over a portion of the printed circuit board, wherein the tracks in the third group are spaced apart from and at least partly interdigitated with the tracks in the fourth group to strengthen the flexible printed circuit board.

In one embodiment, the third and fourth groups of elongate tracks are provided on the first surface of the printed circuit board.

In another embodiment, the third group of elongate tracks is provided on the first surface of the printed circuit board and the fourth group of elongate tracks is provided on the second surface of the printed circuit board.

Advantageously, the elongate tracks in the track arrangement are positioned to be at least partly offset relative to the elongate tracks in the further track arrangement in a plane parallel to the plane of the flexible printed circuit board.

Preferably, the elongate tracks in each group are substantially straight and substantially parallel with the other tracks in the same group.

Conveniently, the or each track arrangement is provided repeatedly at spaced apart positions along the length of the printed circuit board.

Advantageously, the printed circuit board is provided with at least one channel in a side edge of the printed circuit board.

Preferably, the printed circuit board is provided with a plurality of channels in spaced apart positions along a side edge of the printed circuit board.

Conveniently, the printed circuit board is provided with at least one further channel in a further side edge of the printed circuit board.

Advantageously, the or each further channel is aligned with a channel provided in the other side edge of the printed circuit board.

Preferably, the printed circuit board is provided with at least one line of mechanical weakness.

Conveniently, a component is mounted to the first surface of the printed circuit board.

Advantageously, the printed circuit board is provided with at least one thermal via hole.

Preferably, at least one light emitting diode is mounted to the printed circuit board.

Conveniently, the printed circuit board is plastically deformed at one or more spaced apart positions.

Advantageously, the printed circuit board is of epoxy and fibreglass.

Preferably, the printed circuit board is FR-4 printed circuit board.

According to a still further aspect of the present invention, there is provided a printed circuit board comprising a thermal via hole which does not have a circular cross-section.

Advantageously, the thermal via hole has an obround-shaped cross-section

Preferably, the thermal via hole has a cross-shaped cross-section.

Conveniently, the thermal via hole has an L-shaped cross-section.

Advantageously, the thermal via hole has an oval cross-section.

Preferably, the thermal via hole is formed by at least two circular holes which intersect one another.

Conveniently, the circuit board comprises a plurality of thermal via holes which do not have a circular cross-section.

Advantageously, the printed circuit board comprises at least one light emitting diode mounted to a first surface of the printed circuit board and superimposed on the or each thermal via hole, the light emitting diode being in thermal communication with the or each thermal via hole.

Preferably, the printed circuit board comprises a heatsink which is mounted to a second surface of the printed circuit board, the heatsink being in thermal communication with the or each thermal via hole.

Conveniently, the method of manufacturing a printed circuit board comprises forming in the printed circuit board a thermal via hole which does not have a circular cross-section.

According to another aspect of the present invention, there is provided a method of assembling an optical device comprising providing a printed circuit board having a thermal via hole which does not have a circular cross-section, mounting a light emitting diode to one surface of the printed circuit board and providing a thermal connection between the light emitting diode and the thermal via hole.

Preferably, the method further comprises mounting a heatsink to another surface of the printed circuit board so that the heatsink is in thermal communication with the thermal via hole.

In order that the invention may be more readily understood, and so that further features thereof may be appreciated, embodiments of the invention will now be described, by way of example, with reference to the accompanying drawings in which:

Figure 1a is a circuit diagram of a power supply arrangement,

Figure 2a is a schematic perspective view of the core components of a preferred embodiment of the invention,

Figure 3a is a view corresponding to figure 2a with primary, secondary and inductor windings in addition in the core,

Figure 4a is a diagrammatic perspective view of an embodiment of the invention incorporated into a screw connector,

Figure 5a is a view corresponding to figure 4a with the primary and inductor windings in position in the core,

Figure 6a is a diagrammatic perspective view of part of the core shown in figure 1a and a schematic representation of the secondary winding,

Figure 7a is a diagrammatic perspective view of part of the core and the secondary winding mounted to a connector,

Figure 1b is a schematic view of an in-line manufacturing station for manufacturing an electrical device,

Figure 2b is a diagrammatic sectional view through a portion of printed circuit board, showing a line of mechanical weakness having a reduced thickness,

Figure 3b is a diagrammatic plan view of a portion of flexible printed circuit board,

Figure 4b is a diagrammatic view of the underneath of a flexible printed circuit board,

Figure 5b is a diagrammatic perspective view of a portion of flexible printed circuit board which is plastically deformed,

Figure 1c is a diagrammatic sectional view through part of a printed circuit board with an LED and a heatsink mounted to the printed circuit board,

Figure 2c is a diagrammatic view of an obround shaped via hole of one embodiment of the invention,

Figure 3c is a diagrammatic view of a cross-shaped via hole of one embodiment of the invention,

Figure 4c is a diagrammatic view of a via hole of one embodiment of the invention which has an outline shape of two intersecting circles, and

Figure 5c is a diagrammatic view of an oval shaped via hole of one embodiment of the invention.

Referring initially to figure 1a of the accompanying drawings, an AC to DC power supply 1a incorporates an input 2a which is configured to be connected to an AC power source, such as a mains electricity supply. The AC input is rectified by a diode rectifier 3a. The rectified voltage is then fed into a power factor correction arrangement 4a and a DC link voltage output from the power factor correction arrangement is fed into a half-bridge inverter 5a. The half-bridge inverter 5a outputs a high frequency alternating current (HFAC) signal which is fed through a ballasting inductor L and through the primary winding 6a of a transformer 7a. The high frequency alternating current operates at a frequency of between 10kHz to 200kHz and preferably operates at a frequency of 50kHz. A feedback loop 8a senses and feeds back the current measured through the primary winding 6a to the half-bridge inverter 5a.

The transformer 7a incorporates a core 9a which is preferably of a ferrite material. The shape and configuration of the core 9a are discussed in detail below.

The transformer 7a incorporates a secondary winding 10a which is connected to an LED drive circuit 11a. The LED drive circuit 11a is connected to drive a plurality of LEDs 12a.

The AC to DC power supply outputs a regulated DC current to the LEDs 12a or another constant current load. However, it is to be appreciated that other AC to DC power supply arrangements may be used with embodiments of the present invention. For instance, in one embodiment, the power factor correction arrangement 4a is omitted. In another embodiment, the LEDs 12a are replaced by a different load.

Referring now to figure 2a of the accompanying drawings, the core 9a of the transformer 7a incorporates a ferrite member in the form of a main body 13a and a separate retaining plate 14a. The main body 13a is substantially circular in cross-section and axi-symmetric around its central axis 15a. The main body 13a incorporates a central core 16a which is substantially cylindrical in shape. The central core 16a is formed integrally with a base 17a.

An inner wall 18a is formed integrally with the base 17a to surround the central core 16a. An inner chamber 19a is formed between the inner wall 18a and the central core 16a. At least one aperture 20a is formed in the base 17a to provide an access route from the underside of the main body 13a and the inner chamber 19a.

An outer wall 21a is formed integrally with the outer edge of the base 17a so as to be spaced-apart from the inner wall 18a. The outer wall 21a surrounds the inner wall 18a and the central core 16a in a plane intersecting the main body 13a. An outer chamber 22a is formed in the space between the inner wall 18a and the outer wall 21a. At least one further aperture (not shown) is formed in the base 17a to allow access from the underside of the main body 13a into the outer chamber 22a.

All of the parts of the main body 13a are preferably formed integrally with one another out of a ferrous material.

Referring now to figure 3a of the accompanying drawings, the primary winding 6a of the transformer 7a is wound around the central core 16a. The wire of the primary winding 6a enters the inner chamber 19a via the aperture 20a in the base 17a. The primary winding 6a sits in a wound ring configuration within the inner chamber 19a of the main body 13a. The primary winding 6a occupies only part of the space of the inner chamber 19a with part of the space of the inner chamber 19a remaining above the primary winding 6a.

The inductor winding L is formed by an inductor winding 23a which is wound around the outer surface of the inner wall 18a to sit within the outer chamber 22a. The wires of the inductor winding 23a extend out from beneath the main body 13a via the further aperture in the base 17a.

The secondary winding 10a is wound into a toroid and mounted to the underside of the plate 14a. The secondary winding 10a is thus an air-wound coil with an aperture at its centre. The wire of the secondary winding 10a protrudes up through a pair of apertures 24a formed in the plate 14a.

In figure 3a, the secondary winding 10a and the separate plate 14a are shown to be separate from the main body 13a. These parts of the transformer 7a can be separated from one another, as shown in figure 3a, to stop power being conducted from the power supply to the load 12a. However, the parts of the transformer 7a can be connected together by inserting the secondary winding 10a into the inner chamber 17a so that the central core 16a sits within the centre of the secondary winding 10a. In this configuration, the top end of the central core 16a is positioned against the surface of the separate plate 14a.

The components together form an electromagnetic connector in which a magnetic circuit is connected when the secondary winding 10a is moved into the inner chamber 17a of the main body 16a and broken when the secondary winding 10a is removed from the inner chamber 17a. The wires of the windings 6a, 10a and 23a are insulated so that they are not connected electrically to one another and so that no electrical conductor is exposed to the surrounding environment. The electromagnetic connector therefore allows a safe and waterproof connection to be made to connect the load 12a to the power supply.

The inductor winding 23a acts as a ballast which limits the current flowing through the primary winding 6a when the secondary winding 10a is removed from the inner chamber 17a of the main body 13a to break the magnetic circuit. The current flowing through the secondary winding 6a is thus safely turned off when the connector is disconnected by moving the secondary winding 10a from the main body 13a.

The planar disc-shape of the main body 13a with the outer and inner chambers 17a, 22a allows the primary winding 6a and the inductor winding 23a to be integrated into the main body 13a. The integration minimises the size of the connector.

The provision of the conductor winding 23a around the main body 13a of the core 9a partially cancels flux losses between the magnetic connection of the other parts of the core 9a. This partial flux cancellation minimises losses in the core 9a, thereby improving the efficiency of the connector.

Referring to figure 4a of the accompanying drawings, the main body 13a of the core 9a is preferably integrated into a connector body 25a. The connector body 25a incorporates an insulating layer which is preferably of plastic and which is moulded over the inductor winding 23a to form an over-moulding 26a.

The connector body 25a incorporates an electrical connector arrangement 27a which, in this embodiment, is a screw-fit light bulb connector. The electrical connector 27a is configured to be connected to a standard light bulb connector socket.

Referring now to figure 6a of the accompanying drawings, the secondary winding 10a is shown in more detail. Here it can be seen that the secondary winding 10a incorporates a central aperture that is dimensioned to receive the end of the central core 16a.

Referring now to figure 7a of the accompanying drawings, the secondary winding 10a and the plate 14a are preferably attached to a carrier body 26a. The carrier body 26a preferably forms part of an LED lighting device that incorporates one or more LEDs.

An electromagnetic arrangement of an embodiment of the invention couples power which is in the form of a high frequency alternating current operating at a frequency of between 10kHz and 200kHz. The preferred operating frequency of an electromagnetic coupler of an embodiment of the invention is 50kHz.

Embodiments of the invention are highly configurable since the voltage and power rating of the connector may be adjusted by varying the primary winding, the secondary winding or both the primary and secondary windings. For instance, the number of turns in the secondary winding 10a can be set to match a load and the number of turns in the primary winding 6a can be selected to match the voltage of a mains power supply.

Devices incorporating the secondary winding 10a can be sold worldwide without the devices needing to be matched to the different voltages in different countries. Power supply units can be customised for each country by setting the number of turns in the primary winding 6a to match the voltage conversion needed for a particular country.

The power supply unit is separate from the LED device that it powers. Therefore, if the power supply fails then only the power supply needs to be replaced.

An Electrical Device and a Method of Manufacturing an Electrical Device

Referring initially to figure 1b of the accompanying drawings, a manufacturing station 1b is shown in operation. The manufacturing station 1b is an in-line system in the sense that it can run continuously or semi-continuously just as long as materials and components are fed into the manufacturing station 1b.

Flexible printed circuit board 2b is provided initially in a roll 3b for ease of storage and transportation. The roll 3b may be loaded onto a spindle (not shown) to enable to the roll 3b to rotate about its longitudinal axis. As the roll 3b rotates, a length of printed circuit board 2b unfurls from the roll 3b and is fed into the manufacturing station 1b.

The printed circuit board 2b is preferably a fibreglass and epoxy resin printed circuit board which is flexible. In one embodiment, the printed circuit board 2b is FR4 printed circuit board of the type used to form one or more layers of a multi-layer conventional rigid and planar printed circuit board. In one embodiment the thickness of the printed circuit board 2b is 200μm. In other embodiments the thickness of the printed circuit board is less than 300μm or less than 200μm. The printed circuit board 2b is, in any event, thin enough to be flexible so that it can be unwound from the roll 3b.

The printed circuit board 2b is initially provided without etched conductive tracks on either surface. However, in other embodiments, the printed circuit board 2b may, already, be provided with one or more coatings on each of its surfaces.

The printed circuit board 2b is fed into the manufacturing station 1b and travels through the manufacturing station 1b in the general direction indicated by arrow 4b.

An optional first step which occurs towards the beginning of the manufacturing line in the manufacturing station 1b involves a weakening device 5b which is configured to weaken portions of the printed circuit board 2b at predetermined positions. The weakening device 5b preferably forms a line of mechanical weakness 6b transversely across the printed circuit board 2b by thinning a region of the printed circuit board 2b to a reduced thickness, as shown in figure 2b.

The weakening device 5b preferably also cuts one or more notches 7b in one or both of the sides of the printed circuit board 2b, as shown in figures 3b and 4b. The thinned line of mechanical weakness 6b and the notches 7b each weaken the printed circuit board 2b to increase the flexibility of the printed circuit board 2b. The weakened portion 6b of the printed circuit board 2b also improves the ability of the printed circuit board 2b to deform plastically.

In other embodiments, the weakening device 5b is omitted entirely and there is no mechanical weakness formed in the printed circuit board 2b.

As the printed circuit board 2b proceeds through the manufacturing station 1b, the printed circuit board 2b is supported on supports, such as rollers 8b. The printed circuit board 2b may be driven mechanically at one end and/or may be driven by rotation of the rollers 8b.

In a next step in the manufacturing process, the printed circuit board 2b is fed through a track etching device 9b which etches tracks into one or both surfaces of the printed circuit board 2b. The etching device 9b is preferably a photo etching device which etches patterned tracks in one or more copper layers provided on one or more of the surfaces of the printed circuit board 2b.

Referring now to figure 3b of the accompanying drawings, a first surface 10b of the printed circuit board 2b is shown with a first track arrangement 11b etched on the first surface 10b. The first track arrangement 11b comprises a first group 12b of elongate tracks 13b that are substantially aligned with one another and spaced apart from one another over a portion of the first surface 10b. The elongate tracks 13b are preferably straight elongate tracks that are substantially parallel with one another.

A second group 14b of elongate tracks 15b is also etched on the first surface 10b. The elongate tracks 15b in the second group 14b are also substantially aligned with one another and spaced apart from one another over a portion of the first surface 10b.

The first group 12b of elongate tracks 13b is at least partially interdigitated with the second group 14b of elongate tracks 15b, with the elongate tracks 13b,15b being spaced apart from one another. The interdigitated tracks 13b,15b extend over the line of mechanical weakness 6b. The interdigitated tracks 13b,15b serve to strengthen the printed circuit board 2b in a way which minimises the possibility of the printed circuit board 2b cracking along the line of mechanical weakness 6b where the printed circuit board 2b is designed to be deformed plastically. The interdigitated tracks 13b,15b in each group 12b,14b are spaced apart from one another and able to move relative to one another as the printed circuit board 2b is flexed. The interdigitated tracks 13b,15b do not therefore overly inhibit the flexing of the printed circuit board 2b.

In the preferred embodiment, the tracks 13b,15b are elongate straight tracks. However, in other embodiments, the elongate tracks 13b,15b are elongate but not straight. Furthermore, in the illustrated embodiment, there are four elongate tracks 13b in the first group 12b and three elongate tracks 15b in the second group 14b, but in other embodiments of the invention there may be a greater or fewer number of elongate tracks in each group 12b,14b.

In the preferred embodiment, interdigitated elongate tracks 13b,15b are formed only on the first surface 10b and not on a second surface of the printed circuit board 2b. However, in other embodiments, elongate tracks may also be formed on a second surface 16b of the printed circuit board 2b.

In other embodiments, the first and second groups of elongate tracks are formed on opposite surfaces of the printed circuit board 2b to one another. For instance, in one embodiment, the first group of elongate tracks is formed on the first surface 10b of the printed circuit board 2b and the second group of elongate tracks is formed on the second surface 10b of the printed circuit board 2b. In these embodiments, the first and second groups of tracks are still interdigitated with one another even though the groups of tracks are not in the same plane as one another.

Referring now to figure 4b of the accompanying drawings, a third group 17b of elongate tracks 18b and a fourth group 19b of elongate tracks 20b are formed on the second surface 16b of the printed circuit board 2b. The third and fourth groups 17b,19b of elongate tracks 18b,20b are positioned opposite the elongate tracks 13b,15b on the first side 10b. However, the elongate tracks 18b,19b on the second surface 16b are positioned so as not to align with the elongate tracks 13b,15b on the first surface 10b in order to further increase the strength of the printed circuit board 2b. The elongate tracks 18b,20b on the second surface 16b are also interdigitated with one another and spaced apart from one another in a similar configuration to the interdigitated tracks 13b,15b on the first surface 10b. However, the interdigitated tracks 18b,20b on the second surface 16b are preferably a different shape and configuration to the interdigitated tracks 13b,15b on the first surface 10b.

In other embodiments, the third and fourth groups of elongate tracks are formed on opposite surfaces of the printed circuit board 2b to one another. For instance, in one embodiment, the third group of elongate tracks is formed on the first surface 10b of the printed circuit board 2b and the fourth group of elongate tracks is formed on the second surface 10b of the printed circuit board 2b. In these embodiments, the third and fourth groups of tracks are still interdigitated with one another even though the groups of tracks are not in the same plane as one another.

Referring back to figure 1b of the accompanying drawings, as the printed circuit board 2b progresses through the manufacturing station 1b, the printed circuit board 2b passes through a coating and soldering station 21b. The coating and soldering station 21b coats the printed circuit board 2b, for instance to cover the etched tracks 13b,15b,18b,20b. The coating and soldering device 21b also applies solder 22b to one both surfaces 10b,16b of the printed circuit board 2b.

The coated and soldered printed circuit board 2b then progresses to an assembly station 23b. The assembly station 23b comprises a heat application device 24b which applies heat to one or both sides of the printed circuit board 2b. In the preferred embodiment, the heat application device preferably applies heat to one surface of the printed circuit board 2b. As heat is applied to the printed circuit board 2b, the solder 22b on the other surface of the printed circuit board 2b melts.

The assembly station 23b further comprises a pick and place component placement device 25b. The component placement device 25b positions and places a component 26b on one surface of the printed circuit board 2b, adjacent the heat application device 24b which is positioned on the other side of the printed circuit board 2b. The component 26b is preferably a surface mount light emitting diode (LED). However, in other embodiments, the component may be any other component, such as a organic light emitting diode (OLED), a semi conductor device, a resistor, a capacitor or an inductor. As the component 26b is placed on the printed circuit board 2b, the molten solder bonds the component 26b to the surface. The component 26b then continues to remain bonded to the surface of the printed circuit board 2b as the solder cools.

The assembly station 23b also comprises a deformation device 27b which is positioned to apply a deflecting force to the printed circuit board 2b in order to bend the printed circuit board 2b. The deformation device 27b is positioned to deform the printed circuit board 2b at the point where the printed circuit board 2b is heated by the heat application device 24b simultaneously as the component 26b is mounted to the printed circuit board 2b. The heat facilitates bending of the printed circuit board 2b and causes the printed circuit board 2b to deform plastically. The line of mechanical weakness 6b and the notches 7b serve to facilitate the plastic deformation.

After the printed circuit board 2b has been deformed plastically, the printed circuit board 2b passes through a cutting mechanism 28b which cuts the continuous length of printed circuit board 2b into discrete sections 29b,30b. The cut sections 29b,30b are then collected in a collection receptacle 31b.

Referring now to figure 5b of the accompanying drawings, a portion of the printed circuit board 2b is shown plastically deformed with three components 26b mounted at the deformation point. As illustrated in figure 5b, the deformation point is not necessarily a thin angular line, but may be a section of the printed circuit board 2b onto which the components 26b can be mounted.

The manufacturing station 1b is configured to run continuously with a reel of printed circuit board 2b being fed in at one end. The manufacturing station 1b forms the elongate tracks 13b,15b,18b,20b on the surfaces 10b,16b at spaced apart positions and mounts the devices 26b at spaced apart positions along the length of the printed circuit board 2b. The manufacturing station 1b therefore produces identical discrete length 29b,30b which each incorporate elongate tracks and mounted components. The discrete section 29b,30b can then be housed in a casing to complete the construction of an electrical device.

The manufacturing station 1b enables sections of flexible printed circuit board 2b to be assembled into electrical devices. The manufacturing method allows high-temperature resistant printed circuit board 2b to be used as a flexible printed circuit board so that a device can operate at a higher temperature than then temperature of a lower power device that incorporates a conventional flexible printed circuit board.

The in-line manufacturing process is preferably fully automated and can produce large volumes at a low cost. The in-line process is thus particularly well suited to manufacturing large volumes of LED light units.

A Printed Circuit Board

Referring initially to figure 1c of the accompanying drawings, a printed circuit board 1c is provided with a thermal via hole 2c. A surface mount LED 3c is mounted to the upper surface of the printed circuit board 1c. A heatsink 4c is mounted to the lower surface of the printed circuit board 1c.

Thermally conductive solder fills the thermal via hole 2c and is in thermal contact with the underside of the LED 3c to conduct heat from the LED 3c to the heatsink 4c.

In embodiments of the invention a printed circuit board is provided with a thermal via hole 2c which does not have a circular cross section. The thermal via hole 2c is preferably elongate.

In a preferred embodiment of the invention, the thermal via hole is an obround shape such as the obround shape 5c shown in figure 2c. An obround shape is a shape consisting of two semicircles connected by parallel lines tangent to their endpoints.

The obround shape is preferably formed in the circuit board 2c by a router tool. The router tool has a round bit that drills through the circuit board 2c and is then moved transverse to the plane of the circuit board 2c to form the elongate shape.

In a further embodiment of the invention, the thermal via hole is cross-shaped such as the cross-shaped via hole 6c shown in figure 3c. In this embodiment the cross-shape is preferably formed by a router.

In a yet further embodiment of the invention, the shape of the thermal via hole is defined by the intersection of two circular apertures that intersect, such as the thermal via hole 7c shown in figure 4c. In other embodiments, the thermal via hole is defined by more than two intersecting holes.

In a still further embodiment of the invention, the thermal via hole is in the shape of an oval, such as the oval shaped via hole 8c shown in figure 5c.

In another embodiment of the invention, the thermal via hole is L-shaped.

In one embodiment of the invention an optical device is assembled by providing a printed circuit board 1c having a thermal via hole which does not have a circular cross-section, such as one of the thermal via holes discussed above. An LED 3c is mounted to the printed circuit board 1c and thermal solder paste is placed within the thermal via hole. A heatsink 4c is attached to the other surface of the printed circuit board 1c.

Heat is applied as the LED 3c and/or the heatsink is attached to the printed circuit board 1c so that the thermal solder paste melts. The elongate and not circular shaped via hole 2c causes the molten solder to fill the length of the via hole, thereby minimising the chance of solder bulging from either the top or bottom surfaces of the printed circuit board 1c. The LED 3c and the heatsink 4c can therefore be kept flush with the printed circuit board and in good thermal contact with one another.

The features disclosed in the foregoing description, or the following claims, or the accompanying drawings, expressed in their specific forms or in terms of a means for performing the disclosed function, or a method or process for attaining the disclosed result, as appropriate, may, separately, or in any combination of such features, be utilised for realising the invention in diverse forms thereof.

Claims:

1. An electromagnetic arrangement comprising:

a first electromagnetic connector incorporating:

an inductor winding,

a primary transformer winding which is connected electrically in series with the inductor winding, and

a ferrite member, wherein the primary transformer winding is wound around a first part of the ferrite member and the inductor winding is wound around a second part of the ferrite member.

2. An electromagnetic arrangement according to claim 1, wherein the first and second parts of the ferrite member are formed integrally.

3. An electromagnetic arrangement according to claim 1 or claim 2, wherein, in a plane intersecting the ferrite member, the second part of the ferrite member at least partly surrounds the first part of the ferrite member.

4. An electromagnetic arrangement according to claim 3, wherein the second part of the ferrite member is in the shape of a hollow cylinder.

5. An electromagnetic arrangement according to any one of the preceding claims, wherein the ferrite member incorporates a base which connects the first part to the second part.

6. An electromagnetic arrangement according to claim 5, wherein an electrical connection to the primary transformer winding extends through an aperture provided in the base.

7. An electromagnetic arrangement according to claim 5 or claim 6, wherein an electrical connection to the inductor winding extends through a further aperture provided in the base.

8. An electromagnetic arrangement according to any one of the preceding claims, wherein the ferrite member incorporates an outer wall which, in a plane intersecting the ferrite member, surrounds the first and second parts of the ferrite member.

9. An electromagnetic arrangement according to claim 8, wherein the outer wall is in the shape of a hollow cylinder.

10. An electromagnetic arrangement according to any one of the preceding claims, wherein a top surface of the first electromagnetic connector is axi-symmetrical about an axis extending through the connector.

11. An electromagnetic arrangement according to any one of the preceding claims further comprising:

a second electromagnetic connector incorporating a secondary transformer winding which is air-wound with an aperture at its centre.

12. An electromagnetic arrangement according to claim 11, wherein the aperture in the secondary transformer winding is configured to receive part of the first part of the ferrite member of the first electromagnetic connector.

13. An electromagnetic arrangement according to claim 12, wherein the second electromagnetic connector incorporates a further ferrite member which incorporates an aperture through which an electrical connection to the secondary transformer winding extends.

14. An electromagnetic arrangement according to claim 13, wherein the further ferrite member is substantially disc-shaped.

15. A method of manufacturing an electrical device comprising:

providing a flexible printed circuit board having a first surface and a second surface, and

forming a track arrangement on the printed circuit board, wherein the track arrangement comprises:

a first group of elongate tracks that are substantially aligned with one another and spaced apart from one another over a portion of the printed circuit board, and

a second group of elongate tracks that are substantially aligned with one another and spaced apart from one another over a portion of the printed circuit board, and wherein the tracks in the first group are spaced apart from and at least partly interdigitated with the tracks in the second group to strengthen the flexible printed circuit board.

16. A method according to claim 15, wherein the first and second groups of elongate tracks are formed on the first surface of the printed circuit board.

17. A method according to claim 15, wherein the first group of elongate tracks is formed on the first surface of the printed circuit board and the second group of elongate tracks is formed on the second surface of the printed circuit board.

18. A method according to any one of claims 15 to 17, wherein the method further comprises:

forming a further track arrangement on the printed circuit board, wherein the further track arrangement comprises:

a third group of elongate tracks that are substantially aligned with one another and spaced apart from one another over a portion of the printed circuit board, and

a fourth group of elongate tracks that are substantially aligned with one another and spaced apart from one another over a portion of the printed circuit board, and wherein the tracks in the third group are spaced apart from and at least partly interdigitated with the tracks in the fourth group to strengthen the flexible printed circuit board.

19. A method according to claim 18, wherein the third and fourth groups of elongate tracks are formed on the second surface of the printed circuit board.

20. A method according to claim 18, wherein the third group of elongate tracks is formed on the first surface of the printed circuit board and the fourth group of elongate tracks is formed on the second surface of the printed circuit board.

21. A method according to any one of claims 18 to 20, wherein the elongate tracks in the track arrangement are positioned to be at least partly offset relative to the elongate tracks in the further track arrangement in a plane parallel to the plane of the flexible printed circuit board.

22. A method according to any one of claims 15 to 21, wherein the elongate tracks in each group are substantially straight and substantially parallel with the other tracks in the same group.

23. A method according to any one of claims 15 to 22, wherein the printed circuit board is elongate and the step of providing the printed circuit board comprises winding at least part of the printed circuit board to form a roll of printed circuit board.

24. A method according to claim 23, wherein the step of forming the or each track arrangement comprises unwinding a length of printed circuit board from the roll and etching the or each track arrangement on the unwound length of printed circuit board.

25. A method according to claim 23 or claim 24, wherein the method further comprises:

forming the or each track arrangement repeatedly at spaced apart positions along the length of the printed circuit board.

26. A method according to any one of claims 15 to 25, wherein the method further comprises:

forming at least one channel in a side edge of the printed circuit board.

27. A method according to claim 26, wherein the method comprises forming a plurality of channels at spaced apart positions along a side edge of the printed circuit board.

28. A method according to claim 26 or claim 27, wherein the method further comprises:

forming at least one further channel in a further side edge of the printed circuit board.

29. A method according to claim 28 as dependent on claim 27, wherein the or each further channel is aligned with a channel in the other side edge of the printed circuit board.

30. A method according to any one of claims 15 to 29, wherein the method further comprises:

forming at least one line of mechanical weakness in the printed circuit board between two side edges of the printed circuit board.

31. A method according to any one of claims 15 to 30, wherein the method further comprises:

moving a length of the printed circuit board relative to a component mounting device,

stopping the printed circuit board so that part of the printed circuit board is in position adjacent the component mounting device, and

mounting a component to the first surface of the printed circuit board using the component mounting device.

32. A method according to claim 31, wherein the step of mounting the component comprises:

applying heat to a portion of the second surface of the printed circuit board,

applying solder to an adjacent portion of the first surface so that the solder is melted by heat conducted through the printed circuit board from the second surface, and

mounting the component to the first surface using the solder.

33. A method according to claim 32, wherein the method further comprises:

forming at least one thermal via hole in the printed circuit board to facilitate heat applied on one surface of the printed circuit board being conducted to the other surface of the printed circuit board.

34. A method according to any one of claims 31 to 33, wherein the method further comprises mounting a plurality of components to the printed circuit board.

35. A method according to claim 34, wherein the method comprises mounting a plurality of components to the printed circuit board at spaced apart positions along the length of the printed circuit board.

36. A method according to any one of claims 31 to 35, wherein the or each component is a light emitting diode.

37. A method according to any one of claims 15 to 36, wherein the method further comprises:

plastically deforming the printed circuit board at one or more spaced apart positions.

38. A method according to claim 37 as dependent on claim 32 or claim 33, wherein the method comprises deforming the printed circuit board plastically at the portion of the printed circuit board where heat is applied by the component mounting device.

39. A method according to claim 38, wherein the method comprises plastically deforming the printed circuit board at the same time as applying heat to the printed circuit board.

40. A method according to any one of claims 15 to 39, wherein the printed circuit board is of epoxy and fibreglass.

41. A method according to claim 40, wherein the printed circuit board is FR-4 printed circuit board.

42. A method according to any one of claims 15 to 41, wherein the method is an in-line manufacturing process.

43. An electrical device comprising a flexible printed circuit board having a first surface and a second surface, a track arrangement being provided on the printed circuit board, wherein the track arrangement comprises a first group of elongate tracks that are substantially aligned with one another and spaced apart from one another over a portion of the printed circuit board, and a second group of elongate tracks that are substantially aligned with one another and spaced apart from one another over a portion of the printed circuit board, and wherein the tracks in the first group are spaced apart from and at least partly interdigitated with the tracks in the second group to strengthen the flexible printed circuit board.

44. An electrical device according to claim 43, wherein the first and second groups of elongate tracks are provided on the first surface of the printed circuit board.

45. An electrical device according to claim 43, wherein the first group of elongate tracks is provided on the first surface of the printed circuit board and the second group of elongate tracks is provided on the second surface of the printed circuit board.

46. An electrical device according to any one of claims 43 to 45, wherein the printed circuit board is provided with a further track arrangement which comprises a third group of elongate tracks that are substantially aligned with one another and spaced apart from one another over a portion of the printed circuit board, and a fourth group of elongate tracks that are substantially aligned with one another and spaced apart from one another over a portion of the printed circuit board, wherein the tracks in the third group are spaced apart from and at least partly interdigitated with the tracks in the fourth group to strengthen the flexible printed circuit board.

47. An electrical device according to claim 46, wherein the third and fourth groups of elongate tracks are provided on the first surface of the printed circuit board.

48. An electrical device according to claim 46, wherein the third group of elongate tracks is provided on the first surface of the printed circuit board and the fourth group of elongate tracks is provided on the second surface of the printed circuit board.

49. An electrical device according to any one of claims 46 to 48, wherein the elongate tracks in the track arrangement are positioned to be at least partly offset relative to the elongate tracks in the further track arrangement in a plane parallel to the plane of the flexible printed circuit board.

50. An electrical device according to any one of claims 43 to 49, wherein the elongate tracks in each group are substantially straight and substantially parallel with the other tracks in the same group.

51. An electrical device according to any one of claims 43 to 50, wherein the or each track arrangement is provided repeatedly at spaced apart positions along the length of the printed circuit board.

52. An electrical device according to any one of claims 43 to 51, wherein the printed circuit board is provided with at least one channel in a side edge of the printed circuit board.

53. An electrical device according to claim 52, wherein the printed circuit board is provided with a plurality of channels in spaced apart positions along a side edge of the printed circuit board.

54. An electrical device according to claim 52 or claim 53, wherein the printed circuit board is provided with at least one further channel in a further side edge of the printed circuit board.

55. An electrical device according to claim 54, wherein the or each further channel is aligned with a channel provided in the other side edge of the printed circuit board.

56. An electrical device according to any one of claims 43 to 55, wherein the printed circuit board is provided with at least one line of mechanical weakness.

57. An electrical device according to any one of claims 43 to 56, wherein a component is mounted to the first surface of the printed circuit board.

58. An electrical device according to any one of claims 43 to 57, wherein the printed circuit board is provided with at least one thermal via hole.

59. An electrical device according to any one of claims 43 to 58, wherein at least one light emitting diode is mounted to the printed circuit board.

60. An electrical device according to any one of claims 43 to 59, wherein the printed circuit board is plastically deformed at one or more spaced apart positions.

61. An electrical device according to any one of claims 43 to 60, wherein the printed circuit board is of epoxy and fibreglass.

62. An electrical device according to claim 61, wherein the printed circuit board is FR-4 printed circuit board.

63. A printed circuit board comprising a thermal via hole which does not have a circular cross-section.

64. A printed circuit board according to claim 63, wherein the thermal via hole has an obround-shaped cross-section

65. A printed circuit board according to claim 63, wherein the thermal via hole has a cross-shaped cross-section.

66. A printed circuit board according to claim 63, wherein the thermal via hole has an L-shaped cross-section.

67. A printed circuit board according to claim 63, wherein the thermal via hole has an oval cross-section.

68. A printed circuit board according to claim 63, wherein the thermal via hole is formed by at least two circular holes which intersect one another.

69. A printed circuit board according to any one of claims 63 to 68, wherein the circuit board comprises a plurality of thermal via holes which do not have a circular cross-section.

70. A printed circuit board according to any one of claims 63 to 69 comprising at least one light emitting diode mounted to a first surface of the printed circuit board and superimposed on the or each thermal via hole, the light emitting diode being in thermal communication with the or each thermal via hole.

71. A printed circuit board according to any one of claims 63 to 70 comprising a heatsink which is mounted to a second surface of the printed circuit board, the heatsink being in thermal communication with the or each

thermal via hole.

72. A method of manufacturing a printed circuit board comprising forming in the printed circuit board a thermal via hole which does not have a circular cross-section.

73. A method of assembling an optical device comprising:

providing a printed circuit board having a thermal via hole which does not have a circular cross-section,

mounting a light emitting diode to one surface of the printed circuit board and providing a thermal connection between the light emitting diode and the thermal via hole.

74. A method according to claim 73, wherein the method further comprises:

mounting a heatsink to another surface of the printed circuit board so that the heatsink is in thermal communication with the thermal via hole.

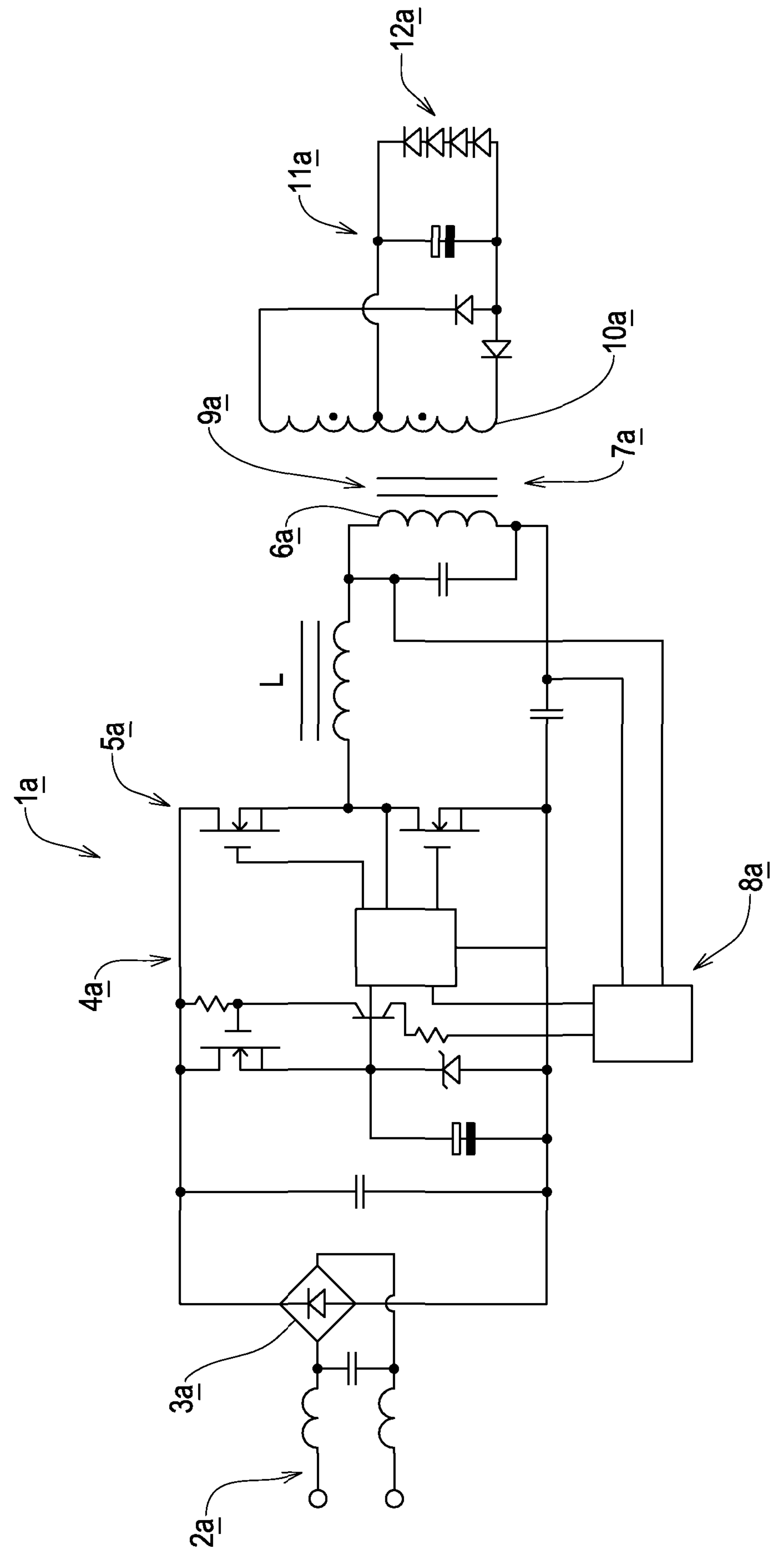

FIG. 1a

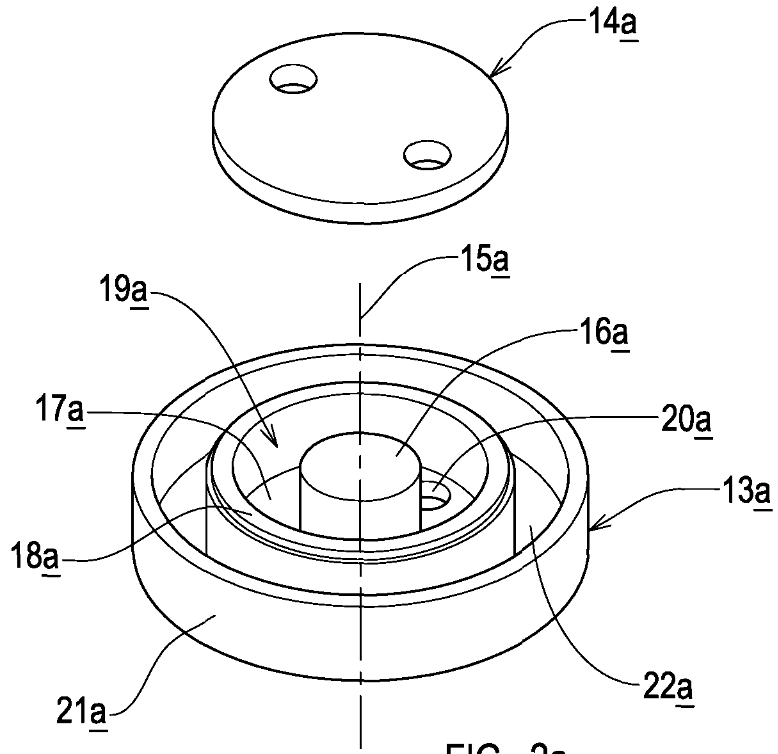

FIG. 2a

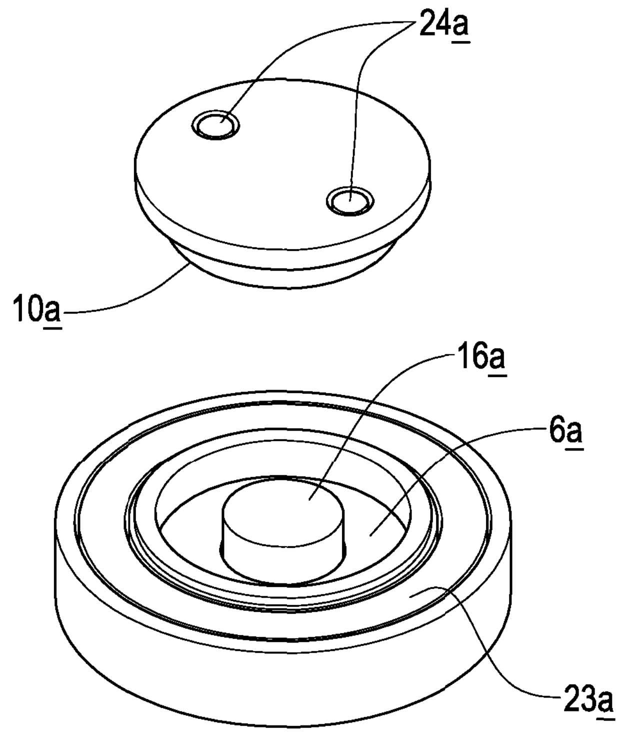

FIG. 3a

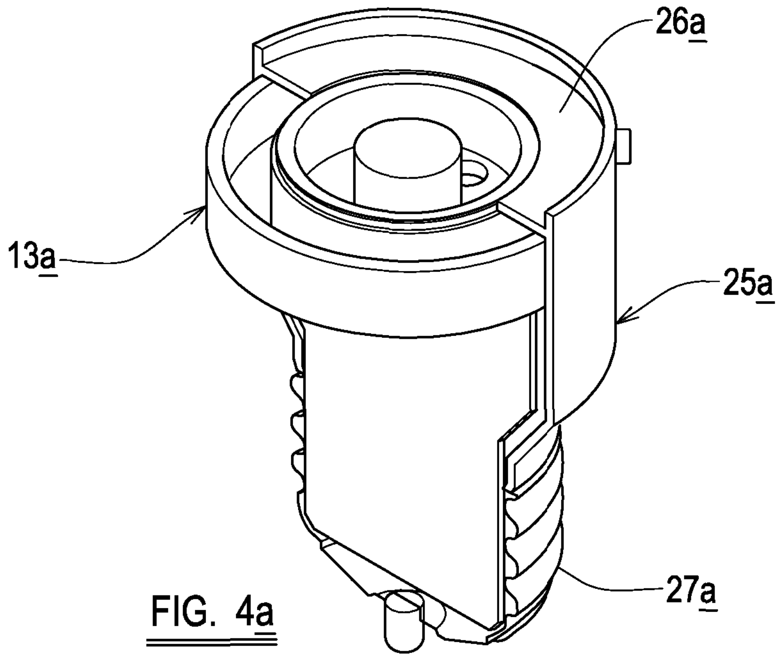

FIG. 4a

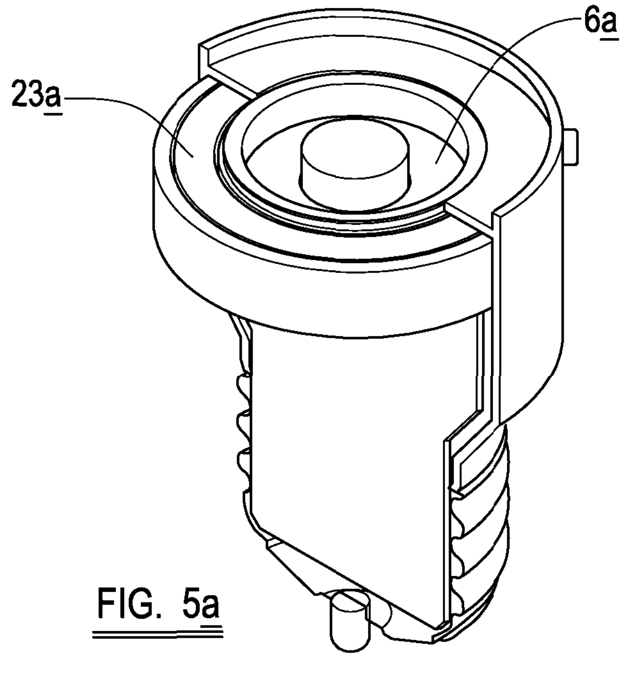

FIG. 5a

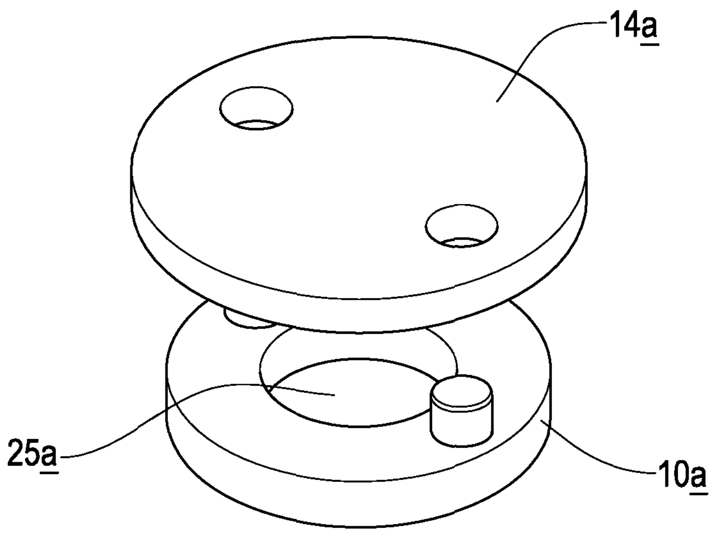

FIG. 6a

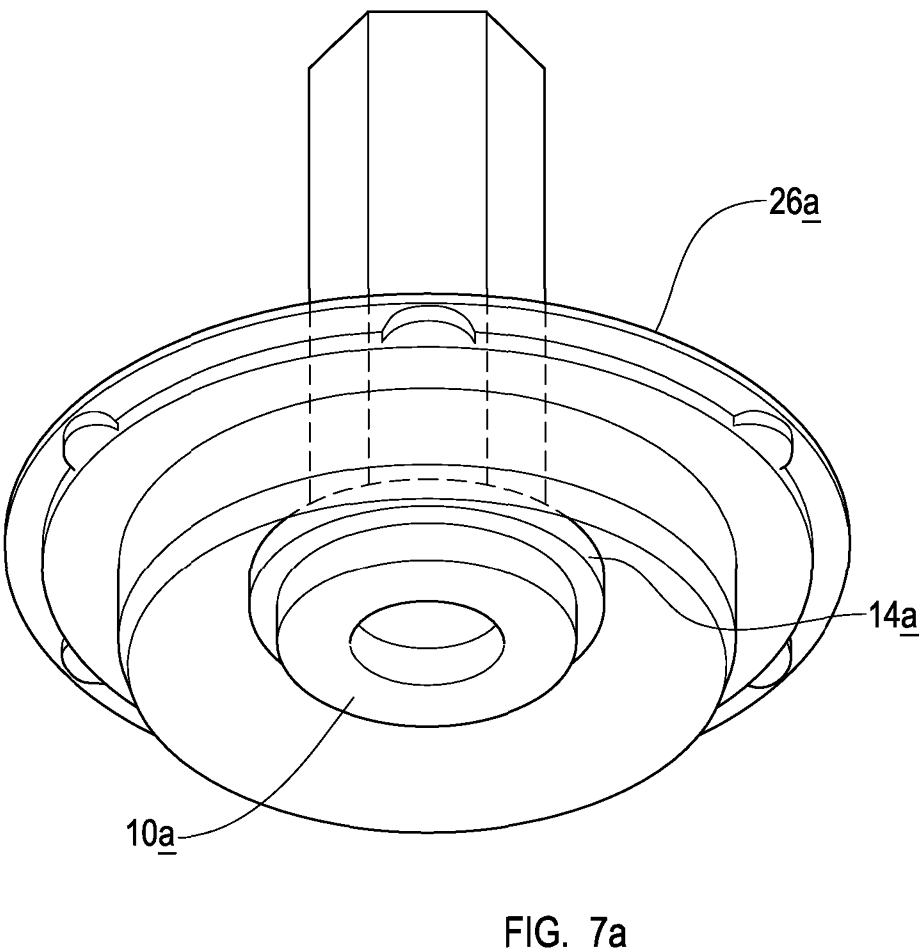

FIG. 7a

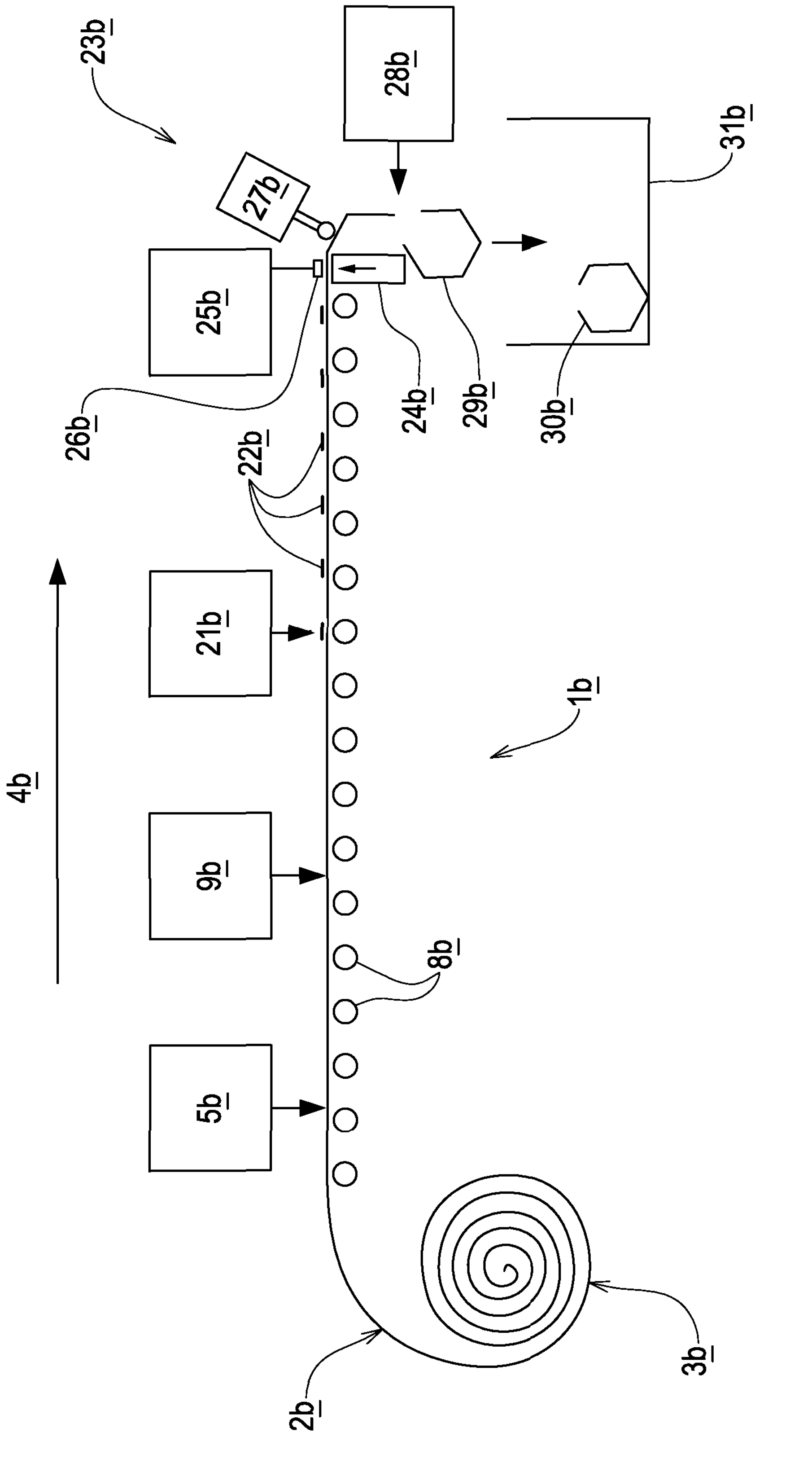

FIG. 1b

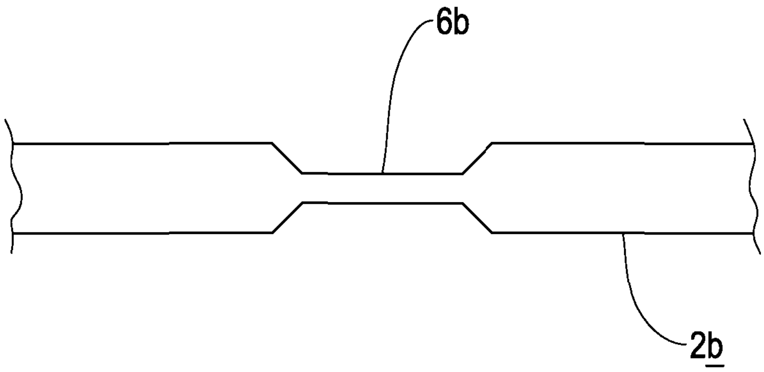

FIG. 2b

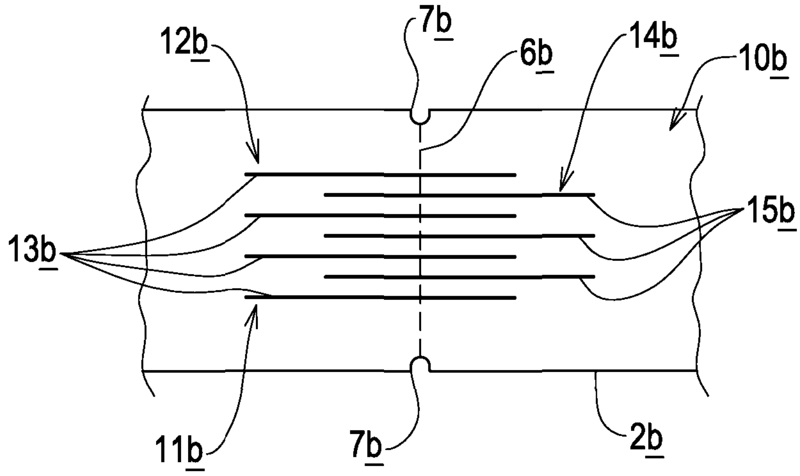

FIG. 3b

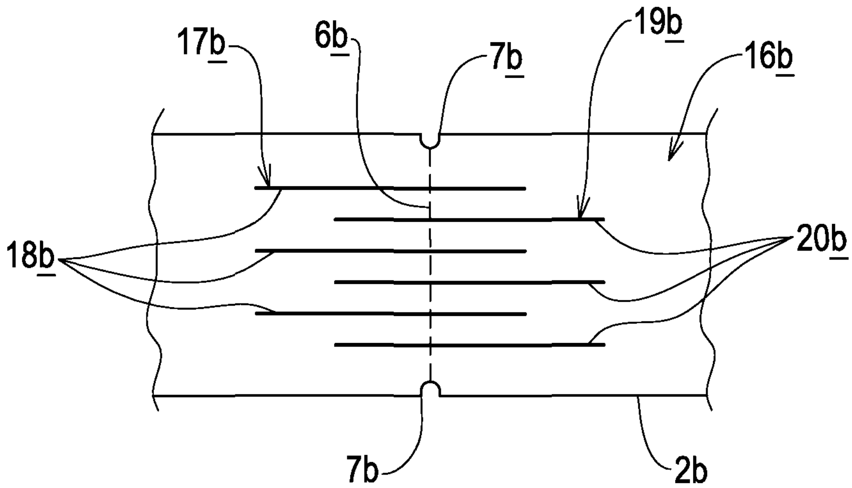

FIG. 4b

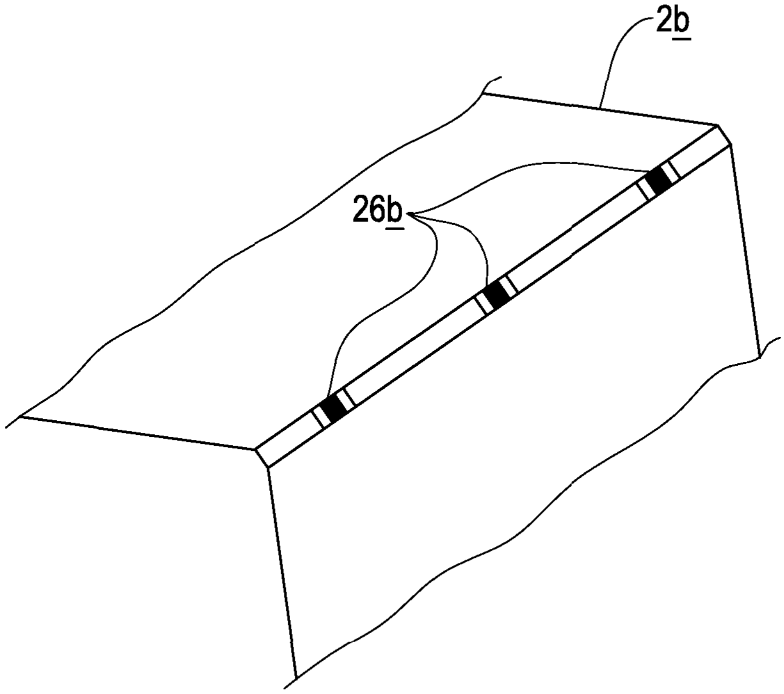

FIG. 5b

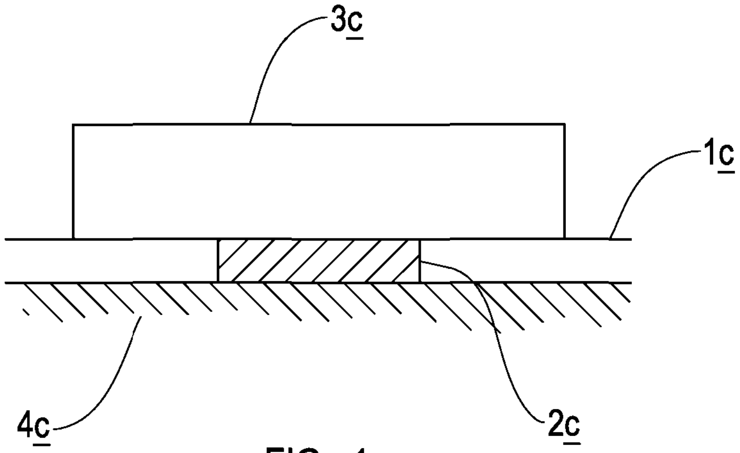

FIG. 1c

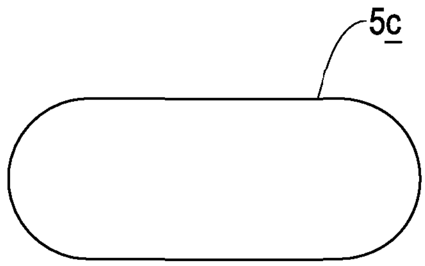

FIG. 2c

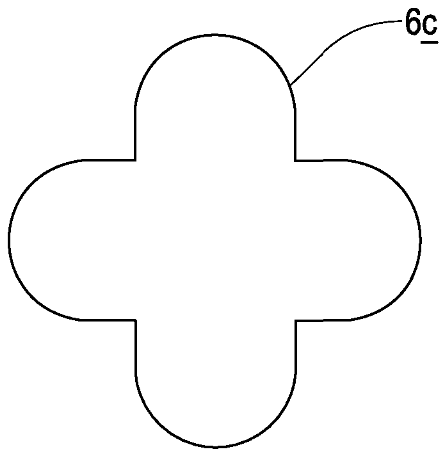

FIG. 3c

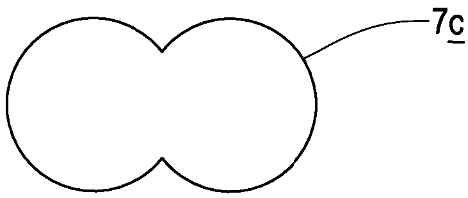

FIG. 4c

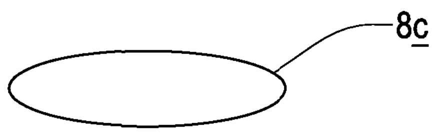

FIG. 5c