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(54) SOUND GENERATING APPARATUS

SCHALLERZEUGENDE VORRICHTUNG

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(56) References cited:
EP-A2- 0 821 540 WO-A1-2008/051009
US-A- 4 608 463 US-A1- 2004 086 146
US-A1- 2007 060 221 US-B1- 6 370 257

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Description

BACKGROUND

Technical Field

[0001] The exemplary and non-limiting embodiments relate generally to a magnet system for use with an electromagnetic coil and, more particularly, to an electrical connection provided by the magnet system.

Brief Description of Prior Developments

[0002] A loudspeaker generally has a magnet, a coil and a diaphragm. The coil is electrically connected by wires or contacts to another member.

[0003] EP0821540 relates to providing electrical connections for a voice coil. The electrical contacting of the voice coil is achieved with two voice coil strands that lead to the upper pole plate. Each of the strands is conductively connected to one of the two parts of the upper pole plate by soldering.

[0004] WO2008/051009 discloses a sound converter which can easily achieve the automation by including a terminal with a top plate function. The sound converter includes a frame, a yoke inserted and installed inside the frame an inner ring magnet with inner ring top plate mounted thereon and an outer ring magnet maintaining a predetermined interval from the side face of the inner ring magnet being mounted at the upper portion of the yoke, a diaphragm provided with a coil portion at least partially inserted between the inner ring magnet and the outer ring magnet and a terminal positioned at the upper portion of the outer ring magnet, for providing a magnetic path and an electric path between a coil and an external connection terminal.

SUMMARY

[0005] The invention for which protection is sought is defined by the appended claims.

[0006] The following summary is merely intended to be exemplary. The summary is not intended to limit the scope of the claims.

[0007] In accordance with one aspect, an apparatus is provided including an electromagnetic coil and a magnet system. The electromagnetic coil includes electrical leads. The magnet system forms electrical conductors connected to the electrical leads of the coil. The magnet system is configured to provide an electrical interface.

[0008] In accordance with another aspect, a method comprises providing a magnet system comprising at least one magnet and at least two pole pieces connected to a non- different pole of the at least one magnet; and connecting electrical leads from an electromagnetic coil to respective ones of the pole pieces. The respective ones of the pole pieces are electrically isolated from each other to provide separate electrical conductors to the electrical

leads of the coil.

[0009] In accordance with another aspect, a method comprises sending current to an electromagnetic coil through a first pole piece of a magnet system; and sending the current from the coil through a second pole piece of the magnet system.

[0010] The scope of protection sought for various embodiments of the invention is set out by the appended independent claims. The embodiments, examples and features, if any, described in this specification that do not fall under the scope of the independent claims are to be interpreted as examples useful for understanding various embodiments of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] The foregoing aspects and other features are explained in the following description, taken in connection with the accompanying drawings, wherein:

Fig. 1 is a perspective view of an example embodiment;

Fig. 2 is a diagram illustrating some of the components of the apparatus shown in Fig. 1;

Fig. 3 is a partial exploded perspective view of components of the apparatus shown in Fig. 1;

Fig. 4 is a perspective view of a top side of the loudspeaker shown in Fig. 3;

Fig. 5 is a perspective view of the loudspeaker shown in Fig. 4 from an opposite bottom side;

Fig. 6 is a schematic cross sectional view of a portion of the apparatus shown in Fig. 1;

Fig. 7 is a perspective view of the loudspeaker shown in Figs 3-5 without the housing;

Fig. 8 is a side view of the loudspeaker as shown in Fig. 7;

Fig. 9 is a bottom view of the loudspeaker shown in Figs. 7-8;

Fig. 10 is a view similar to Fig. 7 showing an alternate example embodiment;

Fig. 11 is a schematic side view of another alternate embodiment;

Fig. 11A is a side view of another alternate embodiment;

Fig. 11B is a side view of another alternate embodiment;

Fig. 11C is a diagram illustrating the magnetic poles of the magnets of the example shown in Fig. 6;

Fig. 11D is a diagram similar to Fig. 11C showing another example;

Fig. 12 is a diagram illustrating an example method;

Fig. 13 is a diagram illustrating another example embodiment;

Fig. 14 is a diagram illustrating another example embodiment;

Fig. 15 is a diagram illustrating another example embodiment;

Fig. 16 is a diagram illustrating another example embodiment;

Figs. 17-25 show different example embodiments of an electrical insulating feature to have pole pieces substantially electrically isolated for each other.

DETAILED DESCRIPTION OF EMBODIMENTS

[0012] Referring to Fig. 1, there is shown a perspective view of an apparatus 10 incorporating features of an example embodiment. Although the features will be described with reference to the example embodiments shown in the drawings, it should be understood that features can be embodied in many alternate forms of embodiments. In addition, any suitable size, shape or type of elements or materials could be used.

[0013] The apparatus 10 in this example is a hand-held portable electronic device comprising a telephone application, Internet browser application, camera application, video recorder application, music player and recorder application, email application, navigation application, gaming application, and/or any other suitable electronic device application. The apparatus 10, in this example embodiment, comprises a housing 12, a touch screen 14 which functions as both a display and a user input, a receiver 16, a transmitter 18, a controller 20 which can include (referring also to Fig. 2) at least one processor 22, at least one memory 24 with software, and a rechargeable battery 26. However, these features are not necessary to implement the protection described below. For example, a touch screen or additionally a conventional keypad or other user input could be used. Thus, features could be used in any suitable type of device, such as a telephone only for example.

[0014] The apparatus 10 also includes a speaker or earpiece 28 and a microphone 30 which each comprise a sound transducer. Referring also to Fig. 3, the apparatus 10 also includes a loudspeaker 40. The housing 12 comprises at least one sound hole 32 for sound to travel from the speaker 28, at least one sound hole 34 for sound

to travel to the microphone, and at least one sound hole 33 for sound to travel from the loudspeaker 40. The description which follows will be in regard to the area at the loudspeaker 40. However, the features described are equally applicable to other coil/magnet assemblies. Features of the invention could be used at the speaker 28 for example.

[0015] Referring also to Figs. 4-6, the loudspeaker 40 is a sound transducer. The sound transducer includes a magnet system 41, a coil 44, and a diaphragm 38 connected to the coil 44. The magnet system 41 comprises two permanent magnets 42a, 42b and four pole pieces 48a, 48b, 49a, 49b. In an alternate embodiment the magnets could be an electromagnet. In the example shown in the drawings the magnet system 41 is comprised of two magnet subsystems 46a, 46b. The first magnet subsystem 46a comprises the first permanent magnet 42a and the first pole pieces 48a, 49a. The second magnet subsystem 46b comprises the second permanent magnet 42b and the second pole pieces 48b, 49b. The magnets 42a, 42b have their poles aligned in the same directions to essentially function as a larger single permanent magnet. In an alternate example more than four pole pieces could be provided. In the example shown the diaphragm 38 has its outer perimeter connected to a housing 50 which can be mounted to a backside of a frame piece 52 (see Fig. 3). The magnets 42 and pole pieces 48, 49 form an area 54 for the coil 44 to move in.

[0016] The two magnet subsystems 46a, 46b are spaced from each other by a gap 68. The two magnet subsystems 46a, 46b are not directly connected to each other. Instead, the two magnet subsystems 46a, 46b are each connected to the printed wiring board (PWB) 21. Thus, the PWB 21 indirectly mechanically connects the two magnet subsystems 46a, 46b to each other. In an alternate embodiment, any suitable mechanical connection of the magnet subsystems 46a, 46b to each other could be provided so long as two isolated electrical conductor paths are provided. For example, the housing 50 can provide this mechanical connection function.

[0017] A pole piece is a structure composed of material of high magnetic permeability that serves to direct the magnetic field produced by a magnet. A pole piece attaches to and, in a sense, extends a pole of the magnet, hence the name. Magnetic flux will travel along the path that offers it the least amount of resistance, (or, more accurately, the least amount of reluctance). Steel components in a magnetic circuit offer the flux a low reluctance path. This fact allows the use of steel pole pieces to capture flux and concentrate it, (or merely redirect it), to the point of interest.

[0018] Focusing of flux can be achieved by tapering the steel. However, one must be aware that as the pole area of the steel pole piece decreases, the flux density within the steel (B) will increase (if the total flux traveling through the steel component remains constant). Steel pole pieces can also be used to homogenize the field over the active volume.

[0019] Pole pieces are needed because magnets are hard to make into complex shapes which may be needed and, thus, expensive. Pole pieces are used with both permanent magnets and electromagnets. In the case of an electromagnet, the pole piece or pieces simply extend the magnetic core and can even be regarded as part of it, particularly if they are made of the same material. The traditional material for pole pieces was soft iron. While still often used with permanent magnets, soft iron suffers from eddy currents which make it less suitable for use with electromagnets, and particularly inefficient when the magnet is excited by alternating current. Pole pieces take many shapes and forms depending on the application. A traditional dynamic loudspeaker has a distinctive annular magnet and pole piece structure which serves to concentrate the magnetic flux on the voice coil. The central, cylindrical pole piece surrounded by the voice coil is normally referred to as the pole piece. A second pole piece in turn surrounds the voice coil.

[0020] For the loudspeaker 40, when the electrical current flowing through the voice coil 44 changes direction, the coil's polar orientation reverses. This changes the magnetic forces between the voice coil and the permanent magnet/pole pieces, moving the coil and attached diaphragm back and forth.

[0021] The electromagnet is positioned in a constant magnetic field created by the permanent magnets 42 and the pole pieces 48, 49. The electromagnet and the permanent magnets interact with each other as any two magnets do. The positive end of the electromagnet is attracted to the negative pole of the permanent magnetic fields, and the negative pole of the electromagnet is repelled by the permanent magnets' negative poles. When the electromagnet's polar orientation switches, so does the direction of repulsion and attraction. In this way, the alternating current constantly reverses the magnetic forces between the voice coil and the permanent magnets. This pushes the coil back and forth rapidly, like a piston.

[0022] When the coil moves, it pushes and pulls on the diaphragm 38. This vibrates the air in front of the diaphragm, creating sound waves. The electrical audio signal can also be interpreted as a wave. The frequency and amplitude of this wave, which represents the original sound wave, dictates the rate and distance that the voice coil moves. This, in turn, determines the frequency and amplitude of the sound waves produced by the diaphragm.

[0023] Referring also to Figs. 7-9, the loudspeaker 40 is shown without the housing 50. Opposite ends 56, 57 of at least one wire which forms the coil 44 extend outward from the coil and are electrically connected to portions 58 of the pole pieces 48a, 48b. The ends 56, 57 form electrical leads for the coil 44. In an alternate example any suitable type of connection between the pole pieces and the coil could be provided. The length and shape of the leads 56, 57 allows the coil 44 to move relative to the pole pieces without the leads breaking. In other words, the leads 56, 57 form flexible electrical connections be-

tween the coil and the pole pieces.

[0024] The leads 56, 57 could be soldered to the portions 58 or slip fit connected, such as loops on the portions 58 for example. Any suitable connection could be provided. The pole pieces 48a, 48b form the sole electrical connection to the coil 44. Thus, the pole pieces 48a, 48b function as both pole pieces for the magnets 42a, 42b and as electrical terminals for the coil 44. An air gap 68 is provided between the two pole pieces 48a, 48b to maintain their electrical isolation from each other. In an alternate example, such as shown in Fig. 10, an electrical insulation material 70 may be provided in the gap 68. This electrical insulation material 70 can also function to mechanically connect the two magnet subassemblies 46a, 46b as a unitary magnet assembly before connection to the PWB 21.

[0025] As seen in Figs. 5 and 9, the outward facing sides 62 of the pole pieces 48a, 48b form contact areas or pads 60, 61 for connection to another member. Thus, the sides 62 and areas 60, 61 form an electrical interface for mechanical and electrical connection to another member. Referring back to Fig. 6, in this example the outward facing sides 62 of the pole pieces 48a, 48b are located directly against a printed wiring board (PWB) 21 of the controller 20. The contact areas 60, 61 are electrically connected directly to contact pads 64, 65 of the PWB 21. Current can be supplied from pad 64 to contact area 60, through first pole piece 48a, to first coil lead 56, through the coil 44, and return back to the PWB through 57, 48b, 61 and 65.

[0026] Features described above may also be used in an electrodynamic loudspeaker which does not use a permanent magnet. Features described above may be most beneficial in loudspeakers used in small size-constrained devices, where also cost is a primary concern.

[0027] The shrinking size of loudspeakers creates various challenges. The highest possible performance is needed from the smallest possible loudspeaker size. This means that one must continuously consider ways of simplifying and miniaturizing the mechanics of loudspeakers, without impacting performance. Another equally important area of optimization is performance versus price.

[0028] The electrical connection to a loudspeaker is usually handled by two contact springs pressing against corresponding pads on the printed wiring board (PWB) under the loudspeaker. Another common method is to provide soldering pads on the loudspeaker, to which wires can be soldered. These springs, or pads, are then internally electrically connected to the voice coil of the loudspeaker (e.g. by welding). The voice coil is situated in a strong permanent magnetic field, and provides the force that drives the loudspeaker diaphragm, thus generating sound. In most small loudspeakers, a single magnet is used. A minority of loudspeakers uses two or more magnets.

[0029] Features described above may have a magnet system (magnets plus pole pieces) which are effectively split into two parts, such as two halves for example, that

are electrically isolated from each other. These two separate parts do double duty as magnet systems and as electrical contact points. It is, therefore, possible to get rid of the conventional separate contact springs or pads, which saves cost and space.

[0030] The split of the magnet system is made in such a way that the magnetic field in the air gap 54 (where the voice coil 44 is located) is reduced as little as possible. Both ends 56, 57 of the voice coil wire are connected to suitable points on the respective magnet subsystems 46a, 46b. The bottom parts 62 of the magnet subsystems 46a, 46b now provide electrical contact pads 60, 61 for the loudspeaker. Alternatively, parts of the magnet assemblies can be left exposed also on the sides of the loudspeaker, providing contact pads there.

[0031] With features of an example embodiment described above, the magnet system is divided into at least two parts that are electrically isolated from each other, and the split may be made in such a way that portions of at least two pole pieces can be used as electrical terminals and contact points for the wires from the coil.

[0032] It should be noted that in alternate embodiments the split can be oriented in some different way than shown in the drawings. Furthermore, the gap between the magnet system parts does not have to be empty, but it may as well be filled with material 70 such as, for example, glue, or generally any material that is electrically nonconductive, or at least has a high electrical resistance.

[0033] It should also be noted that the small width of the split 68 has only a very small or negligible effect on the performance of the loudspeaker. The split(s) between conductive parts of the magnet system may be designed so as to impair the performance of a nearby antenna as little as possible. In other words, the exact dimensions of the various mutually isolated parts could be chosen to achieve a certain desired response to an external RF field.

Advantages can include

[0034]

- Considerably simpler mechanical construction of loudspeaker itself (no separate contact springs or pads)
- Lower cost of loudspeaker itself (whether the total cost is also lower will depend on the chosen connection method)
- Potentially smaller loudspeaker size for a given performance
- Potentially higher thermal power handling capacity (depends on other construction details, not necessarily directly related to the invention)
- Higher reliability (fewer parts and simpler construction leads to a generally lower risk of failure).

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- Potential advantage for antenna integration (smaller contiguous volume of conductive material, therefore potentially impacting the performance of nearby antennas less than a conventionally constructed loudspeaker of the same size).

[0035] In one type of example, the entire magnet system can be effectively split into two parts that are electrically isolated from each other. This allows pole pieces attached to the magnet systems to be used as the two electrical terminals. The coil wires can be welded (or otherwise mechanically and electrically attached) to the pole pieces. Further variations are possible. The magnet system halves could, for example, include protruding soldering pads on the sides of the loudspeaker, etc.

[0036] Thermal conduction from the voice coil 44 to the surrounding mechanics can be improved by good design. The voice coil is connected to the magnet system subsystems 46a, 46b; which are more efficient heat sinks than conventional contact springs would be. This is especially true if more uncommon solutions such as a spider of a loudspeaker is used, since this will provide potentially very efficient thermal conduction from the voice coil to the magnet subsystems 46a, 46b.

[0037] In an alternate example embodiment, a single permanent magnet could be used in the magnet system 41 if the pole pieces 48a, 48b are kept electrically isolated from each other in the magnet system. An example of this is shown in Fig. 11. The magnet system could comprises one permanent magnet 42 and three pole pieces 48a, 48b, 49. In this example, the magnet system still forms two magnet subsystems with pole pieces 48a, 48b electrically isolated from each other, but where each magnet subsystem comprises a portion of the same single magnet 42. In the example shown the two parts or subsystems 72, 73 each form one half of the magnet system with electrical insulator 70 at least partially mechanically connecting the two parts. In this example the magnet 42 is comprised of electrically non-conductive material. However, as noted in the example embodiments described below in Figs. 17-25, the magnet 42 could be comprised of electrically conductive material where the electrical insulation extends between at least one of the pole pieces and the magnet. As another alternative, 48 and 42a could be formed as a single magnet rather than a pole piece connected to a magnet. Likewise, 49 and 42b could be formed as a single magnet rather than a pole piece connected to a magnet. The electrical insulation 70, if located between the magnet(s) and at least one of the pole pieces, should not impair the magnetic circuit(s) too much. The insulating layer may have a high permeability in spite of being electrically nonconductive.

[0038] Fig. 11B shows another example where the magnet system comprises two permanent magnets 42a, 42b and three pole pieces 48a, 48b and 49. The pole

piece 49 keeps the two magnets 42a, 42b mechanically connected to each other in a unitary assembly, but still can allow the pole pieces 48a, 48b to not be directly electrically connected to each other.

[0039] In most conventional loudspeakers, there is one magnet and two pole pieces. In a minority of loudspeakers, there can be more, such as 3 magnets and 4 pole pieces, or perhaps even 5 magnets and 6 pole pieces. These magnets and pole pieces are not deliberately electrically insulated from each other. Neodymium-based magnets are typically used in at least some mobile phone loudspeakers. Providing deliberate electrical insulation between a pole piece and a magnet would perform no purpose in a conventional loudspeaker.

[0040] Features as described herein may differ from a typical loudspeaker in that the magnet system is no longer one single electrically conductive block. Instead, two (or more) subsystems are provided that are electrically isolated from one another. What this means is that the most common kind of magnet system, consisting of 1 magnet and 2 pole pieces, may for example effectively become 2 magnets and 4 pole pieces when split into two halves.

[0041] Referring also to Fig. 11C, the N and S poles of the magnets 42a, 42b for the example shown in Fig. 6 is shown. N and S can of course also be swapped in a different example. Fig. 11D shows another example with more magnets and pole pieces.

[0042] One type of example apparatus, 40 or 10 for example, could comprise an electromagnetic coil 44, where the coil comprises opposite electrical leads 56, 57; and a magnet system forming electrical conductors 48a, 48b connected to the electrical leads of the coil, where the magnet system is configured to electrically connect the coil to another member 21.

[0043] The electrical leads could comprise opposite ends of an electrical wire forming the coil. The electrical leads could comprise conductors connecting opposite electrical ends of the coil to the magnet system. The magnet system could comprise at least one permanent magnet and at least two pole pieces connected to a non-different pole of the at least one permanent magnet. For example, with a single permanent magnet the non-different pole could be a N pole, and for an embodiment with two magnets the non-different pole could be a N pole of both permanent magnets. The at least one permanent magnet could comprise a single permanent magnet. The apparatus may further comprise an electrical insulator which at least partially electrically insulates first and second pole pieces from each other. The electrical insulator may be located, at least partially, between the first pole piece and at least one permanent magnet. The magnet system may comprise at least one permanent magnet and at least two pole pieces connected to the at least one permanent magnet, and the apparatus may further comprise an electrical insulator which at least partially electrically insulates at least one of the pole pieces from the at least one permanent magnet.

[0044] In one type of example embodiment an apparatus may be provided comprising an electromagnetic coil, where the coil comprises electrical leads; a magnet system comprising a first permanent magnet and two pole pieces connected to the first permanent magnet, where at least one of the pole pieces forms an electrical conductor connected to at least one of the electrical leads of the coil; and an electrical insulator at least partially between the first permanent magnet and at least one of the pole pieces.

[0045] Referring also to Fig. 11a, at least one pole piece 49 could have an electrical conductor 92 on it, such as a trace, isolated from the main material of the pole piece by an insulator 90, where the conductor 92 (which is part of the magnet system and integral on the pole piece 49) provides the electrical connection of the coil to the other member. The at least one permanent magnet could comprise a first permanent magnet assembled with a first one of the pole pieces as a first subassembly 72, and a second permanent magnet assembled with a second one of the pole pieces as a second subassembly 73, where the first and second subassemblies are connected together to form the magnet system. The magnet system could comprise a first pole piece and a second pole piece, where the first and second pole pieces are electrically isolated from each other, and where the first and second pole pieces are configured to electrically connect opposite electrical ends of the coil to the another member. The first and second pole pieces could each comprise an electrical contact pad 60, 61 adapted to electrically connect the magnet system to the another member. The apparatus 40 could further comprise a diaphragm 38 mechanically connected to the coil. The apparatus could be a hand held electronic device comprising a printed wiring board 21, and wherein the magnet system comprises at least two pole pieces electrically connected to contact pads 64, 65 of the printed wiring board.

[0046] Referring also to Fig. 12, one example method comprises providing a magnet system comprising at least two magnet subsystems with at least one magnet and at least two pole pieces connected to a non-different pole of the at least one magnet as indicated by block 80; and connecting electrical leads from an electromagnetic coil to respective ones of the pole pieces as indicated by block 82, where the respective ones of the pole pieces are electrically isolated from each other to provide separate electrical conductors to the electrical leads of the coil.

[0047] A pole piece is usually a slab of material attached to a pole of the magnet. The purpose of the pole piece is to act as a kind of "conductor" for the magnetic field. So in one example embodiment, each of the halves of the magnet system would have two pole pieces (one on either pole of the respective magnet). So there would be four pole pieces all in all. In one example embodiment, where the magnet system is split into more than two mutually isolated magnet parts, the pole pieces of only two of the magnet parts might be used for the electrical con-

nection. More and smaller parts potentially interfere less with RF antennas. In another example embodiment the transducer could comprise two voice coils and two magnets, with two diaphragms located on opposite sides of the assembly. In another example embodiment the transducer could comprise two voice coils, two diaphragms and a single magnet.

[0048] Providing the magnet system can comprise the at least one magnet being a single permanent magnet. Providing the magnet system can comprise the at least one magnet being two separate permanent magnets, and connecting a first one of the pole pieces to a first pole of a first one of the permanent magnets, and connecting a second one of the pole pieces to a first pole of a second one of the permanent magnets. Connecting the electrical leads can comprise connecting a first end of a wire forming the coil directly to a first one of the pole pieces, and connecting an opposite second end of the wire forming the coil directly to a second one of the pole pieces. The method could further comprise electrically connecting an electrical contact pad on each of the pole pieces directly to electrical contact pads of another member. The method could further comprise filling a gap between opposing ends of the pole pieces with electrically non-conductive material. Providing the magnet system may comprise at least partially electrically insulating the permanent magnet(s) from at least one of the pole pieces to electrically isolate the pole pieces from each other. Providing the magnet system may comprise providing an electrical insulator at least partially between a first magnet of the at least one magnet and at least one of the pole pieces. Providing the electrical insulator may comprise providing the electrical insulator directly between two of the pole pieces. Providing the magnet system may comprise the at least two pole pieces being connected to a non-different pole of the at least one magnet.

[0049] Another example method comprises sending current to an electromagnetic coil through a first pole piece of a magnet system; and sending the current from the coil through a second pole piece of the magnet system.

[0050] In one example, one of the pole pieces is split, and both of these pole piece halves are attached to the same pole of a same magnet. In such a case one or both of the pole pieces has to be isolated electrically, but not magnetically, from the magnet, otherwise the coils will be short-circuited. This is possible, but requires proper material (i.e. electrically nonconductive but having a high magnetic permeability) between pole piece(s) and magnet.

[0051] Referring also to Fig. 13, in one example embodiment there are no contact springs between the coil 44 and the printed wiring board 21, and the magnet system halves are acting as electrical contacts (resting on some additional pads 64, 65 on the PWB 21). Referring also to Fig. 14, in one example embodiment the magnet system halves 146a, 146b are in direct contact with the PCB 21. Referring also to Fig. 15, in one example em-

bodiment external springs 200 are making the electrical contact to the magnet system halves 146a, 146b. Referring also to Fig. 16, in one example embodiment wires 202 are soldered/welded to pads formed by the magnet system halves 146a, 146b.

[0052] With an example embodiment having features described herein, the electrical connection between the coil and the magnet system can provide a heat transfer path such that the magnet system provides a heat sink for the coil. A portable electronic device 10 could be provided comprising the apparatus as described above and an antenna 19 (see Fig. 1) located proximate the apparatus 40, where a split (or splits) between conductive parts of the magnet system are configured not to substantially impair performance of the antenna to achieve a predetermined desired response to an external RF field.

[0053] Referring also to Fig. 17, an example embodiment is shown similar to Fig. 11 where the assembly 200 comprises a single magnet 42, three pole pieces 48a, 48b, 49, electrical insulation 202, diaphragm 38, coil 44 and leads 56, 57. This example illustrates that a manufacturer may avoid having to split any of the magnets with this type of design. The electrical insulation or insulating layer 202 is at least partially electrically insulating. It does not necessarily have to have a high permeability, but it may help if it has high permeability.

[0054] In various different example embodiments, wherever there is an electrically insulating feature, this insulating feature can be either a simple air gap, or a gap filled or partially filled with some electrically insulating substance (for example, nonconductive glue). This substance might also have a high permeability. The electrically insulating substance does not have to be strictly an insulator. It can also have a high enough electrical resistance to provide good enough insulation to avoid degrading the performance of the loudspeaker. Figs. 18-23 shown various different example embodiments of using electrical insulator(s) 204, 206, 208, 210 which may comprise an air gap and/or an electrically insulating substance.

[0055] In a conventional loudspeaker, a pole piece is either glued or in some other way attached to the magnet. Glue, if used, might in effect create a small gap between the magnet and the pole piece even in a traditional loudspeaker, but this gap is kept as small as possible to avoid degrading the magnetic field where the voice coil is located. Keeping them deliberately electrically insulated from each other provides no benefit in a conventional loudspeaker and, therefore, no intentional and controlled insulation is intentionally provided. Therefore, intentionally electrically insulating a pole piece and magnet is not done in a conventional loudspeaker. Rather, the amount of glue is kept as small as possible, with the result that electrical insulation is not guaranteed in a conventional loudspeaker.

[0056] The insulating feature noted above regarding example embodiments (whether it is air, or electrically

insulating material) may be made as thin as possible. The reason is that if it is too wide, the magnetic field strength at the voice coil will be degraded. However, if the insulating material also has a high magnetic permeability, it can be made thicker with less degradation.

[0057] The lead(s) of the coil may be connected to any spot on the whole bulk of contiguous conductive material forming one of the electrical terminals. So, for example, the wires may be connected to the pole pieces at the upper ends as seen in Fig. 20. The leads 56, 57 might as well be connected to the magnets as seen in Fig. 24, and/or to the pole pieces at the bottom as seen in Fig. 25, or one to top and the other to bottom, or some other combination. It does not matter since in those particular embodiments, each of those pole piece and magnet assemblies make up a single mass of conductive material anyway.

[0058] The magnet(s) may also be made up of some material that is not electrically conductive. If the material used in the magnet is not electrically conductive, a separate electrical insulation may not be necessary between the magnet and one or more of the pole pieces.

[0059] While the figures above have shown the leads or wires from the coil as being on the outside of the magnet system(s), (i.e. close to the outer rim of the loudspeaker), the wires may also be anywhere else.

[0060] In one type of alternate example embodiment, one of the two connections to the coil may be made using a traditional method (coil wire connected to a separate spring or pad), and the other may be made using the idea described above using a pole piece as an electrical conductor.

[0061] An example method may comprise providing a magnet system comprising at least one magnet and at least two pole pieces connected to the at least one magnet; and connecting at least one electrical lead from an electromagnetic coil to at least one of the pole pieces, where at least two of the pole pieces are electrically isolated from each other such that the at least one pole piece provides at least one separate electrical conductor for the at least one electrical lead of the coil. Connecting the at least one electrical lead may comprise connecting a first end of a wire forming the coil directly to a first one of the pole pieces, and connecting an opposite second end of the wire forming the coil directly to a second one of the pole pieces.

[0062] It should be understood that the foregoing description is only illustrative. Various alternatives and modifications can be devised by those skilled in the art. For example, features recited in the various dependent claims could be combined with each other in any suitable combination(s). In addition, features from different embodiments described above could be selectively combined into a new embodiment. Accordingly, the description is intended to embrace all such alternatives, modifications and variances which fall within the scope of the appended claims.

Claims

1. A sound transducer comprising:

5 an electromagnetic coil (44) where the coil (44) comprises electrical leads; and
a magnet system (41) comprising a first magnet subsystem (46a) and a second magnet subsystem (46b) wherein the first magnet subsystem (46a) comprises a first magnet (42a) and a first pole piece (48a, 48c) where the first pole piece (48a, 48c) is coupled to the first magnet (42a) and wherein the second magnet subsystem (46b) comprises a second magnet (42b) and a second pole piece (48b, 48d) where the second pole piece (48b, 48d) is coupled to the second magnet (42b);
10 where the magnet system (41) is configured so that the first magnet subsystem (46a) and the second magnet subsystem (46b) are electrically isolated from each other; and
where the magnet system (41) is configured to provide an electrical interface to electrically connect the electrical leads of the coil (44) to another member, wherein the electrical interface comprises the first pole piece (48a, 48c) and the second pole piece (48b, 48d).

2. The sound transducer as claimed in claim 1, where the electrical leads comprise opposite ends of an electrical wire forming the coil (44).

3. The sound transducer as claimed in claim 1, where the electrical leads comprise conductors connecting opposite electrical ends of an electrical wire forming the coil (44) to the magnet system (41).

4. The sound transducer as claimed in any preceding claim, where the first magnet (42a) and the second magnet (42b) are permanent magnets and where the first pole piece (48a, 48c) and the second pole piece (48b, 48d) are connected to a non-different pole of the first magnet (42a) and the second magnet (42b) respectively.

5. The sound transducer as claimed in any preceding claim, further comprising electrical insulation (70) between the first pole piece (48a, 48c) and the second pole piece (48b, 48d), where the electrical insulation (70) is electrically nonconductive and comprises a high permeability.

6. The sound transducer as claimed in any preceding claim, where the first pole piece (48a, 48c) and the second pole piece (48b, 48d) each comprise an electrical contact area adapted to electrically connect the magnet system (41) to the another member.

7. The sound transducer as claimed in any preceding claim, further comprising a diaphragm mechanically connected to the electromagnetic coil (44).
8. An apparatus comprising a sound transducer as claimed in any preceding claim and a printed wiring board (21), wherein the first pole piece (48a, 48c) and the second pole piece (48b, 48d) are electrically connected to the printed wiring board (21) via contact pads of the printed wiring board (21).
9. The sound transducer as claimed in any of claims 1 to 7 or the apparatus as claimed in claim 8, wherein the first magnet subsystem (46a) further comprises a third pole piece (49a) and the second magnet subsystem (46b) further comprises a fourth pole piece (49b).
10. The sound transducer as claimed in any of claims 1 to 7 or the apparatus as claimed in claim 8, wherein the magnet system (41) comprises a further pole piece (49) mechanically connected to both the first magnet (42a) in the first magnet subsystem (46a) and the second magnet (42b) in the second magnet subsystem (46b).
11. The sound transducer as claimed in any of claims 1 to 7, 9 and 10 or the apparatus as claimed in claim 8, comprising an electrical insulator which at least partially electrically insulates the first pole piece (48a, 48c) and the second pole piece (48b, 48d) from each other.
12. The sound transducer as claimed in any of claims 1 to 7 and 9 to 11 or the apparatus as claimed in claim 8, wherein the magnet system (41) comprises more than two magnet subsystems (46a, 46b) that are electrically isolated from each other.
13. The sound transducer as claimed in any of claims 1 to 7 and 9 to 12 or the apparatus of claim 8, wherein the first pole piece (48a, 48c) and the second pole piece (48b, 48d) form at least part of an exterior rear surface of the sound transducer.
14. A hand-held portable electronic device comprising the sound transducer of any of claims 1 to 7 and 9 to 13 or the apparatus of claim 8.

Patentansprüche

1. Schallwandler, der Folgendes umfasst:

eine elektromagnetische Spule (44), wo die Spule (44) elektrische Leitungen umfasst; und ein Magnetsystem (41), das ein erstes Magnetuntersystem (46a) und ein zweites Magnetun-

tersystem (46b) umfasst, wobei das erste Magnetuntersystem (46a) einen ersten Magneten (42a) und ein erstes Polstück (48a, 48c) umfasst, wo das erste Polstück (48a, 48c) an den ersten Magneten (42a) gekoppelt ist und wobei das zweite Magnetuntersystem (46b) einen zweiten Magneten (42b) und ein zweites Polstück (48b, 48d) umfasst, wo das zweite Polstück (48b, 48d) an den zweiten Magneten (42b) gekoppelt ist; wo das Magnetsystem (41) derart ausgelegt ist, dass das erste Magnetuntersystem (46a) und das zweite Magnetuntersystem (46b) elektrisch gegeneinander isoliert sind; und wo das Magnetsystem (41) dazu ausgelegt ist, zum elektrischen Verbinden der elektrischen Leitungen der Spule (44) mit einem anderen Element eine elektrische Schnittstelle bereitzustellen, wobei die elektrische Schnittstelle das erste Polstück (48a, 48c) und das zweite Polstück (48b, 48d) umfasst.

2. Schallwandler nach Anspruch 1, wo die elektrischen Leitungen gegenüberliegende Enden eines elektrischen Drahtes, der die Spule (44) bildet, umfassen.
3. Schallwandler nach Anspruch 1, wo die elektrischen Leitungen Leiter umfassen, die gegenüberliegende elektrische Enden eines elektrischen Drahtes, der die Spule (44) bildet, mit dem Magnetsystem (41) verbinden.
4. Schallwandler nach einem der vorhergehenden Ansprüche, wo der erste Magnet (42a) und der zweite Magnet (42b) Permanentmagnete sind und wo das erste Polstück (48a, 48c) und das zweite Polstück (48b, 48d) mit einem nicht anderen Pol des ersten Magneten (42a) bzw. des zweiten Magneten (42b) verbunden sind.
5. Schallwandler nach einem der vorhergehenden Ansprüche, der ferner eine elektrische Isolierung (70) zwischen dem ersten Polstück (48a, 48c) und dem zweiten Polstück (48b, 48d) umfasst, wo die elektrische Isolierung (70) elektrisch nicht leitend ist und eine hohe Permeabilität umfasst.
6. Schallwandler nach einem der vorhergehenden Ansprüche, wo das erste Polstück (48a, 48c) und das zweite Polstück (48b, 48d) jeweils eine elektrische Kontaktfläche umfassen, die angepasst ist, das Magnetsystem (41) mit dem anderen Element elektrisch zu verbinden.
7. Schallwandler nach einem der vorhergehenden Ansprüche, der ferner eine Membran umfasst, die mechanisch mit der elektromagnetischen Spule (44) verbunden ist.

8. Einrichtung, die einen Schallwandler nach einem der vorhergehenden Ansprüche und eine Leiterplatte (21) umfasst, wobei das erste Polstück (48a, 48c) und das zweite Polstück (48b, 48d) via Kontaktstellen der Leiterplatte (21) elektrisch mit der Leiterplatte (21) verbunden sind. 5
9. Schallwandler nach einem der Ansprüche 1 bis 7 oder Einrichtung nach Anspruch 8, wobei das erste Magnetuntersystem (46a) ferner ein drittes Polstück (49a) umfasst und das zweite Magnetuntersystem (46b) ferner ein viertes Polstück (49b) umfasst. 10
10. Schallwandler nach einem der Ansprüche 1 bis 7 oder Einrichtung nach Anspruch 8, wobei das Magnetsystem (41) ein weiteres Polstück (49) umfasst, das sowohl mit dem ersten Magneten (42a) im ersten Magnetuntersystem (46a) als auch dem zweiten Magneten (42b) im zweiten Magnetuntersystem (46b) mechanisch verbunden ist. 15 20
11. Schallwandler nach einem der Ansprüche 1 bis 7, 9 und 10 oder Einrichtung nach Anspruch 8, der bzw. die einen elektrischen Isolator umfasst, der das erste Polstück (48a, 48c) und das zweite Polstück (48b, 48d) mindestens teilweise elektrisch gegeneinander isoliert. 25
12. Schallwandler nach einem der Ansprüche 1 bis 7 und 9 bis 11 oder Einrichtung nach Anspruch 8, wobei das Magnetsystem (41) mehr als zwei Magnetuntersysteme (46a, 46b), die elektrisch gegeneinander isoliert sind, umfasst. 30
13. Schallwandler nach einem der Ansprüche 1 bis 7 und 9 bis 12 oder Einrichtung nach Anspruch 8, wobei das erste Polstück (48a, 48c) und das zweite Polstück (48b, 48d) mindestens einen Teil einer äußeren hinteren Fläche des Schallwandlers bilden. 35 40
14. Tragbare elektronische Handvorrichtung, die den Schallwandler von einem der Ansprüche 1 bis 7 und 9 bis 13 oder die Einrichtung von Anspruch 8 umfasst. 45

Revendications

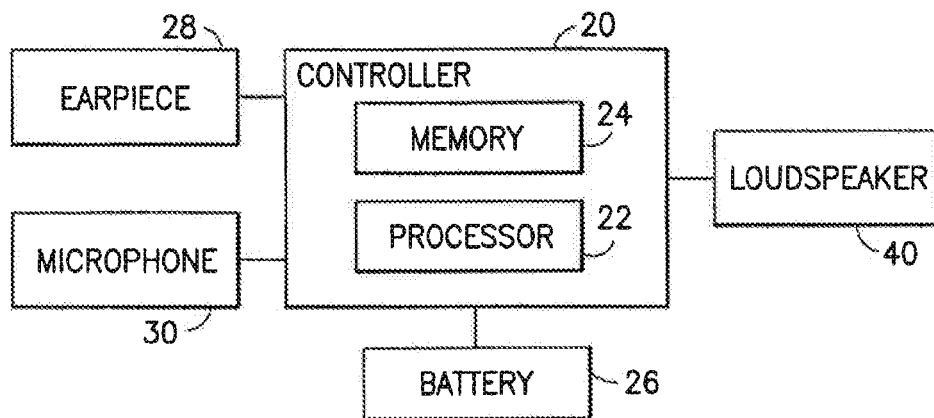
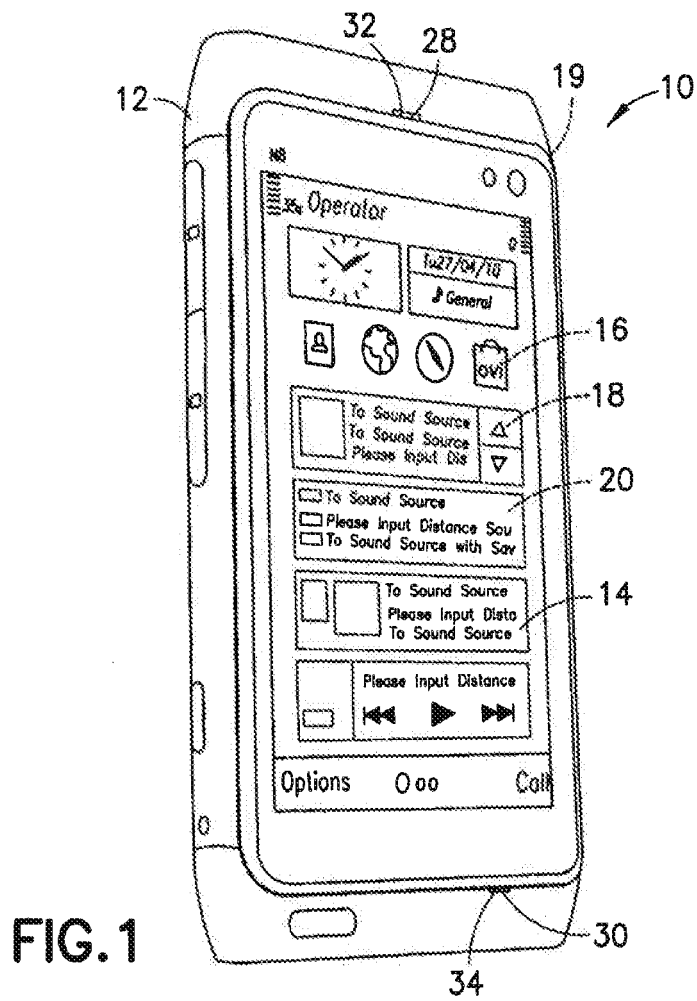
1. Transducteur acoustique comprenant : 50

une bobine électromagnétique (44), dans lequel la bobine (44) comprend des conducteurs électriques ; et
un système magnétique (41) comprenant un premier sous-système magnétique (46a) et un second sous-système magnétique (46b), dans lequel le premier sous-système magnétique (46a) comprend un premier aimant (42a) et une 55

première pièce polaire (48a, 48c), dans lequel la première pièce polaire (48a, 48c) est accouplée au premier aimant (42a) et dans lequel le second sous-système magnétique (46b) comprend un second aimant (42b) et une deuxième pièce polaire (48b, 48d), dans lequel la deuxième pièce polaire (48b, 48d) est accouplée au second aimant (42b) ;
dans lequel le système magnétique (41) est conçu de manière que le premier sous-système magnétique (46a) et le second sous-système magnétique (46b) soient électriquement isolés l'un de l'autre ; et
dans lequel le système magnétique (41) est conçu pour procurer une interface électrique afin de connecter électriquement les conducteurs électriques de la bobine (44) à un autre élément, dans lequel l'interface électrique comprend la première pièce polaire (48a, 48c) et la deuxième pièce polaire (48b, 48d).

2. Transducteur acoustique tel que revendiqué dans la revendication 1, dans lequel les conducteurs électriques comprennent les extrémités opposées d'un fil électrique formant la bobine (44).
3. Transducteur acoustique tel que revendiqué dans la revendication 1, dans lequel les conducteurs électriques comprennent des conducteurs connectant les extrémités électriques opposées d'un fil électrique formant la bobine (44) au système magnétique (41).
4. Transducteur acoustique tel que revendiqué dans l'une quelconque des revendications précédentes, dans lequel le premier aimant (42a) et le second aimant (42b) sont des aimants permanents et dans lequel la première pièce polaire (48a, 48c) et la deuxième pièce polaire (48b, 48d) sont connectées à un pôle équivalent du premier aimant (42a) et du second aimant (42b) respectivement.
5. Transducteur acoustique tel que revendiqué dans l'une quelconque des revendications précédentes, comprenant en outre une isolation électrique (70) entre la première pièce polaire (48a, 48c) et la deuxième pièce polaire (48b, 48d), dans lequel l'isolation électrique (70) est électriquement non conductrice et possède une perméabilité élevée.
6. Transducteur acoustique tel que revendiqué dans l'une quelconque des revendications précédentes, dans lequel la première pièce polaire (48a, 48c) et la deuxième pièce polaire (48b, 48d) comprennent chacune une aire de contact électrique destinée à connecter électriquement le système magnétique (41) à l'autre élément.

7. Transducteur acoustique tel que revendiqué dans l'une quelconque des revendications précédentes, comprenant en outre une membrane mécaniquement reliée à la bobine électromagnétique (44). 5
8. Appareil comprenant un transducteur acoustique tel que revendiqué dans l'une quelconque des revendications précédentes et une carte imprimée (21), dans lequel la première pièce polaire (48a, 48c) et la deuxième pièce polaire (48b, 48d) sont électriquement connectées à la carte imprimée (21) par l'intermédiaire de plages de contact de la carte imprimée (21). 10
9. Transducteur acoustique tel que revendiqué dans l'une quelconque des revendications 1 à 7 ou appareil tel que revendiqué dans la revendication 8, dans lesquels le premier sous-système magnétique (46a) comprend en outre une troisième pièce polaire (49a) et le second sous-système magnétique (46b) comprend en outre une quatrième pièce polaire (49b). 15 20
10. Transducteur acoustique tel que revendiqué dans l'une quelconque des revendications 1 à 7 ou appareil tel que revendiqué dans la revendication 8, dans lesquels le système magnétique (41) comprend une pièce polaire (49) supplémentaire, mécaniquement reliée à la fois au premier aimant (42a) dans le premier sous-système magnétique (46a) et au second aimant (42b) dans le second sous-système magnétique (46b). 25 30
11. Transducteur acoustique tel que revendiqué dans l'une quelconque des revendications 1 à 7, 9 et 10 ou appareil tel que revendiqué dans la revendication 8, comprenant un isolateur électrique qui isole électriquement au moins en partie la première pièce polaire (48a, 48c) et la deuxième pièce polaire (48b, 48d) l'une de l'autre. 35 40
12. Transducteur acoustique tel que revendiqué dans l'une quelconque des revendications 1 à 7 et 9 à 11 ou appareil tel que revendiqué dans la revendication 8, dans lesquels le système magnétique (41) comprend plus de deux sous-systèmes magnétiques (46a, 46b) qui sont électriquement isolés les uns des autres. 45 50
13. Transducteur acoustique tel que revendiqué dans l'une quelconque des revendications 1 à 7 et 9 à 12 ou appareil selon la revendication 8, dans lesquels la première pièce polaire (48a, 48c) et la deuxième pièce polaire (48b, 48d) forment au moins une partie d'une surface arrière extérieure du transducteur acoustique. 55
14. Dispositif électronique portable, à main, comprenant le transducteur acoustique selon l'une quelconque des revendications 1 à 7 et 9 à 13 ou l'appareil selon la revendication 8.



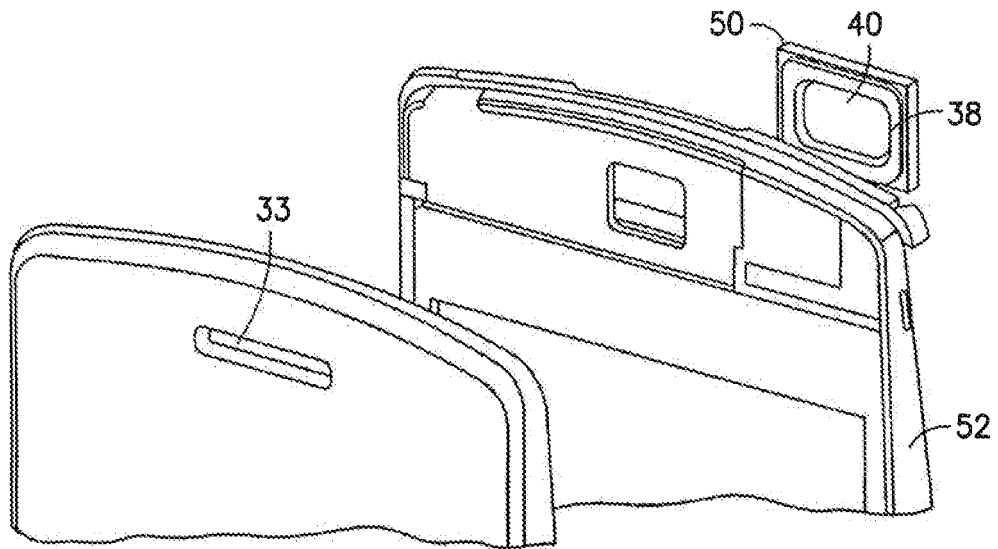


FIG. 3

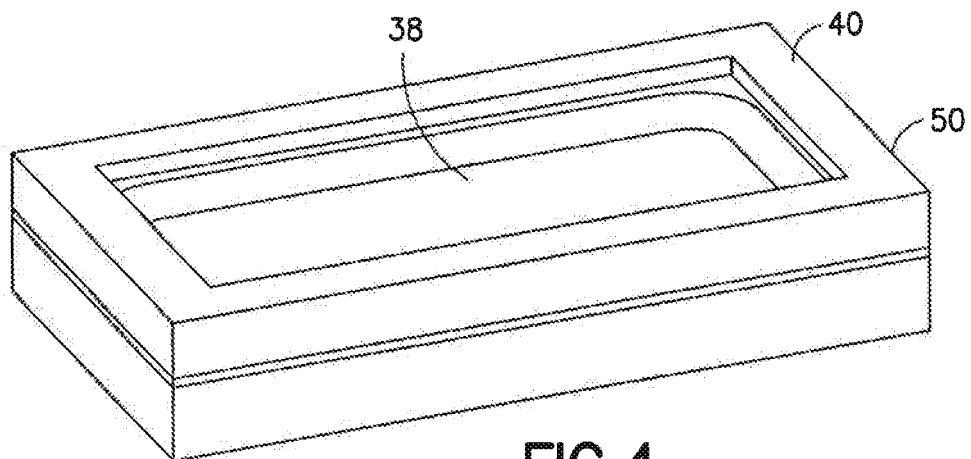


FIG. 4

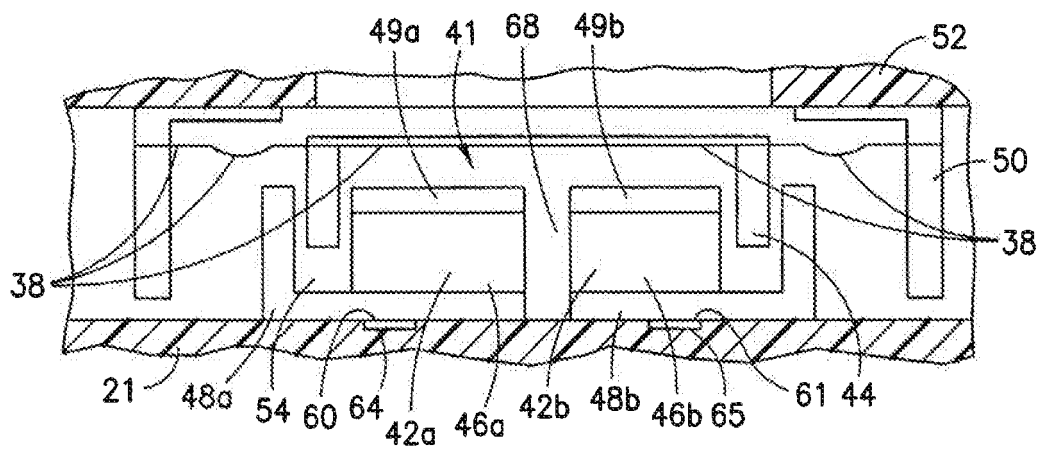


FIG.6

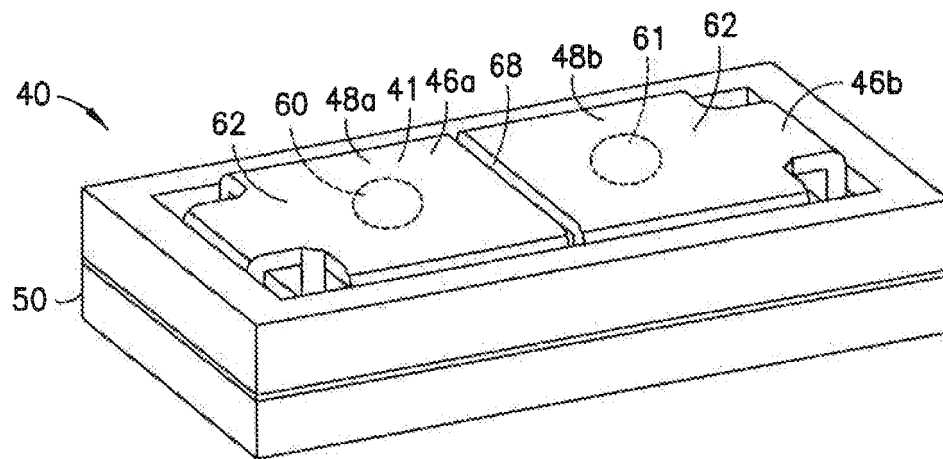


FIG. 5

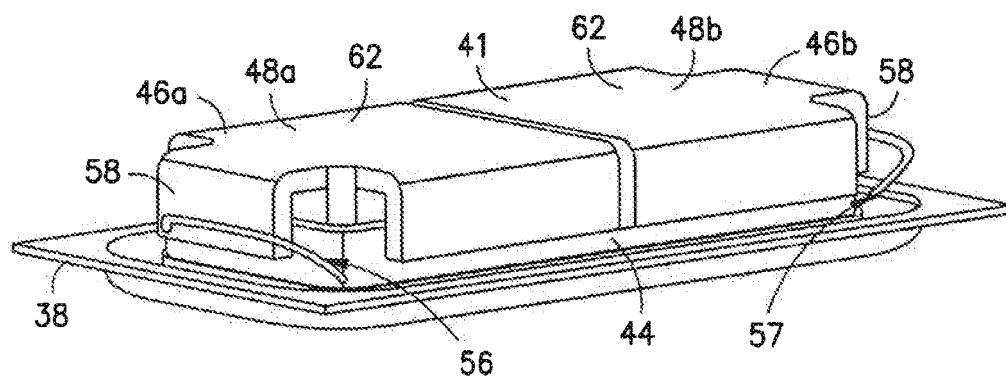
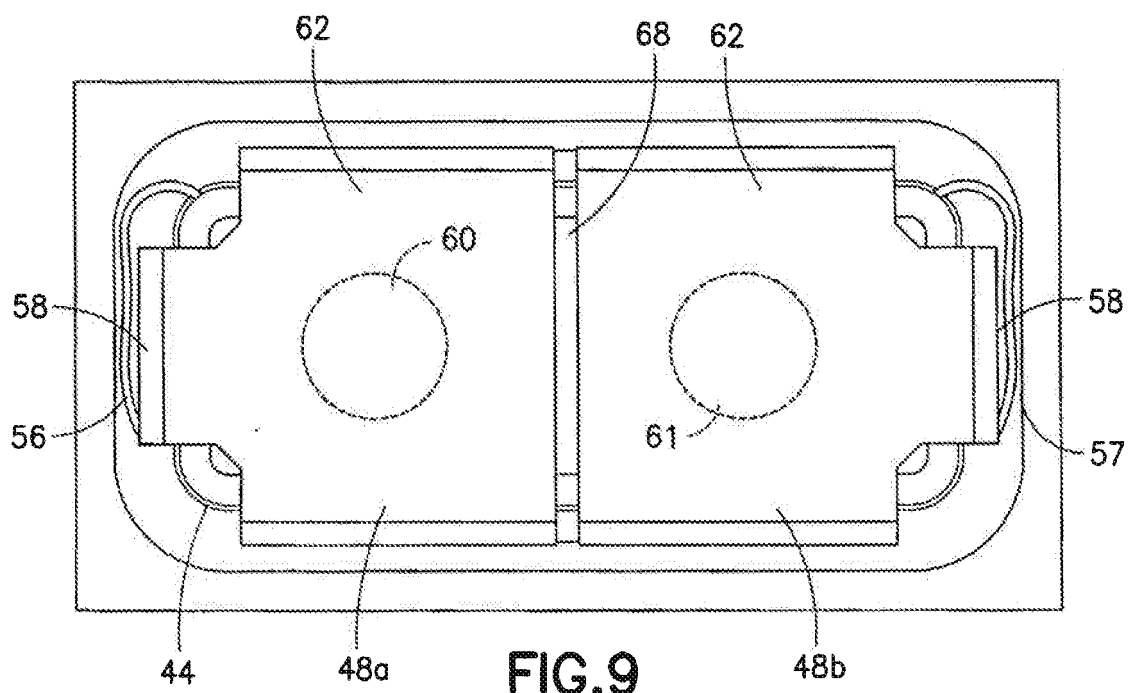
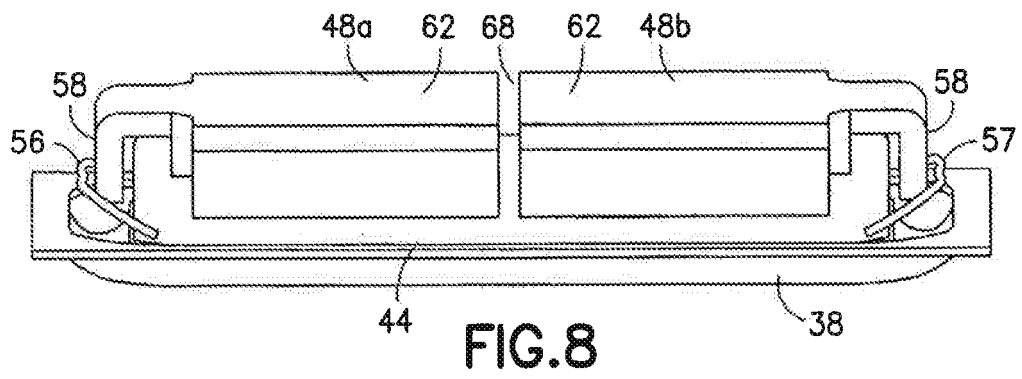


FIG. 7



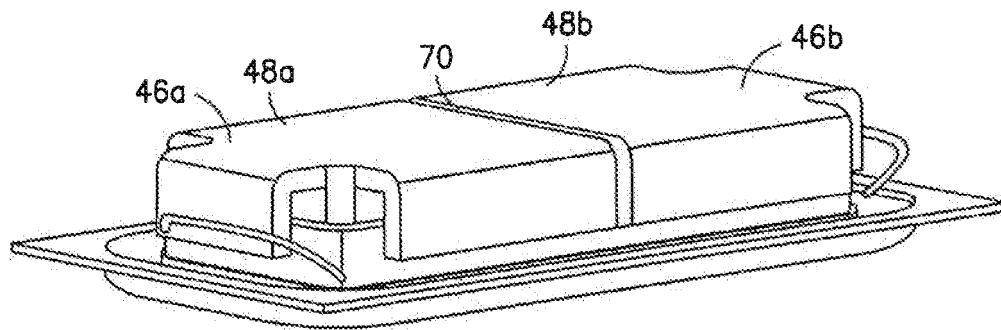


FIG. 10

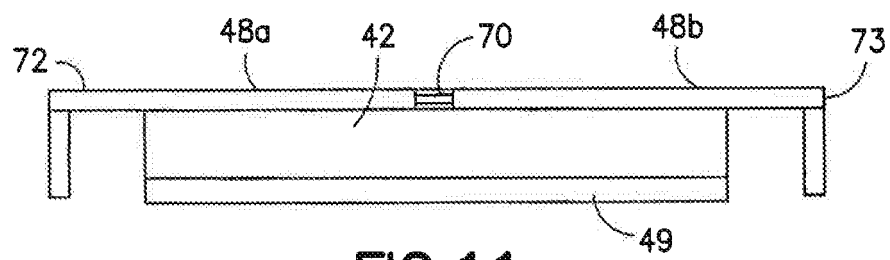


FIG. 11

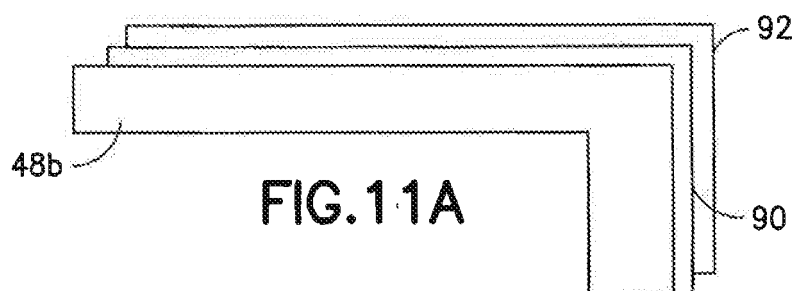


FIG. 11A

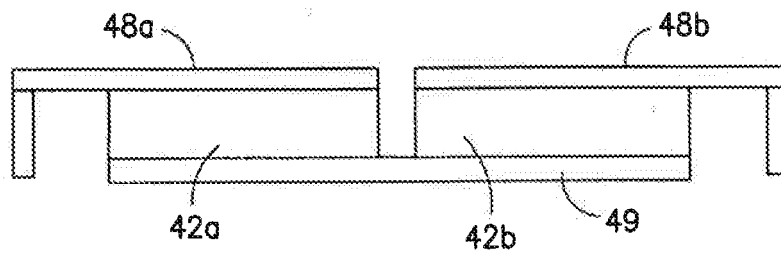


FIG. 11B

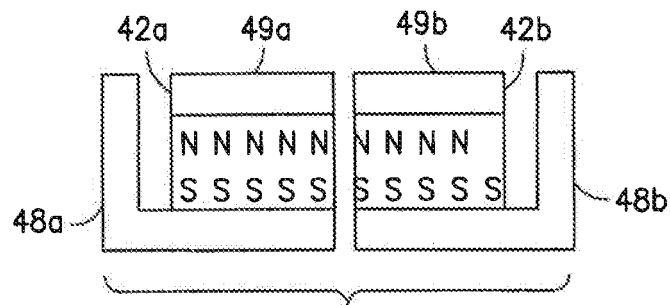


FIG. 11C

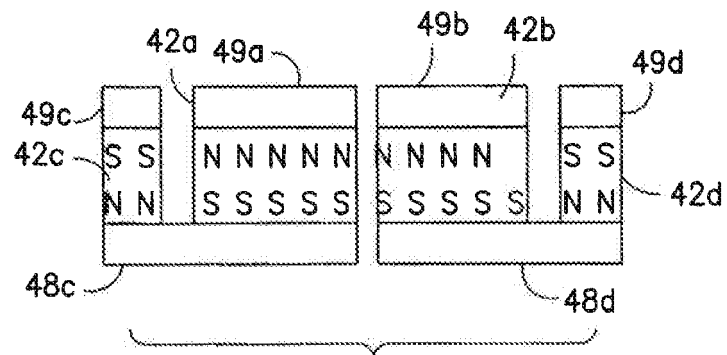


FIG. 11D

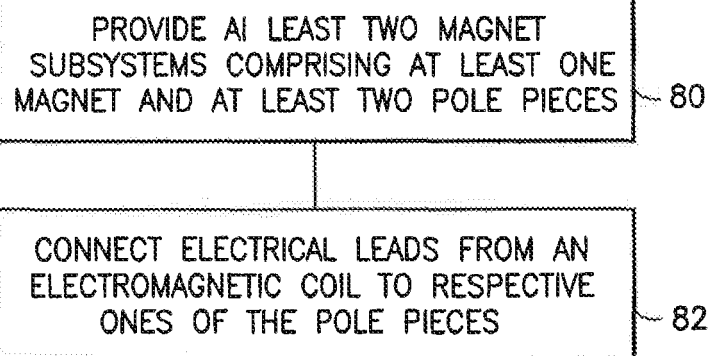


FIG.12

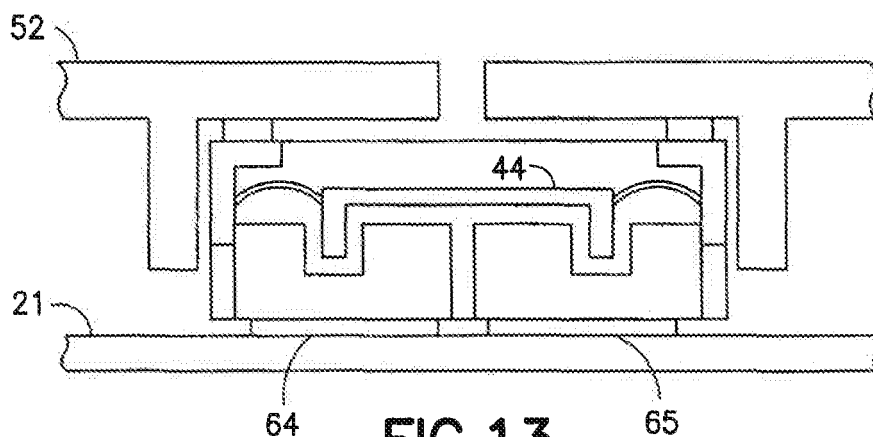


FIG.13

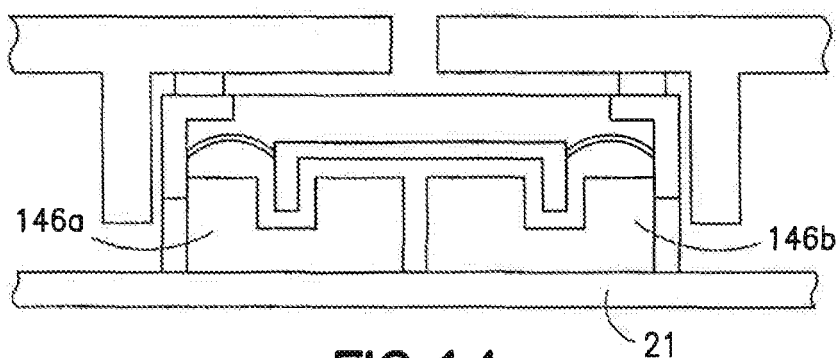
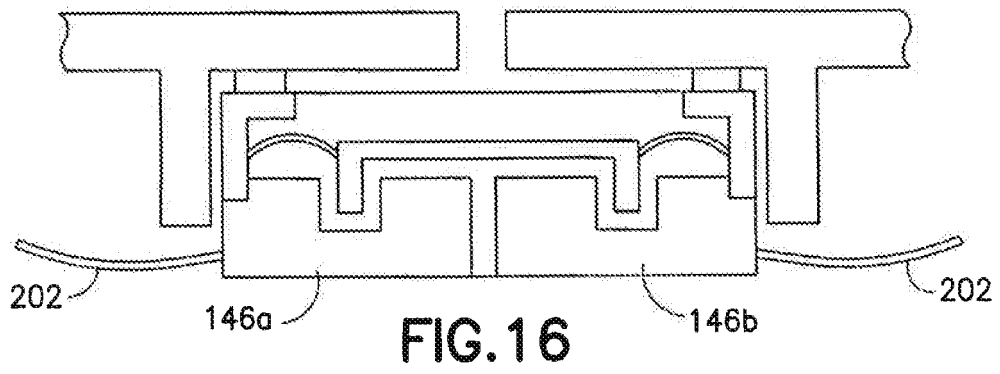
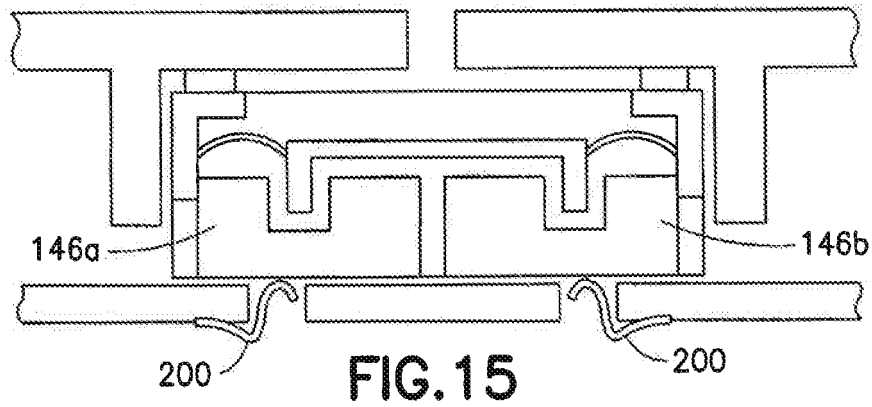
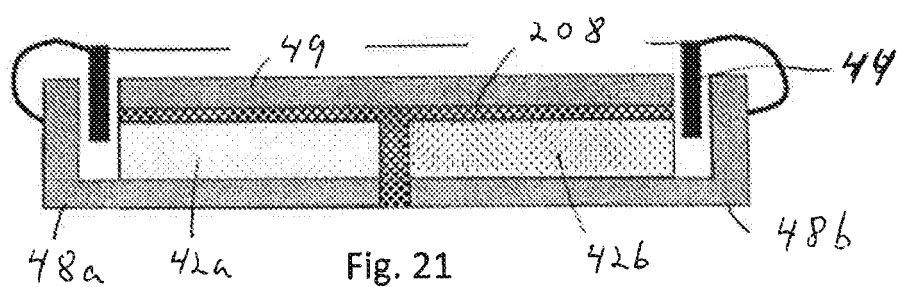
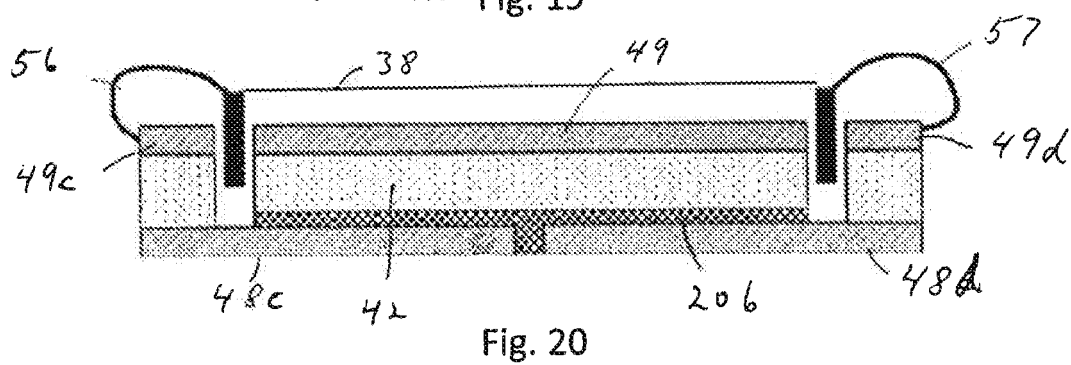
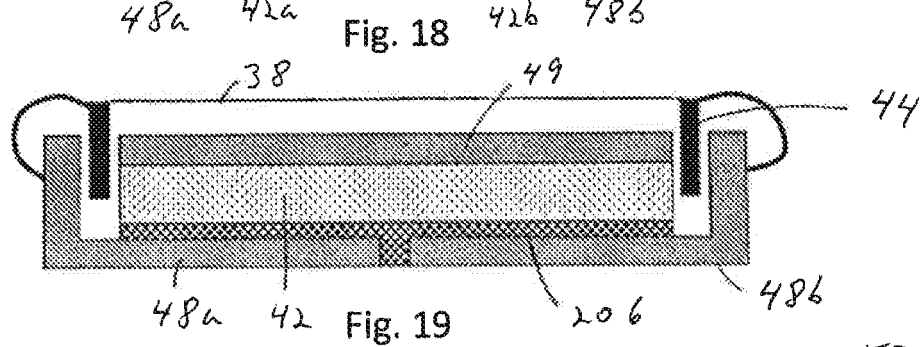
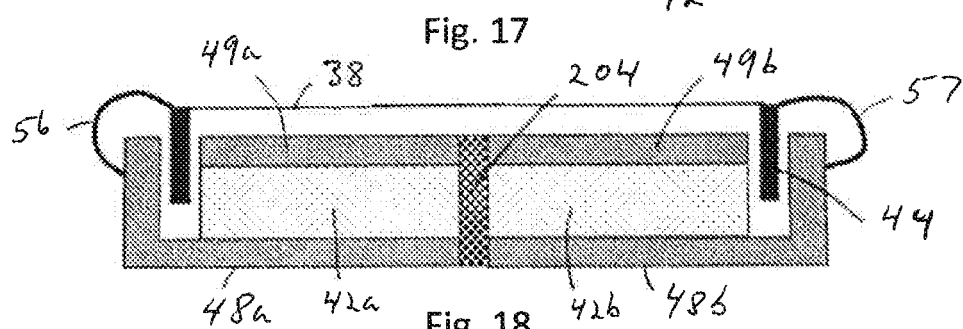
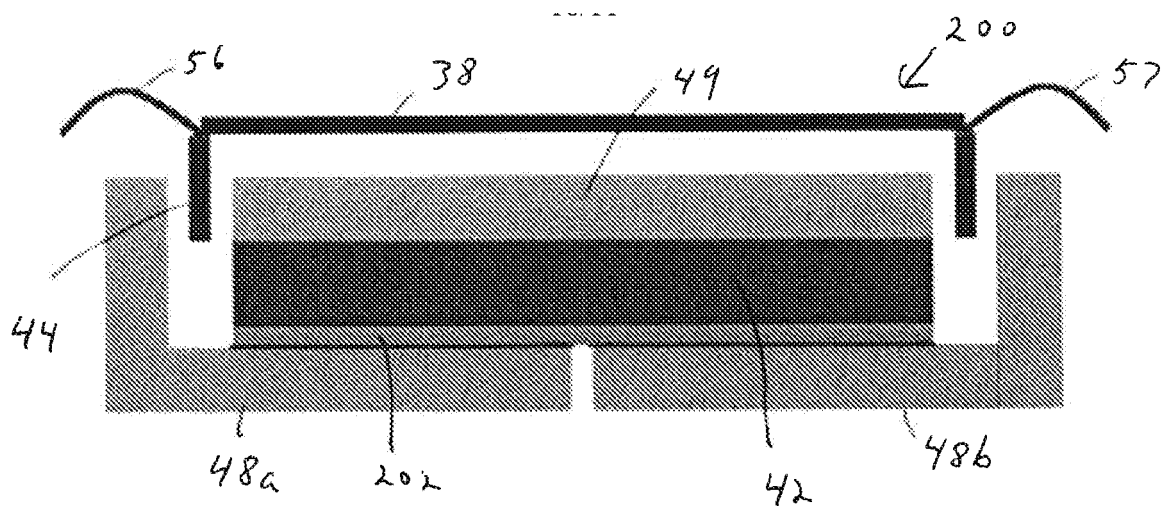


FIG.14





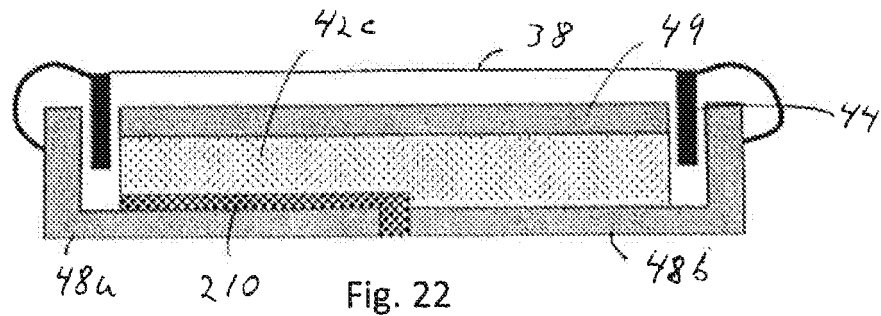


Fig. 22

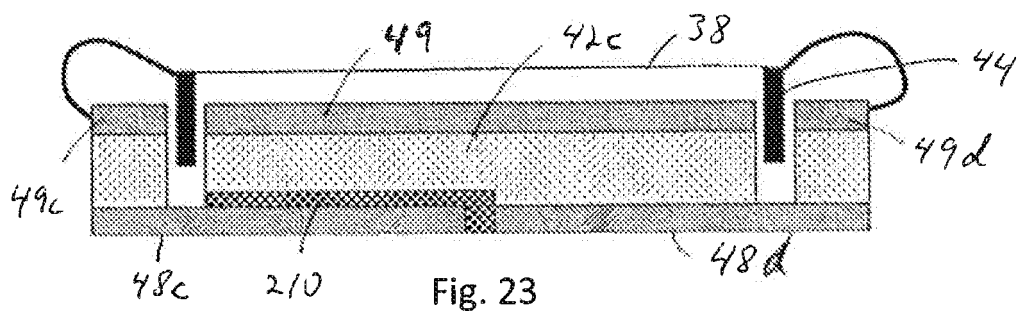


Fig. 23

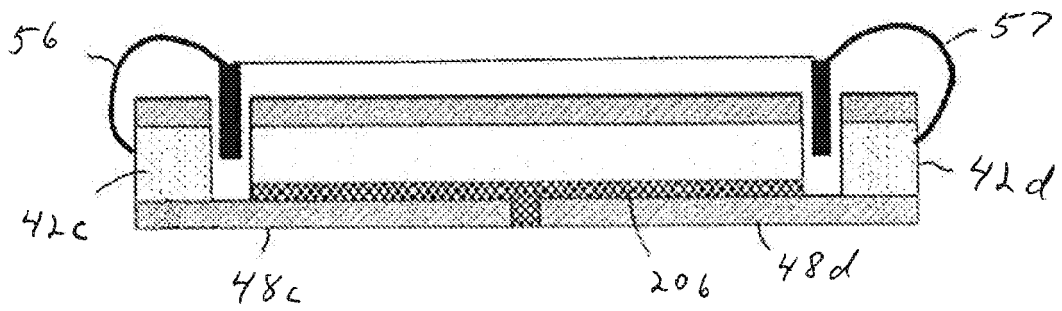


Fig. 24

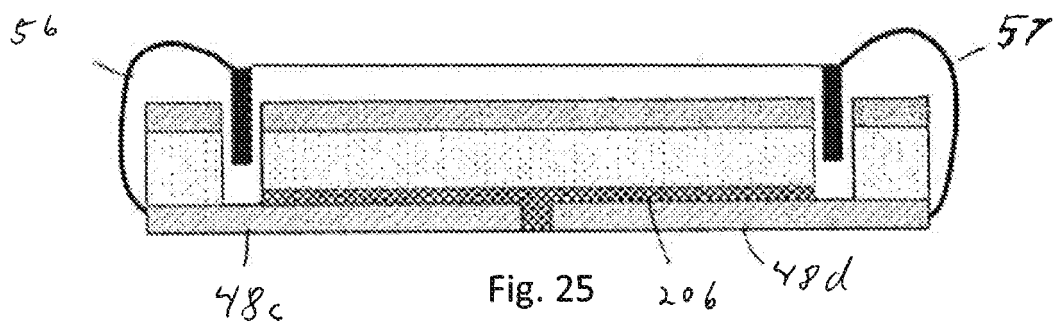


Fig. 25

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- EP 0821540 A [0003]
- WO 2008051009 A [0004]