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# MINIATURE SILICON CONDENSER MICROPHONE AND METHOD FOR PRODUCING SAME

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## DESCRIPTION

*159159*

### Technical Field

The present invention relates generally to a housing for a transducer. More particularly, this invention relates to a miniature silicon condenser microphone comprising a housing for shielding a transducer produced on the surface of a silicon die. The silicon die must be packaged to produce a functional microphone of this type.

### Related Application

This Application claims the benefit of Provisional Patent Application Serial No. 60/253,543 filed November 28, 2000.

### Background of the Invention

There have been a number of disclosures related to building microphone elements on the surface of a silicon die. Certain of these disclosures have come in connection with the hearing aid field for the purpose of reducing the size of the hearing aid unit. While these disclosures have reduced the size of the hearing aid, they have not disclosed how to protect the transducer from outside interferences. For instance, transducers of this type are fragile and susceptible to physical damage. Furthermore, they must be protected from light and electromagnetic interferences. Moreover, they require an acoustic pressure reference to function properly. For these reasons, the silicon die must be shielded.

Some shielding practices have been used to house these devices. For instance, insulated metal cans or discs have been provided. Additionally, DIPs and small outline integrated circuit (SOIC) packages have been utilized. However, the drawbacks associated with manufacturing these housings, such as lead time, cost, and tooling, make these options undesirable.

### Summary of the Invention

The present invention is directed to a silicon condenser microphone package which allows acoustic energy to contact a transducer which provides the

necessary pressure reference while at the same time protects transducer from light, electromagnetic interference, and physical damage. A silicon condenser microphone package comprises a transducer, a substrate, and a cover. The substrate has an upper surface with a recess formed therein. The transducer is attached to the upper surface of the substrate and overlaps at least a portion of the recess so that a back volume of the transducer is formed between the transducer and the substrate. The cover is placed over the transducer and includes an aperture adapted for allowing sound waves to reach the silicon condenser transducer.

Other features and advantages of the invention will be apparent from the following specification taken in conjunction with the following drawings.

**Brief Description of the Drawings**

Figure 1 is a cross-sectional view of a first embodiment of a silicon condenser microphone of the present invention;

Figure 2 is a cross-sectional view of a second embodiment of a silicon condenser microphone of the present invention;

Figure 3 is a cross-sectional view of a third embodiment of a silicon condenser microphone of the present invention;

Figure 4 is a cross-sectional view of the third embodiment of the present invention affixed to an end user circuit board;

Figure 5 is a cross-sectional view of the third embodiment of the present invention affixed to an end user circuit board in an alternate fashion; and

Figure 6 is a plan view of a substrate to which a silicon condenser microphone is fixed;

Figure 7 is a longitudinal cross-sectional view of a microphone package of the present invention;

Figure 8 is a lateral cross-sectional view of a microphone package of the present invention;

Figure 9 is a longitudinal cross-sectional view of a microphone package of the present invention;

*Figure 10 is a lateral cross-sectional view of a microphone package of the* present invention;

Figure 11 is a cross-sectional view of a top portion for a microphone package of the present invention;

Figure 12 is a cross-sectional view of a top portion for a microphone package of the present invention;

Figure 13 is a cross-sectional view of a top portion for a microphone package of the present invention;

Figure 24a is a cross-sectional view of a laminated bottom portion of a housing for a microphone package of the present invention;

Figure 14b is a plan view of a layer of the laminated bottom portion of Figure 14a;

Figure 14c is a plan view of a layer of the laminated bottom portion of Figure 14a;

Figure 14d is a plan view of a layer of the laminated bottom portion of Figure 14a;

Figure 15 is a cross-sectional view of a bottom portion for a microphone package of the present invention;

Figure 16 is a cross-sectional view of a bottom portion for a microphone package of the present invention;

Figure 17 is a cross-sectional view of a bottom portion for a microphone package of the present invention;

Figure 18 is a cross-sectional view of a bottom portion for a microphone package of the present invention;

Figure 19 is a plan view of a side portion for a microphone package of the present invention;

Figure 20 is a cross-sectional view of a side portion for a microphone package of the present invention;

Figure 21 is a cross-sectional view of a side portion for a microphone package of the present invention;

Figure 22 is a cross-sectional view of a side portion for a microphone package of the present invention;

Figure 23 is a cross-sectional view of a microphone package of the present invention;

Figure 24 is a cross-sectional view of a microphone package of the present invention;

Figure 25 is a cross-sectional view of a microphone package of the present invention;

Figure 26 is a cross-sectional view of a microphone package of the present invention;

Figure 27 is a cross-sectional view of a microphone package of the present invention with a retaining ring;

Figure 28 is a cross-sectional view of a microphone package of the present invention with a retaining wing; and

Figure 29 is a cross-sectional view of a microphone package of the present invention with a retaining ring.

**Detailed Description of the Preferred Embodiments**

While this invention is susceptible of embodiments in many different forms, there is shown in the drawings and will herein be described in detail preferred embodiments of the invention with the understanding that the present disclosure is to be considered as an exemplification of the principles of the invention and is not intended to limit the broad aspect of the invention to the embodiments illustrated.

The present invention is directed to microphone packages. The benefits of the microphone packages disclosed herein over microphone packaging utilizing plastic body/lead frames include the ability to process packages in panel form allowing more units to be formed per operation and at much lower cost. The typical lead frame for a similarly functioning package would contain between 40 and 100 devices connected together. The present disclosure would have approximately 14,000 devices connected together (as a panel). Also, the embodiments disclosed herein

require minimal "hard-tooling." This allows the process to adjust to custom layout requirements without having to redesign mold, lead frame, and trim/form tooling.

Moreover, these embodiments have a better match of thermal coefficients of expansion with the end user's PCB since this part would typically be mounted of FR-4 which is the same material used by end users. The present designs may also eliminate the need for wire bonding that is required in plastic body/lead frame packages. The foot print is typically smaller than that would be required for a plastic body/lead frame design since the leads are formed by plating a through-hole in a circuit board of which one half will eventually form the pathway to the solder pad. In a typical plastic body/lead frame design, a gull wing configuration would be used in which the leads widen the overall foot print.

Now, referring to Figures 1-3, three embodiments of a silicon condenser microphone package 10 of the present invention are illustrated. The silicon microphone package 10 of the present invention generally comprises a transducer 12, e.g. a silicon condenser microphone as disclosed in U.S. Patent No. 5,870,482 which is hereby incorporated by reference, a substrate 14, an amplifier 16, a back volume or air cavity 18 which provides a pressure reference for the transducer 12, and a cover 20. The substrate 14 is typically formed of FR-4 material which may be processed in circuit board panel form, thus taking advantage of economies of scale in manufacturing. Figure 6 is a plan view of the substrate 14 showing the back volume 18 surrounded a plurality of terminal pads.

The back volume 18 may be formed by a number of methods, including controlled depth drilling of an upper surface 19 of the substrate 14 to form a recess over which the silicon condenser microphone is mounted (Figure 1); drilling and routing of several individual sheets of FR-4 and laminating the individual sheets to form the back volume 18 which may or may not have internal support posts (Figure 2); or drilling completely through the substrate 14 and providing a sealing ring 22 on the bottom of the device that will seal the back volume 18 during surface mounting to a user's "board" 28 (Figures 3-5). In this example, the combination of the substrate and the user's board 28 creates the back volume 18. The back volume 18 is covered

by the transducer 12 (MEMS device) which is "bumpbonded" and mounted face down. The boundary is sealed such that the back volume 18 is "air-tight".

The cover 20 is attached for protection and processibility. The cover 20 contains an aperture 24 which may contain a sintered metal insert 26 to prevent water, particles and/or light from entering the package and damaging the internal components inside; i.e. semiconductor chips. The aperture 24 is adapted for allowing sound waves to reach the transducer 12.

Referring to Figures 4 and 5, the final form of the product (shown without the cover 20) is a silicon condenser microphone package 10 which would most likely be attached to a end user's PCB 28 via a solder reflow process. Figure 5 illustrates a method of enlarging the back volume 18 by including a chamber 32 within the end user's circuit board 28.

Another embodiment of a silicon condenser microphone package 40 of the present invention is illustrated in Figures 7-10. In this embodiment, a housing 42 is formed from layers of materials, such as those used in providing circuit boards. Accordingly, the housing 42 generally comprises alternating layers of conductive and non-conductive materials 44, 46. The non-conductive layers 46 are typically FR-4 board. The conductive layers 44 are typically copper.

In the embodiment illustrated, the housing 42 includes a top portion 48 and a bottom portion 50 spaced by a side portion 52. The housing 42 further includes an aperture or acoustic port 54 for receiving an acoustic signal and an inner chamber 56 which is adapted for housing a transducer unit 58, typically a silicon die microphone or a ball grid array package (BGA). The top, bottom, and side portions 48, 50, 52 are electrically connected, for example with a conductive adhesive 60. Each portion may comprise alternating conductive and non-conductive layers of 44, 46.

The chamber 56 includes an inner lining 61. The inner lining 61 is primarily formed by conductive material. It should be understood that the inner lining may include portions of non-conductive material, as the conductive material may not fully cover the non-conductive material. The inner lining 61 protects the transducer 58 against electromagnetic interference and the like, much like a faraday cage.

In the various embodiments illustrated in Figures 7-10 and 23-26, the portions of the housing 42 that include the aperture or acoustic port 54 further include a layer of material that forms an environmental barrier 62 over or within the aperture 54. This environmental barrier 62 is typically a polymeric material formed to a film, such as a polytetrafluoroethylene (PTFE) or a sintered metal. The environmental barrier 62 is supplied for protecting the chamber 56 of the housing 42, and, consequently, the transducer unit 58 within the housing 42, from environmental elements such as sunlight, moisture, oil, dirt, and/or dust.

The environmental barrier layer 62 is generally sealed between two layers of conductive material 44. When the environmental barrier layer 62 is sandwiched between two layers of conductive material 44, it may act as a capacitor (with electrodes defined by the metal) that can be used to filter input and output signals or the input power. The environmental barrier layer 62 may further serve as a dielectric protective layer when in contact with the conductive layers 44 in the event that the conductive layers also contain thin film passive devices such as resistors and capacitors.

In addition to protecting the chamber 56 from environmental elements, the barrier layer 62 allows subsequent wet processing, board washing of the external portions of the housing 42, and electrical connection to ground from the walls via thru hole plating. The environmental barrier layer 62 also allows the order of manufacturing steps in the fabrication of the printed circuit board-based package to be modified. This advantage can be used to accommodate different termination styles. For example, a double sided package can be fabricated having a pair of apertures 54 (see Figure 25), both including an environmental barrier layer 62. The package would look and act the same whether it is mounted face up or face down, or the package could be mounted to provide directional microphone characteristics.

Referring to Figures 7, 8, and 11-13, the transducer unit 58 is generally not mounted to the top portion 48 of the housing. This definition is independent of the final mounting orientation to an end user's circuit board. It is possible for the top portion 48 to be mounted face down depending on the orientation of the transducer

58 as well as the choice for the bottom portion 50. The conductive layers 44 of the top portion 48 may be patterned to form circuitry, ground planes, solder pads, ground pads, and plated through hole pads. Referring to Figures 11-13, there may be additional alternating conductive layers 44, non-conductive layers 46, and environmental protective membranes 62 as the package requires. Alternatively, some layers may be deliberately excluded as well. The first non-conductive layer 46 may be patterned so as to selectively expose certain features on the first conductive layer 44.

Figure 11 illustrates an alternative top portion 48 for a microphone package. In this embodiment, a connection between the layers can be formed to provide a conduit to ground. The top portion of Figure 11 includes ground planes and/or pattern circuitry 64 and the environmental barrier 62. The ground planes and or pattern circuitry 64 are connected by pins 65.

Figure 12 illustrates another embodiment of a top portion 48. In addition to the connection between layers, ground planes/pattern circuitry 64, and the environmental barrier 62, this embodiment includes conductive bumps 66 (e.g. Pb/Sn or Ni/Au) patterned on the bottom side to allow secondary electrical contact to the transducer 58. Here, conductive circuitry would be patterned such that electrical connection between the bumps 66 and a plated through hole termination is made.

Figure 13 illustrates yet another embodiment of the top portion 48. In this embodiment, the top portion 48 does not include an aperture or acoustic port 54.

Referring to Figures 7, 8 and 14-18, the bottom portion 50 is the component of the package to which the transducer 58 is primarily mounted. This definition is independent of the final mounting orientation to the end user's circuit board. It is possible for the bottom portion 50 to be mounted facing upwardly depending on the mounting orientation of the transducer 58 as well as the choice for the top portion 48 construction. Like the top portion 48, the conductive layers 44 of the bottom portion 50 may be patterned to form circuitry, ground planes, solder pads, ground pads and plated through hole pads. As shown in Figures 14-18, there may be additional alternating conductive layers 44, non-conductive layers 46, and

environmental protective membranes 62 as the package requires. Alternatively, some layers may be deliberately excluded as well. The first non-conductive layer 46 may be patterned so as to selectively expose certain features on the first conductive layer 44.

Referring to Figures 14a through 14d, the bottom portion 50 comprises a laminated, multi-layered board including layers of conductive material 44 deposited on layers of non-conductive material 46. Referring to Figure 14b, the first layer of conductive material is used to attach wire bonds or flip chip bonds. This layer includes etched portions to define lead pads, bond pads, and ground pads. The pads would have holes drilled through them to allow the formation of plated through-holes.

As shown in Figure 14c, a dry film 68 of non-conductive material covers the conductive material. This illustration shows the exposed bonding pads as well as an exposed ground pad. The exposed ground pad would come in electrical contact with the conductive epoxy and form the conenction to ground of the side portion 52 and the base portion 50.

Referring to Figure 14d, ground layers can be embedded within the base portion 50. The hatched area represents a typical ground plane 64. The ground planes do not overlap the power or output pads, but will overlap the transducer 58.

Referring to Figure 15, an embodiment of the bottom portion 50 is illustrated. The bottom portion 50 of this embodiment includes a solder mask layer 68 and alternating layers of conductive and non-conductive material 44, 46. The bottom portion further comprises solder pads 70 for electrical connection to an end user's board.

Figures 16 and 17 illustrate embodiments of the bottom portion 50 with enlarged back volumes 18. These embodiments illustrate formation of the back volume 18 using the conductive/non-conductive layering.

Figure 18 shows yet another embodiment of the bottom portion 50. In this embodiment, the back portion 50 includes the acoustic port 54 and the environmental barrier 62.

Referring to Figure 7-10 and 19-22, the side portion 52 is the component of the package that joins the bottom portion 50 and the top portion 48. The side portion 51 may include a single layer of a non-conductive material 46 sandwiched between two layers of conductive material 44. The side portion 48 forms the internal height of the chamber 56 that houses the transducer 58. The side portion 52 is generally formed by one or more layers of circuit board material, each having a routed window 72 (see Figure 18).

Referring to Figures 19-22, the side portion 52 includes inner sidewalls 74. The inner side walls 74 are generally plated with a conductive material, typically copper, as shown in Figures 20 and 21. The sidewalls 74 are formed by the outer perimeter of the routed window 72 and coated/metallized with a conductive material.

Alternatively, the sidewalls 74 may be formed by many alternating layers of non-conductive material 46 and conductive material 44, each having a routed window 72 (see Figure 19). In this case, the outer perimeter of the window 72 may not require coverage with a conductive material because the layers of conductive material 44 would provide effective shielding.

Figures 23-26 illustrate various embodiments of the microphone package 40. These embodiments utilize top, bottom, and side portions 48, 50, and 52 which are described above. It is contemplated that each of the top, bottom, and side portion 48, 50, 52 embodiments described above can be utilized in any combination without departing from the invention disclosed and described herein.

In Figure 23, connection to an end user's board is made through the bottom portion 50. The package mounting orientation is bottom portion 50 down Connection from the transducer 58 to the plated through holes is be made by wire bonding. The transducer back volume 18 is formed by the back hole (mounted down) of the silicon microphone only. Bond pads, wire bonds and traces to the terminals are not shown. A person ordinary skilled in the art of PCB design will understand that the traces reside on the first conductor layer 44. The wire bonds from the transducer 58 are be connected to exposed pads. The pads are connected to the solder pads via plated through holes and traces on the surface.

In Figure 24, connection to the end user's board is also made through the bottom portion 50. Again, the package mounting orientation is bottom portion 50 Connection from the transducer 58 to the plated through holes are made by wire bonding. The back volume 18 is formed by a combination of the back hole of the transducer 58 (mounted down) and the bottom portion 50.

In Figure 25, connection to the end user's board is also made through the bottom portion 50. Again, the package mounting orientation is bottom portion 50 Connection from the transducer 58 to the plated through holes are made by wire bonding. With acoustic ports 54 on both sides of the package, there is no back volume, This method is suitable to a directional microphone.

In Figure 26, connection to the end user's board is made through the top portion 48 of the bottom portion 50. The package mounting orientation is either top portion 48 down or bottom portion 50 down. Connection from the transducer 58 to the plated through holes is made by flip chipping and trace routing. The back volume 18 is formed by using the air cavity created by laminating the bottom portion 50 and the top portion 48 together. Some portion of the package fabrication is performed after the transducer 58 has been attached. In particular, the through hole formation, plating, and solder pad definition would be done after the transducer 58 is attached. The protective membrane 62 is hydrophobic and prevent corrosive plating chemistry from entering the chamber 56.

Referring to Figures 27-29, the portion to which the transducer unit 58 is mounted may include a retaining ring 84. The retaining ring 84 prevents wicking of an epoxy 86 into the transducer 58 and from flowing into the acoustic port or aperture 54. Accordingly, the shape of the retaining ring 84 will typically match the shape of the transducer 58 foot print. The retaining ring 84 comprises a conductive material (e.g., 3 mil. thick copper) imaged on a non-conductive layer material.

Referring to Figure 27, the retaining ring 84 is imaged onto a non-conductive layer. An epoxy is applied outside the perimeter of the retaining ring 84, and the transducer 58 is added so that it overlaps the epoxy 86 and the retaining ring

84. This reduces epoxy 86 wicking up the sides of the transducer's 58 etched port (in the case of a silicon die microphone).

Alternatively, referring to Figure 28, the retaining ring 84 can be located so that the transducer 58 does not contact the retaining ring 84. In this embodiment, the retaining ring 84 is slightly smaller than the foot print of the transducer 58 so that the epoxy 86 has a restricted path and is, thus, less likely to wick. In Figure 29, the retaining ring 84 is fabricated so that it contacts the etched port of the transducer 58.

The following tables provide an illustrative example of a typical circuit board processing technique for fabrication of the housing of this embodiment.

Table 1: Materials

| Material | Type | Component | Note |
|---|---|---|---|
| 1 | 0.5/0.5 oz. DST Cu 5 core FR-4 | Bottom Portion (Conductive Layers 1 and 2; Non-Conductive Layer 1) | |
| 2 | 0.5/0.5 oz. DST Cu 5 core FR-4 | Bottom Portion (Conductive Layers 3 and 4; Non-Conductive Layer 2) | |
| 3 | 106 pre-preg | | For Laminating Material 1 and Material 2 |
| 4 | 0.5/0.5 oz. DST Cu 40 Core FR-4 | Side Portion | Metallized Afterward |
| 5 | Bare/0.5 oz Cu 2 core FR-4 (2 pieces) | Top Portion (Each Piece Includes 1 Conductive and 1 Non-Conductive Layer) | |
| 6 | Expanded PTFE | Environmental Barrier | |

Table 2: Processing of Materials (Base Portion Material 1)

| Step | Type | Description | Note |
|---|---|---|---|
| 1 | Dry Film Conductive Layers | | |
| 2 | Expose | Mask Material 1 (Lower Conductive Layer) | Forms Ground Plane on Lower Conductive Layer |
| 3 | Develop | | |
| 4 | Etch Cu | | No Etching on Upper Conductive Layer |
| 5 | Strip Dry Film | | |

Table 3: Processing of Materials (Bottom Portion Material 2)

| Step | Type | Description | Note |
|---|---|---|---|
| 1 | Dry Film Conductive Layers | | |
| 2 | Expose | Mask Material 2 (Upper Conductive Layer) | Forms Ground Plane on Upper Conductive Layer |
| 3 | Develop | | |
| 4 | Etch Cu | | No Etching on Lower Conductive Layer |
| 5 | Strip Dry Film | | |

Table 4: Processing of Materials 1, 2, and 3 (Form Bottom Portion)

| Step | Type | Description | Note |
|---|---|---|---|
| 1 | Laminate | Materials 1 and 2 Laminated Using Material 3 | |
| 2 | Drill Thru Holes | Drill Bit = 0.025 in. | |
| 3 | Direct Metallization/Flash Copper | Plates Thru Holes | |
| 4 | Dry Film (L1 and L4) | | |
| 5 | Expose | Mask Laminated Materials 1 and 2 (Upper and Lower Conductive Layers) | Forms Traces and Solder Pads |
| 6 | Develop | | |
| 7 | Electrolytic Cu | 1.0 mil | |
| 8 | Electrolytic Sn | As Required | |
| 9 | Strip Dry Film | | |
| 10 | Etch Cu | | |
| 11 | Etch Sn | | |
| 12 | Insert Finishing Option Here | NG Option (See Table Below) | NG Option for Proof of Principle |
| 13 | Dry Film (cover lay) on Upper Conductive Layer Only | 2.5 mil | Minimum Thickness on Upper Conductive Layer |

| | | | |
|---|---|---|---|
| 14 | Expose | Mask Laminated Materials 1 and 2 (upper and lower) | This mask defines an area on the upper conductive layer that will receive a dry film solder mask (cover lay). The bottom layer will not have dry film applied to it. The plated through holes will be bridged over by the coating on the top. |
| 15 | Develop | | |
| 16 | Cure | | Full Cure |
| 17 | Route Panels | Route Bit = As Required | Forms 4" x 4" pieces. Conforms to finished dims |

Table 5 describes the formation of the side portion 52. This process involves routing a matrix of openings in FR-4 board. However, punching is thought to be the cost effective method for manufacturing. The punching may done by punching through the entire core, or, alternatively, punching several layers of no-flow pre-preg and thin core c-stage which are then laminated to form the wall of proper thickness.

After routing the matrix, the board will have to be electroless or DM plated. Finally, the boards will have to be routed to match the bottom portion. This step can be done first or last. It may make the piece more workable to perform the final routing as a first step.

Table 5: Processing of Material 4 (Side Portion)

| Step | Type | Description | Note |
|---|---|---|---|
| 1 | Route/Punch Matric of Openings | Route Bit = 0.031 in. | Forms Side Portion |
| 2 | Direct Metallization/ Flash Cu | 0.25 mil minimum | Forms Sidewalls on Side Portion |
| 3 | Route Panels | | |

Table 6 describes the processing of the top portion. The formation of the top portion 48 involves imaging a dry film cover lay or liquid solder mask on the bottom (i.e. conductive layer forming the inner layer. The exposed layer of the top portion 48 will not have a copper coating. It can be processed this way through etching or purchased this way as a one sided laminate.

A matrix of holes is drilled into the lid board. Drilling may occur after the imaging step. If so, then a suitable solder mask must be chosen that can survive the drilling process.

Table 6: Processing of Top Portion

| Step | Type | Description | Note |
|---|---|---|---|
| 1 | Dry Film | Conductive Layer | |
| 2 | Expose | Mask Bare Layer | Form Conduction Ring |
| 3 | Develop | | |
| 4 | Cure | | |
| 5 | Drill Matrix of Holes | Drill Bit = 0.025 in. | Acoustic Ports |
| 6 | Laminate | PTFE (Environmental Barrier) Between 2 Pieces of Material 5 | Forms Top Portion |

Table 7: Processing of Laminated Materials 1 and 2 with Material 4

| Step | Type | Description | Note |
|---|---|---|---|
| 1 | Screen Conductive Adhesive on Material 4 | | |
| 2 | Laminate | Bottom Portion with Side Portion | Forms Bottom Portion with Side Portion (spacer) |
| 3 | Add Transducer Assembly | Silicon Die Microphone and Integrated Circuit | |

Table 8: Processing of Laminated Materials 1, 2, and 4 with Material 5

| Step | Type | Description | Note |
|---|---|---|---|
| 1 | Screen Conductive Adhesive on Top Portion | | |
| 2 | Laminate | Bottom Portion and Side Portion with Top Portion | Forms Housing |
| 3 | Dice | | |

Table 9: Finishing Option NG (Nickel/Gold)

| Step | Type | Description | Note |
|---|---|---|---|
| 1 | Immersion Ni (40-50 $\mu$-in) | | |
| 2 | Immersion Au (25-30 $\mu$-in) | | |

Table 10: Finishing Option NGT (Nickel/Gold/Tin)

| Step | Type |
|---|---|
| 1 | Mask L2 (using thick dry film or high tack dicing tape) |
| 2 | Immersion Ni (40-50 $\mu$-in) |
| 3 | Immersion Au (25-30 $\mu$-in) |
| 4 | Remove Mask on L2 |
| 5 | Mask L1 (using thick dry film or high tack dicing tape) bridge over cavity created by wall |
| 6 | Immersion Sn (100-250 $\mu$-in) |
| 7 | Remove Mask on L1 |

Table 11: Finishing Option ST (Silver/Tin)

| Step | Type |
|---|---|
| 1 | Mask L2 (using thick dry film or high tack dicing tape) |
| 2 | Immersion Ag (40-50 $\mu$-in) |
| 3 | Remove Mask on L2 |
| 4 | Mask L1 (using thick dry film or high tack dicing tape) bridge over cavity created by wall |
| 5 | Immersion Sn (100-250 $\mu$-in) |
| 6 | Remove Mask on L1 |

While specific embodiments have been illustrated and described, numerous modifications come to mind without significantly departing from the spirit of the invention, and the scope of protection is only limited by the scope of the accompanying Claims.

## CLAIMS

I claim:

1. A microphone package comprising:

a printed circuit board comprising a plurality of layers, at least one layer comprising a conductive material and at least one layer comprising an insulating material;

a cover comprising a conductive layer, the printed circuit board and the cover forming at least a portion of a housing, the housing comprising an aperture for receiving a signal and an inner lining for providing a shield against an electromagnetic interference, the inner lining comprising the conductive layer and the at least one layer of a conductive material; and

a transducer unit mounted within the housing.

2. The microphone package of Claim 1 further comprising a spacer member between the printed circuit board and the cover, the spacer member cooperating with the printed circuit board and the cover to form the housing, the spacer member comprising a sidewall at least partially covered by a conductive material, the conductive material providing a portion of the inner lining.

3. The microphone package of Claim 2 further comprising a first layer of conductive adhesive for joining the spacer member to the cover.

4. The microphone package of Claim 3 further comprising a second layer of conductive adhesive for joining the spacer member to the circuit board.

5. The microphone package of Claim 1 further comprising a environmental barrier located within the aperture.

6. The microphone package of Claim 5 wherein the aperture is within the cover, the cover comprising a nonconductive layer for providing the environmental barrier.

7. The microphone package of Claim 5 wherein the aperture is located within the cover, the cover comprising a polymeric layer for providing the environmental barrier.

8. The microphone package of Claim 5 wherein the aperture is located within the printed circuit board, the printed circuit board comprising a polymeric layer for providing the environmental barrier.

9. The microphone package of Claim 5 wherein the environmental barrier comprises a polymeric material.

10. The microphone package of Claim 9 wherein the polymeric material is a film.

11. The microphone package of Claim 10 wherein the film comprises a polytetrafluoroethylene.

12. The microphone package of Claim 1 wherein the conductive material comprises copper.

13. The microphone package of Claim 1 wherein the printed circuit board comprises a plurality of layers of a conductive material and a plurality of layers of an insulating material.

14. The microphone package of Claim 13 wherein one of the plurality of layers of a conductive material comprises a pair of lead pads for electrical connection to the transducer unit.

15. The microphone package of Claim 14 wherein one of the plurality of layers of a conductive material provides a first electrical ground plane.

16. The microphone package of Claim 15 wherein one of the plurality of layers of a conductive material provides a second electrical ground plane.

17. The microphone package of Claim 16 wherein the first and second ground planes are electrically connected to the pair of lead pads.

18. The microphone package of Claim 17 wherein one of the plurality of layers of a conductive material comprises a pair of connectors for electrical connection to an external device.

19. A microphone package comprising:

a transducer unit; and

a housing substantially covering the transducer unit and providing protection against an electromagnetic interference, the housing comprising a first layer of a non-conductive material and a second layer of a conductive material substantially covering the first layer, the second layer substantially forming an inner lining of the housing, the housing further comprising an aperture for receiving a signal into the housing.

20. The microphone package of Claim 19 further comprising a third layer of a non-conductive material, the third layer substantially covering the aperture for providing an environmental barrier.

21. The microphone package of Claim 20 wherein the third layer comprises a polymeric material.

22. The microphone package of Claim 21 wherein the polymeric material is a polytetrafluoroethylene.

23. The microphone package of Claim 19 further comprising a retaining ring, the transducer unit engaging the retaining ring.

24. A silicon condenser microphone package comprising:

a transducer unit;

a substrate including an upper surface having a recess formed therein, the transducer unit attached to the upper surface of the substrate overlapping at least a portion of the recess wherein a back volume of the transducer unit is formed between the transducer unit and the substrate; and

a cover placed over the transducer unit, the cover including an aperture.

25. A silicon condenser microphone package comprising:

a transducer unit;

a substrate including an upper surface for supporting the transducer unit;

a cover placed over a portion of the substrate, the cover comprising an aperture and an inner surface, a portion of the inner surface comprising a metallic material for shielding the transducer unit from an interference signal.

26. A microphone package comprising:

a transducer unit;

a substrate including an upper surface for supporting the transducer unit;

a cover sealed over a portion of the substrate, the cover having an aperture for receiving a signal and an inner surface comprising a shielding material for protecting the transducer from an interference signal.

27. A microphone package comprising:

a transducer unit;

a substrate comprising a layer of an insulating material and a layer of conductive material, the substrate further comprising a surface for supporting the transducer unit;

a cover placed over a portion of the substrate; the cover comprising a shielding material for protecting the transducer from an interference signal.

28. A microphone package comprising:

a printed circuit board comprising a first insulating layer and a first conductive layer;

a transducer unit supported by the printed circuit board; and

a cover over a portion of the printed circuit board and forming a housing therewith for protecting the transducer unit, the cover comprising an aperture, a second insulating layer, and a second conductive layer, a portion of the second conductive layer exposed to the transducer for shielding the transducer from an interference signal.

29. A microphone package comprising:

a printed circuit board comprising a first insulating layer, a first conductive layer, and an aperture;

a transducer unit; and

a cover over a portion of the printed circuit board and forming a housing therewith for protecting the transducer unit, the cover comprising a second insulating layer and a second conductive layer, a portion of the second conductive layer exposed to the transducer for shielding the transducer from an interference signal.

30. A microphone housing for a silicon condenser microphone, the microphone housing comprising:

an inner lining for providing a shield from an electromagnetic interference, the inner lining comprising an aperture adapted for receiving a signal;

a printed circuit board comprising a first insulating layer and a first conductive layer, the first conductive layer forming at least a portion of the inner lining; and

a cover comprising a second conductive layer forming at least a portion of the inner lining.

31. A method of producing a microphone package, the method including the steps of:

providing a housing comprising a first layer of a non-conductive material, an inner lining comprising a conductive material substantially covering the non-conductive material, and an aperture for receiving an acoustic signal;

providing a transducer unit; and

mounting the transducer within the housing wherein the inner lining provides an electromagnetic interference protection to the transducer unit.

32. The method of Claim 31 further comprising the steps of:

providing an environmental barrier layer comprising a polymeric material filter; and

securing the environmental barrier layer to housing and over the aperture wherein the environmental barrier layer provides a protection from environmental conditions to the transducer while allowing a substantial portion of the acoustic signal to pass through the aperture.

33. The method of Claim 32 further comprising the step of providing second layer of a conductive material between the first layer and the environmental barrier layer.

34. The method of Claim 33 further comprising the steps of:

providing a third layer of a conductive material; and

attaching the third layer to the environmental barrier layer wherein the environmental barrier layer is between the second layer and the third layer.

35. The method of Claim 34 further comprising the steps of:

providing a fourth layer of a non-conductive material; and

depositing the fourth layer on the third layer.

36. The method of Claim 35 further comprising the steps of:

providing a fifth layer of a conductive material; and

depositing the fifth layer on the fourth layer.

37. The method of Claim 36 wherein the housing further comprises a cover, the cover comprising an outer layer of non-conductive material and inner layer of a conductive material substantially covering the outer layer and providing at least a portion of the inner lining.

38. The method of Claim 37 wherein the cover further comprises an external layer of a conductive material secured to the outer layer and forming a portion of an outer surface of the housing.