(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
29 November 2018 (29.11.2018)

WIPO | PCT

(10) International Publication Number
WO 2018/218073 A1

(51) International Patent Classification:
H04R 1/04 (2006.01) *B81B 7/00* (2006.01)
H01L 23/28 (2006.01)

(21) International Application Number:
PCT/US2018/034475

(22) International Filing Date:
24 May 2018 (24.05.2018)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
62/511,221 25 May 2017 (25.05.2017) US

(71) Applicant: **KNOWLES ELECTRONICS, LLC** [US/US]; 1151 Maplewood Drive, Itasca, Illinois 60143 (US).

(72) Inventors: **LIM, Tony K.**; c/o Knowles Electronics, LLC, 1151 Maplewood Drive, Itasca, Illinois 60143 (US). **SZCZECH, John**; c/o Knowles Electronics, LLC, 1151 Maplewood Drive, Itasca, Illinois 60143 (US). **WATSON, Joshua**; c/o Knowles Electronics, LLC, 1151 Maplewood Drive, Itasca, Illinois 60143 (US).

(74) Agent: **BELDEN, Brett P.** et al.; c/o Foley & Lardner LLP, 3000 K Street NW, Suite 600, Washington, District of Columbia 20007 (US).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

WO 2018/218073 A1

(54) Title: MICROPHONE PACKAGE FOR FULLY ENCAPSULATED ASIC AND WIRES

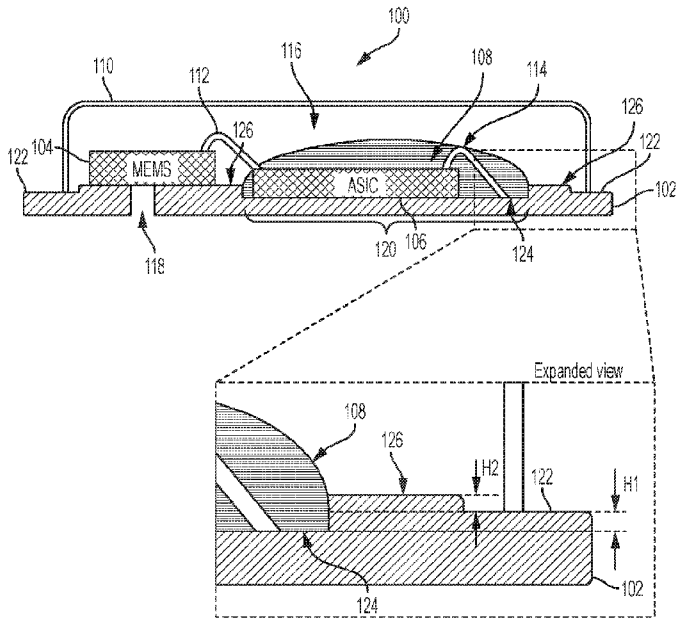


Figure 1

(57) Abstract: A microphone device includes a substrate having a cavity. The device also includes a microelectromechanical systems (MEMS) transducer mounted on the substrate outside of the cavity and an application specific integrated circuit mounted in the cavity. A first set of bonding wires connect the MEMS transducer to the ASIC and a second set of bonding wires connect the ASIC to a conductor within the cavity. An encapsulating material completely covers the ASIC and at least a portion of the second set of wires and is substantially confined within the cavity. A cover is installed over the substrate to cover the MEMS transducer, the encapsulating material, the ASIC, the first set of bonding wires, and the second set of bonding wires.

[Continued on next page]

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

MICROPHONE PACKAGE FOR FULLY ENCAPSULATED ASIC AND WIRES

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of and priority to U.S. Provisional Application No. 62/511,221, filed May 25, 2017, the entire contents of which are incorporated herein by reference.

BACKGROUND

[0002] In a micro electro mechanical system (MEMS) microphone, a MEMS die includes at least one diaphragm and at least one back plate. The MEMS die is supported by a base or substrate and enclosed by a housing (e.g., a cup or cover with walls). A port may extend through the substrate (for a bottom port device) or through the top of the housing (for a top port device). Sound energy traverses through the port, moves the diaphragm, and creates a changing electrical potential of the back plate, which creates an electrical signal. Microphones are deployed in various types of devices such as personal computers or cellular phones.

SUMMARY

[0003] In an embodiment, a microphone device includes a substrate having a first surface and having a cavity formed in the first surface. The device also includes a microelectromechanical systems (MEMS) transducer mounted on the substrate outside the cavity and an application specific integrated circuit (ASIC) mounted on the substrate within the cavity. The device also includes a first set of wires electrically connecting the MEMS transducer to the ASIC, and a second set of wires electrically connecting the ASIC to a conductor on the substrate within the cavity. The device further includes an encapsulating material completely covering the ASIC and at least partially covering the second set of wires.

[0004] In one or more embodiments, the encapsulating material completely covers both the ASIC and the second set of wires. In one or more embodiments, the substrate further includes a platform located at a periphery of the cavity, and where the MEMS transducer is mounted on the platform. In one or more embodiments, the platform is raised above the first surface of the substrate. In one or more embodiments, the platform surrounds the entire periphery of the cavity. In one or more embodiments, the platform separates the cavity from a cover mounting surface structured to receive a cover. In one or more embodiments, the MEMS transducer is mounted on the first surface. In one or more embodiments, the encapsulating material includes epoxy. In one or more embodiments, the first set of wires are at least partially covered by the encapsulating material. In one or more embodiments, the substrate defines an opening at a portion of the substrate over which the MEMS transducer is mounted. In one or more embodiment, the substrate includes a wall surrounding the ASIC, and wherein the first surface forms a top surface of the wall.

[0005] In one or more embodiments, the microphone device also includes an electrically conductive heat shield disposed within the encapsulating material that at least partially covers the ASIC. In one or more embodiments, the heat shield is electrically connected to a ground plane disposed on the substrate. In one or more embodiments, the heat shield includes at least one of aluminum, copper, gold, or silver.

[0006] In an embodiment, a method for manufacturing a microphone device includes providing a substrate having a first surface. The method further includes forming a cavity in the first surface of the substrate. The method also includes mounting a microelectromechanical systems (MEMS) transducer on the substrate outside of the cavity. The method additionally includes mounting an application specific integrated circuit (ASIC) on the substrate within the cavity. The method further includes installing a first set of wires electrically connecting the MEMS transducer to the ASIC, and installing a second set of wires electrically connecting the ASIC to a conductor on the substrate within the cavity. The method also includes depositing an encapsulating material into the cavity such that the encapsulating material completely covers the ASIC and at least partially covers the second set of wires.

[0007] In one or more embodiments, depositing the encapsulating material into the cavity includes depositing the encapsulating material into the cavity such that the encapsulating material completely covers both the ASIC and the second set of wires. In one or more embodiments, the method further includes forming a platform on the substrate at a periphery of the cavity, and where mounting the MEMS transducer on the substrate includes mounting the MEMS transducer on the platform. In one or more embodiments, the platform is raised above the first surface of the substrate. In one or more embodiments, forming the platform includes forming the platform to surround the entire periphery of the cavity. In one or more embodiments, forming the platform includes forming the platform such that the platform separates the periphery of the cavity from a cover mounting surface structured to receive a cover. In one or more embodiments, mounting the MEMS transducer includes mounting the MEMS transducer over the first surface of the substrate. In one or more embodiments, depositing the encapsulating material includes depositing the encapsulating material such that the first set of wires are partially covered by the encapsulating material. In one or more embodiments, the method further includes forming a wall on the substrate, the wall surrounding the ASIC, where a top surface of the wall is the first surface of the substrate.

[0008] In one or more embodiments, the encapsulating material is a first layer of encapsulating material, and the method further includes depositing a conductive material over the first layer of encapsulating material, and depositing a second layer of encapsulating material over the conductive material. In one or more embodiments, depositing the conductive material over the first layer of encapsulating material includes depositing at least one of conductive nano-sized metal particles suspended in a solution or an organometallic solution using a jetting or micro-spray over the first layer of encapsulating material.

[0009] In an embodiment, a microphone device includes a substrate having a first surface. The microphone device also includes a wall formed on the first surface, the wall at least partially surrounding a first portion of the first surface. The microphone device further includes a MEMS transducer mounted on the substrate outside the first portion of the first surface, and an ASIC mounted on the substrate and within the first portion of the surface. The microphone device additionally includes a first set of wires connecting the MEMS transducer to the ASIC, and a second set of wires connecting the ASIC to a conductor on the substrate

within the cavity. The microphone device also includes an encapsulating material deposited over the first portion at least partially surrounded by the wall and completely covering the ASIC and at least partially covering the second set of wires.

[0010] In one or more embodiments, a height of the ASIC is greater than a height of the wall. In one or more embodiments, both the wall and the substrate are formed of different materials. In one or more embodiments, the wall and the substrate are formed of different materials. In one or more embodiments, the wall includes a solder mask material.

[0011] In one or more embodiments, the microphone device also includes an electrically conductive heat shield disposed within the encapsulating material that at least partially covers the ASIC. In one or more embodiments, the heat shield is electrically connected to a ground plane disposed on the substrate. In one or more embodiments, the heat shield includes at least one of aluminum, copper, gold, or silver.

[0012] The foregoing summary is illustrative only and is not intended to be in any way limiting. In addition to the illustrative aspects, embodiments, and features described above, further aspects, embodiments, and features will become apparent by reference to the following drawings and the detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] The foregoing and other features of the present disclosure will become more fully apparent from the following description and appended claims, taken in conjunction with the accompanying drawings. Understanding that these drawings depict only several embodiments in accordance with the disclosure and are, therefore, not to be considered limiting of its scope, the disclosure will be described with additional specificity and detail through use of the accompanying drawings.

[0014] Figure 1 is a representation of a cross-sectional view of first example microphone device according to embodiments of the present disclosure.

[0015] Figure 2 depicts a representation of a top view of the first example microphone device shown in Figure 1.

[0016] Figure 3 shows a representation of a cross-sectional view of a second example microphone device according to embodiments of the present disclosure.

[0017] Figure 4 shows a flow diagram of an example process for manufacturing a microphone device according to embodiments of the present disclosure.

[0018] Figures 5 and 6 depict representations of a cross-sectional view and a top view, respectively, of a third example microphone device according to embodiments of the present disclosure.

[0019] Figure 7 shows a flow diagram of an example process for manufacturing a microphone device according to embodiments of the present disclosure.

[0020] Figure 8 shows a representation of a cross-sectional view of a fourth example microphone device according to embodiments of the present disclosure.

[0021] Figure 9 shows a flow diagram of an example process for manufacturing a microphone device according to embodiments of the present disclosure.

[0022] In the following detailed description, reference is made to the accompanying drawings, which form a part hereof. In the drawings, similar symbols typically identify similar components, unless context dictates otherwise. The illustrative embodiments described in the detailed description, drawings, and claims are not meant to be limiting. Other embodiments may be utilized, and other changes may be made, without departing from the spirit or scope of the subject matter presented here. It will be readily understood that the aspects of the present disclosure, as generally described herein, and illustrated in the figures, can be arranged, substituted, combined, and designed in a wide variety of different configurations, all of which are explicitly contemplated and make part of this disclosure.

DETAILED DESCRIPTION

[0023] The present disclosure describes devices and techniques for improving robustness of microphone devices, such as those incorporating microelectromechanical systems (MEMS) transducers. In some embodiments, the devices and techniques described in the present

disclosure reduce the risk of damage to the MEMS transducer via use of an encapsulating material used to cover other components of the microphone device. In some embodiments, the radio frequency response of the MEMS transducer is improved, such as by reducing noise across one or more frequency ranges.

[0024] In one or more embodiments, an encapsulating material is deposited over an application specific integrated circuit and a set of wires such that the encapsulating material completely covers the application specific integrated circuit and/or the set of wires.

[0025] In one or more embodiments, the MEMS transducer is mounted on a raised platform of a substrate that can further isolate the MEMS transducer from the encapsulating material.

[0026] In one or more embodiments, the microphone device can include a heat shield within the encapsulating material that at least partially covers the ASIC and that reflects heat radiation generated by the ASIC.

[0027] Figure 1 is a representation of a cross-sectional view of first example microphone device 100 according to embodiments of the present disclosure. The first example microphone device 100 includes a substrate 102, a microelectromechanical systems (MEMS) transducer 104, an application specific integrated circuit (ASIC) 106, an encapsulating material 108, and a cover 110. The MEMS transducer 104 and the ASIC 106 are disposed on one side of the substrate 102. A first set of wires 112 electrically connect the MEMS transducer 104 to the ASIC 106, while a second set of wires 114 electrically connect the ASIC 106 to conductive traces (not shown) on the substrate 102. The MEMS transducer 104, the ASIC 106, and the substrate 102 can include conductive bounding pads to which ends of the first set of wires 112 and the second set of wires 114 can be bonded. In some embodiments, the first set of wires 112 and the second set of wires 114 can be bonded to the appropriate bonding pads using a solder. The cover 110 can be affixed on the substrate 102 to enclose and protect the MEMS transducer 104, the ASIC 106 and any bonding wires. The cover 110 can include materials such as plastic or metal. The cover 110, the substrate 102, the MEMS transducer 104 and the ASIC 106 define an enclosed back-volume 116, a magnitude of which can be factored into selecting performance parameters of the MEMS transducer 104. In some embodiments, the cover 110 is affixed to the substrate 102, and, in some embodiments, the

enclosed volume is hermetically sealed. The substrate 102 can include a cover bonding surface (discussed below in relation to Figure 2) for bonding the cover 110 onto the substrate 102.

[0028] The MEMS transducer 104 can include a conductive diaphragm positioned in a distance relationship with a conductive back plate. The diaphragm is configured to move in relation with the back plate in response to incident acoustic signals. The movement of the diaphragm in relation to the back plate causes a capacitance associated with the MEMS transducer 104 to vary. The change in the capacitance of the MEMS transducer 104 in response to the acoustic signals can be measured and converted into a corresponding electrical signal.

[0029] The ASIC 106 can include a package that encloses analog and/or digital circuitry for processing electrical signals received from the MEMS transducer 104. In one or more embodiments, the ASIC 106 can be an integrated circuit package having a plurality of pins or bonding pads that facilitate electrical connectivity to components outside of the ASIC 106 via wires. In particular, the ASIC 106 can include bonding pads to which the first set of wires 112 and the second set of wires 114 can be connected. The analog or digital circuitry can include amplifiers, filters, analog-to-digital converters, digital signal processor, and other electrical circuitry for processing the electrical signals received from the MEMS transducer 104 and other components on the substrate 102.

[0030] The substrate 102 can include, without limitation, a printed circuit board, a semiconductor substrate, or a combination thereof. A portion of the substrate 102 adjacent to the MEMS transducer 104 defines a through-hole that forms a port 118 of the first example microphone device 100. Acoustic signals enter the first example microphone device 100 through the port 118, and cause the displacement of the diaphragm on the MEMS transducer 104. The MEMS transducer 104, based on its response characteristics, can generate electrical signals corresponding to the incident audio signals.

[0031] The substrate 102 can define an ASIC cavity 120 in the front surface 122 of the substrate 102. The substrate 102 may extend from a front surface 122 of the substrate 102 to an ASIC mounting surface 124 of the substrate 102. In the illustrated embodiment, the front

surface 122 and the ASIC mounting surface 124 are on separate planes. In some embodiments, the front surface 122 and the ASIC mounting surface 124 may be in the same plane; for example, in some embodiments, the MEMS transducer 104 may be mounted on a raised platform, such as in the manner described in further detail below, and the front surface 122 and the mounting surface 124 may be in the same plane. The ASIC 106 is positioned on the ASIC mounting surface 124 of the ASIC cavity 120. In some embodiments, the ASIC 106 is mounted on the ASIC mounting surface 124 using a binding material such as solder or glue. While not shown in Figure 1, the ASIC mounting surface can include one or more conductive bonding pads to provide a connection between conductive traces on the substrate and the ASIC 106. The second set of wires 114 connect the bonding pads on the ASIC mounting surface 124 to the bonding pads on the ASIC 106. In some embodiments, a height H1 of the ASIC cavity 120 (i.e., a height from the ASIC mounting surface 124 to the front surface 122) can be less than the height of the ASIC 106, such that a portion of the ASIC extends above the cavity.

[0032] The substrate 102 also includes a platform 126 that is raised up above the front surface 122. In the illustrated embodiment, the height H1 of the ASIC cavity 120 is greater than a height H2 by which the platform 126 is raised above the front surface 122. In some embodiments, the height H2 may be greater than or equal to the height H1. The platform 126 can be formed around the perimeter of the ASIC cavity 120. In some embodiments, the platform 126 can form a sidewall of the ASIC cavity 120. In some other embodiments, the platform 126 can be separated from the ASIC cavity 120 by the front surface 122. The MEMS transducer 104 is mounted on a top surface of the platform 126. The port 118, discussed above, extends through the substrate 102 at a position where the MEMS transducer 104 is mounted.

[0033] The encapsulating material 108 completely covers the ASIC 106 and/or the second set of wires 114, and, in some embodiments, completely covers both the ASIC 106 and the second set of wires 114. The encapsulating material 108 can be a non-conductive material such as epoxy. One process stage during the manufacturing of the first example microphone device 100 can include the deposition of the encapsulating material 108 over the ASIC 106. The encapsulating material 108 can be deposited such that it completely covers the ASIC 106

and the second set of wires 114 that extend from the ASIC 106 to the substrate 102. During deposition, the encapsulating material 108 can be in a high temperature and low viscosity state. Over time, the encapsulating material 108 cools and solidifies to form a covering over the ASIC 106 and the second set of wires 114. But during deposition, the low viscosity of the encapsulating material 108 can result in lateral spreading of the encapsulating material. In instances where the ASIC 106 and the MEMS transducer 104 are disposed on the same surface of the substrate 102, the lateral spreading of the encapsulating material 108 may result in the encapsulating material 108 making contact with the MEMS transducer 104. This may damage the MEMS transducer 104. By placing the ASIC 106 and the second set of wires 114 within the ASIC cavity 120, the lateral spreading of the encapsulating material 108, during and after deposition, is confined to within the sidewalls of the ASIC cavity 120. Thus, the MEMS transducer 104, and other components mounted on the substrate 102, can be protected from undesirable contact with the encapsulating material 108.

[0034] After the encapsulating material 108 solidifies, its upper surface can form a curvature that encloses the ASIC 106 and the second set of wires 114. In some embodiments, a height of the encapsulating material 108 can be represented by a greatest distance between a point on a top surface of the encapsulating material 108 and the ASIC mounting surface 124. In some embodiments, the height of the encapsulating material 108 can be equal to or greater than a greatest distance that the second set of wires 114 or the ASIC 106 extend from the ASIC mounting surface 124.

[0035] The platform 126 provides additional protection from the encapsulating material 108. That is, mounting the MEMS transducer 104 on the platform 126 further isolates the MEMS transducer 104 from the encapsulating material 108. In some embodiments, a height of the platform 126 can be based on the volume of encapsulating material 108 that needs to be deposited to completely cover the ASIC 106 and the second set of wires 114, and the available volume within the ASIC cavity 120.

[0036] Figure 2 depicts a representation of a top view of the first example microphone device 100 shown in Figure 1. In particular, the top view is shown without the cover 110. The encapsulating material 108 completely covers the ASIC 106 and the second set of wires 114, which extend from the ASIC 106 to the substrate 102. The platform 126 surrounds the

encapsulating material 108, which, in the illustrated embodiment of Figure 2, is completely covering the ASIC cavity 120 shown in Figure 1. The first set of wires 112, which extend between the MEMS transducer 104 and the ASIC 106 are partially covered by the encapsulating material 108. The front surface 122 of the substrate 102 also includes a cover bonding surface 128, which facilitates bonding the cover 110 with the substrate 102. In the illustrated embodiment, the cover bonding surface 128 is separated from the platform 126 by a portion of the front surface 122 (i.e., such that, front an inner portion of the microphone device 100, the surfaces transition from the platform 126 to an inner portion of the front surface 122, then to the cover bonding surface 128, and finally to an outer portion of the front surface 122). In some embodiments, the cover bonding surface 128 may extend to the edge of the platform 126 with no intervening portion of the front surface 122. In some embodiments, the cover bonding surface 128 can be a metal surface that can bond with a metal periphery of the cover 110 using a solder or a glue. The platform 126 not only protects the MEMS transducer 104 from the encapsulating material 108, but also protects the cover bonding surface 128 from contact with the encapsulating material 108. This prevents any defect in bonding of the cover 110 to the substrate, which may occur if the encapsulating material 108 were to spill over to the cover bonding surface 128. In one or more embodiments, the platform 126 may not completely surround the ASIC cavity 120. For example, the platform 126 may extend only on one side of the ASIC cavity 120 that is adjacent to the MEMS transducer 104. In some other embodiments, the platform 126 may extend along a complete or partial length of one or more sides of the ASIC cavity 120.

[0037] Figure 3 shows a representation of a cross-sectional view of a second example microphone device 200 according to the embodiments of the present disclosure. Several elements of the second example microphone device 200 are similar to the components of the first example microphone device 100 shown in Figure 1. To that extent, the similar elements have been labeled with similar reference numbers. The second example microphone device 200 does not include a platform. The substrate 202 has an ASIC cavity 220 formed within a front surface 222 of the substrate 202, and a bottom surface of the ASIC cavity 220 serves as an ASIC mounting surface 224. The height H1' of the ASIC cavity 220 is greater than the height of the ASIC 106, such that the entirety of the ASIC 106 falls within a volume of the ASIC cavity 220. In some embodiments, the height H1' can be equal to or greater than the

height of ASIC 106. In still further embodiments, the height H1' can be less than the height of the ASIC 106. For example, the ASIC 106 may be taller than the height H1' of the cavity, but the difference in the heights may be sufficiently small such that an encapsulating material 208 does not contacts the MEMS transducer 104 and/or a cover mounting surface during deposition. By having the height of the ASIC cavity 220 to be greater than a height of the ASIC 106, the risk of spillover of the encapsulating material 208 during deposition can be reduced while ensuring that the encapsulating material 208 fully covers the ASIC 106 and at least a portion of the second set of wires 114.

[0038] The substrate 202 can also include a cover mounting surface (not shown) to facilitate bonding the cover 110 onto the front surface 222 of the substrate 202. The cover mounting surface can be similar to the cover bonding surface 128 discussed above in relation to Figure 2.

[0039] In one or more embodiments, more than one ASIC can be mounted within the cavity. For example, the more than one ASICs can be disposed side-by-side within the cavity. In another example, the more than one ASICs can be stacked on top of each other. In yet another example, the more than one ASICs may be both stacked on top of each other and disposed side-by-side within the cavity. The encapsulation material can be deposited in the cavity such that it completely covers the more than one ASICs regardless of the manner in which they are arranged within the cavity.

[0040] As discussed above in relation to Figures 1–3, the encapsulating material 108 and 208 fully cover the ASIC 106 and fully or partially cover the second set of wires 114. By covering the ASIC 106 and the second set of wires 114 within the encapsulating material 108 or 208, an effect of radio frequency signals, generated by the ASIC 106 and the second set of wires 114, on the MEMS transducer 104 and other components mounted on the substrate 102 or 202 can be reduced. In some embodiments, completely covering the ASIC and partially or completely covering the wires in encapsulating material may cause a substantial reduction in noise in the microphone device as compared to a microphone device that does not include encapsulating material or only partially encapsulates an ASIC. By reducing the radio frequency interference, a level of noise in the electrical signals generated by the MEMS transducer 104 and the other components on the substrate 102 and 202 can be reduced. In

some embodiments, an improvement in noise attenuation of about -15 dB is obtained for the microphone device having an encapsulating material completely covering the ASIC in comparison with a microphone device having no encapsulation material.

[0041] Figure 4 shows a flow diagram of an example process 400 for manufacturing a microphone device according to the embodiments of the present disclosure. The process 400 includes providing a substrate (stage 402), forming an ASIC cavity on a front surface of the substrate (stage 404), mounting a MEMS transducer on the substrate (stage 406), mounting an ASIC on an ASIC mounting surface in the ASIC cavity (stage 408), installing a first set of bonding wires between the ASIC and the MEMS transducer, and a second set of wires between the ASIC and the substrate (stage 410), and depositing an encapsulation material into the ASIC cavity to completely cover the ASIC and the second set of wires (stage 412). It should be noted that the order of stages described herein is provided by way of example only, and the present disclosure is not limited to any particular order of performing the stages. For example, in some embodiments, the MEMS transducer may be mounted prior to mounting of the ASIC, while in other embodiments, the ASIC may be mounted prior to mounting of the MEMS transducer.

[0042] The process 400 includes providing a substrate (stage 402). As discussed above in relation to Figures 1–3, the substrate can include a printed circuit board or a semiconductor material. In some embodiments, the substrate can be similar to the substrate 102 or the substrate 202 shown in Figures 1–3. The substrate can include a single-layered or a multi-layered printed circuit board, where each layer can include a set of conductive traces separated by insulators. The conductive traces can be patterned based on the locations connectivity of the components, such as the MEMS transducer and the ASIC to be mounted on the substrate.

[0043] The process 400 further includes creating an ASIC cavity on a front surface of the substrate (stage 404). One example implementation of this process stage is discussed above in relation to Figures 1. The ASIC cavity 120 is created on a front surface 122 of the substrate 102. In another example, as shown in Figure 3, the ASIC cavity 220 is formed on the front surface 222 of the substrate 202. In some embodiments, the cavity in the front surface of the substrate can be created using one or more of chemical etching, a photoengraving routing,

stamping or blanking through a substrate layer, and the like. The bottom of the cavity can form an ASIC mounting surface for mounting an ASIC. The ASIC mounting surface can include one or more bonding pads that can be connected to bonding pads on the ASIC using wire bonding. In some embodiments, the process 400 also can include forming a ledge or a platform adjacent to the ASIC cavity. One example of such a platform is discussed above in relation to Figures 1 and 2. In one or more embodiments, the platform can be formed by etching the surface of the substrate around the desired location of the platform. In some other embodiments, the platform can be formed by depositing additional layers of the substrate at the desired location of the platform. In one or more embodiments, the substrate and the platform can be formed of the same material. In one or more embodiments, the substrate and the platform can be formed of different materials. For example, materials used for forming the substrate and the platform can include materials such as fiberglass, epoxy resin, and solder mask.

[0044] The process 400 further includes mounting a MEMS transducer on a front surface of the substrate (stage 406) and mounting an ASIC on an ASIC mounting surface (stage 408). Example implementations of these process stages are discussed above in relation to Figures 1–3. For example, as shown in Figures 1–3, the MEMS transducer 104 is mounted on the substrate 102 or 202, and the ASIC 106 is mounted on the ASIC mounting surface 124 or 224. The MEMS transducer 104 and the ASIC 106 can be mounted manually or by machine (e.g, using a “pick and place machine”). In some embodiments, flip-chip techniques also can be used to mount the MEMS transducer 104 and the ASIC 106.

[0045] The process 400 also includes installing a first set of bonding wires between the ASIC and the MEMS transducer, and a second set of wires between the ASIC and the substrate (stage 410). Examples of the implementation of this process stage are discussed above in relation to Figures 1–3. For example, a first set of wires 112 are installed to electrically connect the MEMS transducer 104 to the ASIC 106. A second set of wires 114 are installed to electrically connect the ASIC 106 to conductive traces on the substrate 102. The first set of wires 114 and the second set of wires can include conductive materials such as aluminum, copper, silver, gold, and the like. The wires can be installed using techniques such as ball bonding, wedge bonding, and compliant bonding.

[0046] The process 400 additionally includes depositing an encapsulation material into the ASIC cavity to completely cover the ASIC and the second set of wires (stage 412). Examples of the implementation of this process stage are discussed above in relation to Figures 1–3. For example, as shown in Figure 1 and 2, the encapsulating material 108 completely cover the ASIC 106 and the second set of wires 114. Similarly, as shown in Figure 3, the encapsulating material 208 completely covers the ASIC 106 and the second set of wires 114. In some embodiments, the encapsulating material can be an epoxy, or materials such as resins, polymers, glass, plastic, and the like. Before deposition, the encapsulating material can be heated to a predetermined temperature to allow the encapsulating material to flow. The heated epoxy can be deposited in the ASIC cavity such that it completely covers the ASIC and the second set of wires that connect the ASIC to the substrate. During deposition, the sidewalls of the ASIC cavity confine the encapsulating material to within the cavity, and reduce the risk of the encapsulating material coming in contact with the MEMS transducer or other components on the substrate. The deposited encapsulating material can be given time to settle into a steady state with regard to flow within the ASIC cavity. If in the steady state, portions of the ASIC or the second set of wires remain exposed, additional encapsulating material can be added. The encapsulating material can then be cooled until it solidifies.

[0047] It should be noted that process stages in the process 400 depicted in Figure 4 can be performed in an order different from the one shown in Figure 4. For example, mounting the ASIC in the ASIC cavity (stage 408) can be carried out before mounting the MEMS transducer on the substrate (stage 406). Further, installation of the wires between the ASIC and the MEMS transducer and the ASIC and the substrate (stage 410) can be carried out in any order.

[0048] Figures 5 and 6 depict representations of a cross-sectional view and a top view, respectively, of a third example microphone device 500 according to embodiments of the present disclosure. In the third example, microphone 500 shown in Figures 5 and 6, an ASIC cavity 520 is formed by a wall 526 that rises above a front surface 522 of the substrate 502. The wall 526 has a top surface 540 that is positioned at a height H5 above the front surface 522 of the substrate 502. The height H5 can be greater than, equal to, or less than a height of the ASIC 106. A periphery 542 of the wall 526 defines an edge of the cavity 520. The ASIC

106 is mounted on a mounting surface 524 that is a portion of the front surface of the substrate 502.

[0049] The encapsulating material 508 is deposited within the ASIC cavity 520 and completely covers the ASIC 106 and at least partially covers the second set of wires 114. In one or more embodiments, the encapsulating material 508 entirely covers the second set of wires 114.

[0050] The wall 526 can completely surround the ASIC 106 and a portion of the front surface 522 of the substrate 502. In one or more embodiments, the wall 526 can be discontinuous. In one or more embodiments, the wall 526 may not entirely surround the ASIC 106. For example, the wall 526 may extend between the MEMS transducer 104 and the ASIC 106, so as to reduce the risk of the encapsulating material 508 making contact with the MEMS 104 during and after deposition. In one or more embodiments, the wall 526 can be incorporated in the first and the second example microphone devices 100 and 200 discussed above in relation to Figures 1-4. In some embodiments, the top surface 540 can be considered a top or front surface of the substrate, such that the cavity is formed in part or in whole as an area surrounded by the wall 526.

[0051] Figure 7 shows a flow diagram of an example process 700 for manufacturing a microphone device according to some embodiments of the present disclosure. In particular, the process 700 can be utilized for manufacturing the third example microphone device discussed above in relation to Figures 5 and 6, in some embodiments. The process 700 includes providing a substrate having a wall formed on a front surface of the substrate, where the wall forms an ASIC cavity (stage 702); mounting a MEMS transducer on the substrate (stage 704), mounting an ASIC on an ASIC mounting surface in the ASIC cavity (stage 706), installing a first set of bonding wires between the ASIC and the MEMS transducer, and a second set of wires between the ASIC and the substrate (stage 708), and depositing an encapsulation material into the ASIC cavity to completely cover the ASIC and the second set of wires (stage 710).

[0052] The process 700 includes providing a substrate having a wall formed on a front surface of the substrate, where the wall forms an ASIC cavity (stage 702). On example of this

process stage is discussed above in relation to Figures 5 and 6, where the wall 526 forms a cavity 520 on the substrate 502. In one or more embodiments, the wall 526 can be formed of the same material as the substrate. For example, the wall can be formed by depositing additional layers of the substrate material. In one or more embodiments, the wall can be formed using a solder mask, a solder stop mask, or a solder resist. Multiple layers of the solder mask can be deposited around the ASIC in the desired pattern to form the wall. Stages 704-710 can be performed in a manner similar to that discussed above in relation to stages 406-412. It should be noted that the order of stages described herein is provided by way of example only, and the present disclosure is not limited to any particular order of performing the stages. For example, in some embodiments, the MEMS transducer may be mounted prior to mounting of the ASIC, while in other embodiments, the ASIC may be mounted prior to mounting of the MEMS transducer.

[0053] Figure 8 is a representation of a cross-sectional view of a fourth example microphone device 800 according to embodiments of the present disclosure. The fourth example microphone device 800, in many aspects, is similar to the first example microphone device 100 discussed above in relation to Figures 1 and 2, and similar elements are referred to with similar reference numerals. The fourth example microphone device 800 includes a heat shield 850 embedded into the encapsulating material. In particular, a first portion of an encapsulating material 808a is deposited over the ASIC 106, over which a layer of heat shield 850 is deposited. A second portion of the encapsulating material 808b can be deposited over the heat shield 850, in some embodiments.

[0054] The heat shield 850 improves the performance of the fourth example microphone device 800. Specifically, the performance of the fourth example microphone device 800 may be affected by the heat radiated by the ASIC 106. The heat 846 radiated by the ASIC 106 may dissipate into the back volume 116 and raise the temperature of the air enclosed therein. This increase in the temperature may result in changes in pressure in the back volume 116, which in turn can affect the performance of the MEMS transducer 104. By including a heat shield 850 within the encapsulation material and over the ASIC 106, at least a portion of the heat 846 radiated by the ASIC 106 can be reflected back towards the ASIC 106 and away from the back volume. As a result, the impact of the heat 846 radiated by the ASIC 106 on

the temperature or pressure of the air in the back volume 116 and on the performance of the MEMS transducer 104 is reduced.

[0055] The heat shield 850 can include metals, such as, for example, aluminum, copper, gold, silver, and the like. The heat shield 850 may also include other materials that can reflect radiated heat. In one or more embodiments, the heat shield 850 can be structured as a continuous film. In some other embodiments, the heat shield 850 can be structured as a discontinuous film, such as for example a grid-shaped or net-shaped structure. In one or more embodiments, the heat shield 850 can be electrically connected to a ground plane of the fourth microphone device 800. For example, as shown in the expanded view, an electrical connector 852 can be disposed over the platform 126, where the electrical connector 852 electrically connects the heat shield 850 to a ground plane (not shown) disposed on the platform 126. Electrically grounding the heat shield 850 can provide an additional benefit of shielding the MEMS transducer 104 from electromagnetic interference due to the electromagnetic energy generated by the ASIC 106. The electrical connector 852 may also make contact with the cover 110, which may also be electrically connected to the ground plane.

[0056] FIG. 9 shows a flow diagram of an example process 900 for manufacturing a microphone device according to the embodiments of the present disclosure. The process 900 includes providing a substrate (stage 902), forming an ASIC cavity on a front surface of the substrate (stage 904), mounting a MEMS transducer on the substrate (stage 906), mounting an ASIC on an ASIC mounting surface in the ASIC cavity (stage 908), installing a first set of bonding wires between the ASIC and the MEMS transducer and a second set of wires between the ASIC and the substrate (stage 910), depositing a first layer of encapsulating material over the ASIC (stage 912), depositing a heat shield over the first layer of encapsulating material (stage 914), and, optionally, depositing a second layer of encapsulating material (stage 916).

[0057] The process 900 including the stages 902, 904, 906, 908, and 910 can be similar to those discussed above in relation to the process 400 (Figure 4) stages 402, 404, 406, 408, and 410, respectively. The process 900 further includes depositing a first layer of encapsulating material over the ASIC (stage 912). As shown in Figure 8, the first layer of encapsulating material 808a is deposited over the ASIC 106. In some embodiments, the first layer of

encapsulating material 808a can completely cover the ASIC 106 and the second set of wires 114.

[0058] After the deposition of the first layer of encapsulating material 808a, a heat shield can be deposited over the first layer of encapsulating material (stage 914). As shown in Figure 8, the heat shield 850 is deposited over the first layer of encapsulating material 808a. The heat shield can be deposited using any deposition technique that can deposit a conductive material. In one or more embodiments, a metal sputtering technique can be utilized to coat the exposed surfaces of the first layer of encapsulating material 808a with the conductive material. In one or more embodiments, the deposition technique can utilize a solution including nano-sized metal particles, or can utilize an organometallic solution. The solution including suspended nano-sized metal particles or the organometallic solution can be deposited over the first layer of encapsulating layer 808a by a jetting or micro/nano spray such that the deposited conductive material covers the exposed surface of the first layer of encapsulating material 808a.

[0059] A mask can also be utilized to limit the area over which the conductive material is deposited. For example, the mask can be structured to avoid the deposition of the conductive material over the MEMS 104. The mask can also be structured to allow deposition of the conductive material over the platform 126 to form the electrical connection with the ground plane. In instances where the electrical connector 852 is provided separately from the deposition of the conductive material to form the heat shield, the mask can be structured such that the conductive material is deposited on at least a portion of the electrical connector 852 to provide an electrical connection between the electrical connector 852 and the heat shield 850. In one or more embodiments, the conductive material can be deposited to form a continuous film. In other embodiments, a partially discontinuous film may also be formed. The mask can be structured to provide, for example, a grid-like or a net-like structure to the heat shield 850. In one or more embodiments, the mask can be structured such that the conductive material does not make contact with the first set of wires 112, to avoid a short circuit. For example, the mask can be structured to introduce an aperture or a cut out in the heat shield 850 through which the first set of wires 112 can pass without making an electrical contact.

[0060] In some instances, insulated bonding wires can be used to implement the first set of wires 112. The insulated bonding wires can provide electrical isolation for the current carried on the first set of wires from the conductive material of the heat shield. In some such instances, there may be no need to use a mask to form an aperture or a cut out in the heat shield 850, thereby reducing the manufacturing cost and time. In one or more embodiments, the insulated bonding wires used to implement the first set of wires 112 can have a diameter of about 15 microns to about 25 microns, or about 20 microns. In one or more embodiments, the insulated bonding wires can be used to implemented the second set of wires 114 as well.

[0061] In one or more embodiment, the deposited conductive material can be baked at a temperature of about 200 to about 300 degrees C if the deposited conductive material is suspended in a solution. Of course, this temperature is merely an example, and can be a function, in part, of the conductive material used. In instances where an organometallic solution is deposited, the deposited solution can be baked at less than about 200 degrees C. Depending upon the particle size of the conductive material and the baking temperature, the resulting conductive film can be "tuned" to exhibit different surface properties (such as, e.g., emissivity and absorptivity) with respect to incident radiation (such as, e.g., infra-red). As an example, particle sizes of about 15 angstrom to about 25 angstrom or about 20 angstrom and a baking temperature greater than about 200 degrees C can result in the formation of a conductive film with surface properties that are similar to bulk or near-bulk surface properties of gold, for example. In some embodiments, the particle sizes of the conductive material and/or the baking temperature can be adjusted to achieve the desired surface properties.

[0062] After the deposition and formation of the heat shield 850 over the first layer of encapsulation material 808a, a second layer of encapsulation material 808b can optionally be deposited over the heat shield 850. The second layer of encapsulated material 808b can completely cover the heat shield and partially cover the first set of wires 112. The material composition of the first layer of the encapsulation material and the second layer of encapsulating material 808b can be similar to that of the encapsulating material 108 discussed above in relation to Figures 1-3. In addition, the technique of depositing the first and second layer of encapsulating material 808a and 808b can be similar to that discussed in relation to the encapsulating material 108.

[0063] The heat shield 850 discussed above in relation to Figure 8 and 9 can also be included in other embodiments discussed above. For example, each of the second example microphone device 200 shown in Figure 3, and the third example microphone device 500 shown in Figure 5 can include a heat shield within the encapsulating materials 208 and 508, respectively. The methods of manufacture of each of these example microphone devices can be adapted to include the process of depositing two layers of encapsulating materials and a conductive layer therebetween to form a heat shield.

[0064] Various example embodiments discussed herein can provide substantial advantages over existing designs, such as substrate-embedded ASIC packages. In such packages, the ASIC is completely surrounded by the substrate material, and is embedded inside the substrate during the manufacturing process of the substrate. However, embedding the ASIC inside the substrate raises overall cost of the microphone device. For example, defects in substrate can cause a good ASIC embedded in the defected substrate to be discarded along with the defected substrate. Further, there is an increased burden in the design phase to finalize the designs of the ASIC and the substrate early in the manufacturing process because of the additional lead-time needed to embed the ASIC into the substrate. Further, the inventory of ASICs is held up inside the substrate. Various embodiments discussed herein, on the other hand, allow the microphone device to be manufactured with established substrate and semiconductor processes, as the ASIC is encapsulated after the manufacture of the substrate. Moreover, the ASIC inventory is not held up during the manufacture of the substrate. This reduces the complexity of the manufacturing process of an encapsulated ASIC and reduces the time to market.

[0065] The herein described subject matter sometimes illustrates different components contained within, or connected with, different other components. It is to be understood that such depicted architectures are illustrative, and that in fact many other architectures can be implemented which achieve the same functionality. In a conceptual sense, any arrangement of components to achieve the same functionality is effectively "associated" such that the desired functionality is achieved. Hence, any two components herein combined to achieve a particular functionality can be seen as "associated with" each other such that the desired functionality is achieved, irrespective of architectures or intermedial components. Likewise,

any two components so associated can also be viewed as being "operably connected," or "operably coupled," to each other to achieve the desired functionality, and any two components capable of being so associated can also be viewed as being "operably couplable," to each other to achieve the desired functionality. Specific examples of operably couplable include but are not limited to physically mateable and/or physically interacting components and/or wirelessly interactable and/or wirelessly interacting components and/or logically interacting and/or logically interactable components.

[0066] With respect to the use of plural and/or singular terms herein, those having skill in the art can translate from the plural to the singular and/or from the singular to the plural as is appropriate to the context and/or application. The various singular/plural permutations may be expressly set forth herein for sake of clarity.

[0067] It will be understood by those within the art that, in general, terms used herein, and especially in the appended claims (e.g., bodies of the appended claims) are generally intended as "open" terms (e.g., the term "including" should be interpreted as "including but not limited to," the term "having" should be interpreted as "having at least," the term "includes" should be interpreted as "includes but is not limited to," etc.).

[0068] It will be further understood by those within the art that if a specific number of an introduced claim recitation is intended, such an intent will be explicitly recited in the claim, and in the absence of such recitation no such intent is present. For example, as an aid to understanding, the following appended claims may contain usage of the introductory phrases "at least one" and "one or more" to introduce claim recitations. However, the use of such phrases should not be construed to imply that the introduction of a claim recitation by the indefinite articles "a" or "an" limits any particular claim containing such introduced claim recitation to inventions containing only one such recitation, even when the same claim includes the introductory phrases "one or more" or "at least one" and indefinite articles such as "a" or "an" (e.g., "a" and/or "an" should typically be interpreted to mean "at least one" or "one or more"); the same holds true for the use of definite articles used to introduce claim recitations. In addition, even if a specific number of an introduced claim recitation is explicitly recited, those skilled in the art will recognize that such recitation should typically be interpreted to mean at least the recited number (e.g., the bare recitation of "two

recitations," without other modifiers, typically means at least two recitations, or two or more recitations).

[0069] Furthermore, in those instances where a convention analogous to "at least one of A, B, and C, etc." is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (e.g., "a system having at least one of A, B, and C" would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, etc.). In those instances where a convention analogous to "at least one of A, B, or C, etc." is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (e.g., "a system having at least one of A, B, or C" would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, etc.). It will be further understood by those within the art that virtually any disjunctive word and/or phrase presenting two or more alternative terms, whether in the description, claims, or drawings, should be understood to contemplate the possibilities of including one of the terms, either of the terms, or both terms. For example, the phrase "A or B" will be understood to include the possibilities of "A" or "B" or "A and B." Further, unless otherwise noted, the use of the words “approximate,” “about,” “around,” “substantially,” etc., mean plus or minus ten percent.

[0070] The foregoing description of illustrative embodiments has been presented for purposes of illustration and of description. It is not intended to be exhaustive or limiting with respect to the precise form disclosed, and modifications and variations are possible in light of the above teachings or may be acquired from practice of the disclosed embodiments. It is intended that the scope of the invention be defined by the claims appended hereto and their equivalents.

WHAT IS CLAIMED IS:

1. A microphone device comprising:

a substrate having a first surface and having a cavity formed in the first surface;

a microelectromechanical systems (MEMS) transducer mounted on the substrate outside the cavity;

an application specific integrated circuit (ASIC) mounted on the substrate within the cavity;

a first set of wires electrically connecting the MEMS transducer to the ASIC;

a second set of wires electrically connecting the ASIC to a conductor on the substrate within the cavity; and

an encapsulating material completely covering the ASIC and at least partially covering the second set of wires.

2. The microphone device of claim 1, wherein the encapsulating material completely covers both the ASIC and the second set of wires.

3. The microphone device of claim 1, wherein the substrate further includes a platform located at a periphery of the cavity, and wherein the MEMS transducer is mounted on the platform.

4. The microphone device of claim 3, wherein the platform is raised above the first surface of the substrate.

5. The microphone device of claim 3, wherein the platform surrounds the entire periphery of the cavity.

6. The microphone device of claim 3, wherein the platform separates the cavity from a cover mounting surface structured to receive a cover.

7. The microphone device of claim 1, wherein the MEMS transducer is mounted on the first surface.

8. The microphone device of claim 1, wherein the encapsulating material comprises epoxy.

9. The microphone device of claim 1, wherein the first set of wires are at least partially covered by the encapsulating material.

10. The microphone device of claim 1, wherein the substrate defines an opening at a portion of the substrate over which the MEMS transducer is mounted.

11. The microphone device of claim 1, wherein the substrate includes a wall surrounding the ASIC and the first surface forms a top surface of the wall, such that the cavity comprises an area surrounded by the wall.

12. The microphone device of claim 1, further comprising an electrically conductive heat shield disposed over the encapsulating material, the heat shield at least partially covering the ASIC.

13. The microphone device of claim 12, wherein the encapsulating material is a first layer of encapsulating material, the microphone device further comprising a second layer of encapsulating material disposed over at least a portion of the heat shield.

14. The microphone device of claim 12, wherein the heat shield is electrically connected to a ground plane disposed on the substrate.

15. The microphone device of claim 12, wherein the heat shield includes at least one of aluminum, copper, gold, or silver.

16. A method for manufacturing a microphone device comprising:

providing a substrate having a first surface;

forming a cavity in the first surface of the substrate;

mounting a microelectromechanical systems (MEMS) transducer on the substrate outside of the cavity;

mounting an application specific integrated circuit (ASIC) on the substrate within the cavity;

installing a first set of wires electrically connecting the MEMS transducer to the ASIC;

installing a second set of wires electrically connecting the ASIC to a conductor on the substrate within the cavity;

depositing an encapsulating material into the cavity such that the encapsulating material completely covers the ASIC and at least partially covers the second set of wires.

17. The method of claim 16, wherein depositing the encapsulating material into the cavity includes depositing the encapsulating material into the cavity such that the encapsulating material completely covers both the ASIC and the second set of wires.

18. The method of claim 16, further comprising forming a platform on the substrate at a periphery of the cavity, and wherein mounting the MEMS transducer on the substrate includes mounting the MEMS transducer on the platform.

19. The method of claim 18, wherein the platform is raised above the first surface of the substrate.

20. The method of claim 18, wherein forming the platform includes forming the platform to surround the entire periphery of the cavity.

21. The method of claim 18, wherein forming the platform includes forming the platform such that the platform separates the periphery of the cavity from a cover mounting surface structured to receive a cover.

22. The method of claim 16, wherein mounting the MEMS transducer includes mounting the MEMS transducer over the first surface of the substrate.

23. The method of claim 16, wherein depositing the encapsulating material includes depositing the encapsulating material such that the first set of wires are partially covered by the encapsulating material.

24. The method or claim 16, further comprising forming a wall on the substrate, the wall surrounding the ASIC, wherein a top surface of the wall is the first surface of the substrate and the cavity comprises an area surrounded by the wall.

25. The method of claim 16, wherein the encapsulating material is a first layer of encapsulating material, the method further comprising:

depositing a conductive material over the first layer of encapsulating material; and

depositing a second layer of encapsulating material over the conductive material.

26. The method of claim 25, wherein depositing the conductive material over the first layer of encapsulating material includes depositing at least one of conductive nano-sized metal particles suspended in a solution or an organometallic solution using a jetting or micro-spray over the first layer of encapsulating material.

27. A microphone device comprising:

a substrate having a first surface;

a wall formed on the first surface, the wall at least partially surrounding a first portion of the first surface;

a microelectromechanical systems (MEMS) transducer mounted on the substrate outside the first portion of the first surface;

an application specific integrated circuit (ASIC) mounted on the substrate and within the first portion of the first surface;

a first set of wires electrically connecting the MEMS transducer to the ASIC;

a second set of wires electrically connecting the ASIC to a conductor on the substrate; and

an encapsulating material deposited over the first portion at least partially surrounded by the wall and completely covering the ASIC and at least partially covering the second set of wires.

28. The microphone device of claim 27, wherein a height of the ASIC is greater than a height of the wall.

29. The microphone device of claim 27, wherein both the wall and the substrate are formed of a same material.

30. The microphone device of claim 27, wherein the wall and the substrate are formed of different materials.

31. The microphone device of claim 27, wherein the wall comprises a solder mask material.

32. The microphone device of claim 27, further comprising an electrically conductive heat shield disposed over the encapsulating material, the heat shield at least partially covering the ASIC.

33. The microphone device of claim 32, wherein the encapsulating material is a first layer of encapsulating material, the microphone device further comprising a second layer of encapsulating material disposed over at least a portion of the heat shield.

34. The microphone device of claim 32, wherein the heat shield is electrically connected to a ground plane disposed on the substrate.

35. The microphone device of claim 32, wherein the heat shield includes at least one of aluminum, copper, gold, or silver.

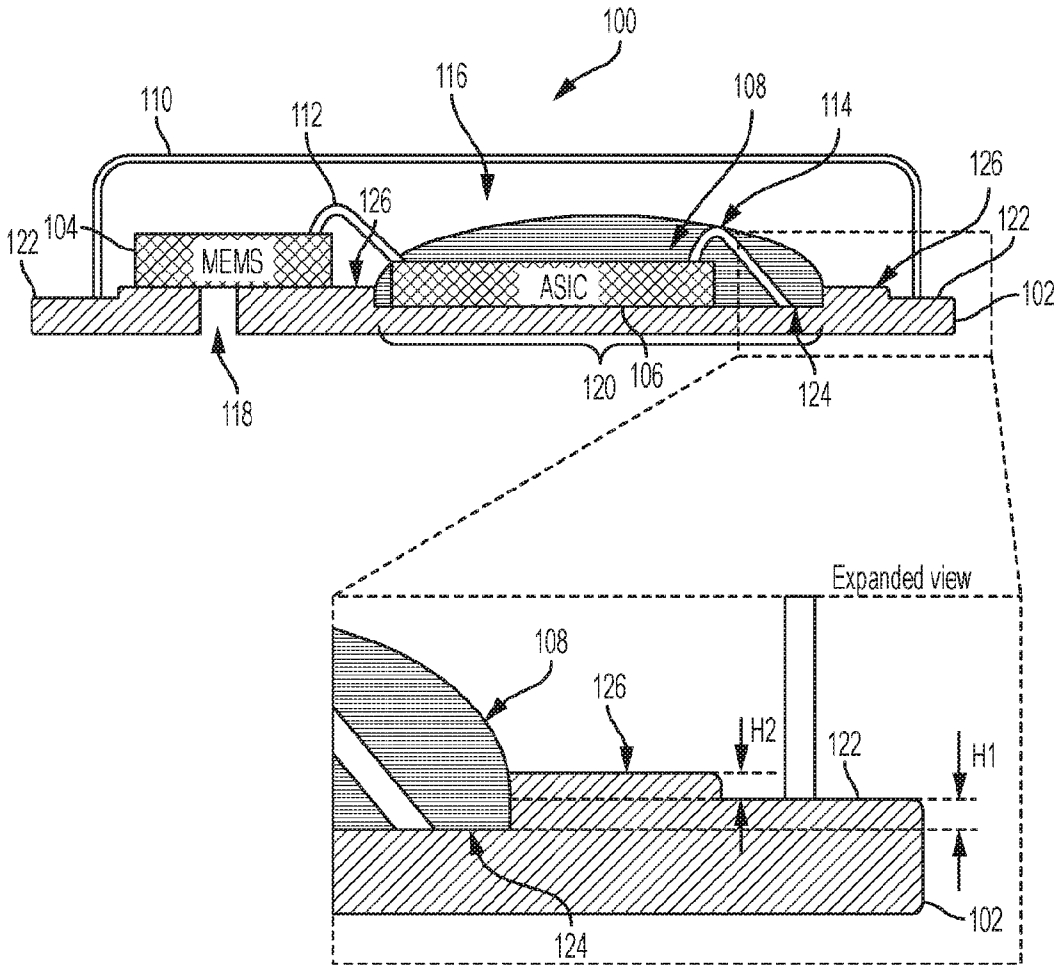

100
110
112
116
108
114
126
122
104
126
122
MEMS
ASIC
102
118
120
106
124
Expanded view
108
126
H2
122
H1
102
124

Figure 1

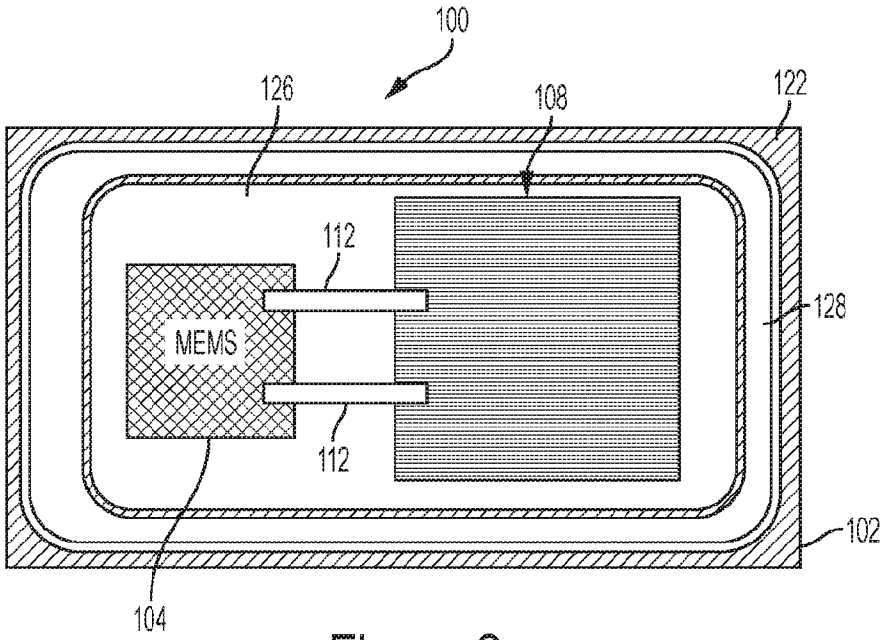


Figure 2

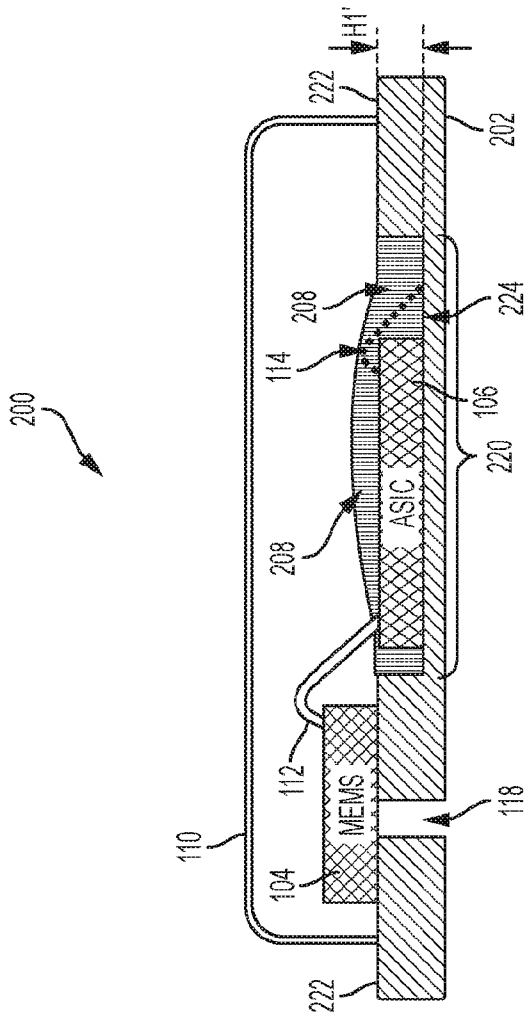

200
H1'
222
202
208
224
114
106
220
ASIC
208
112
MEMS
118
110
104
222

Figure 3

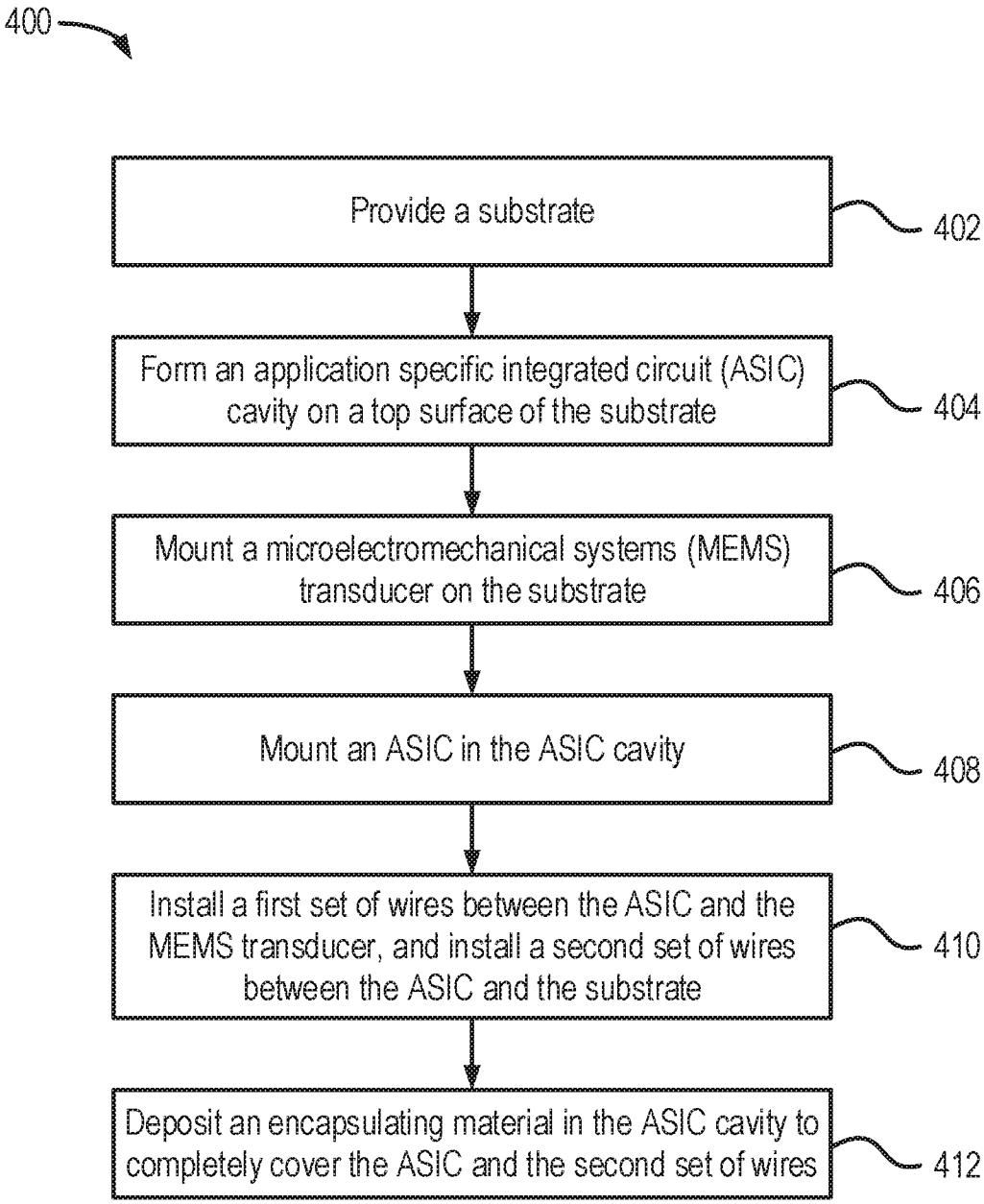

400
Provide a substrate
402
Form an application specific integrated circuit (ASIC) cavity on a top surface of the substrate
404
Mount a microelectromechanical systems (MEMS) transducer on the substrate
406
Mount an ASIC in the ASIC cavity
408
Install a first set of wires between the ASIC and the MEMS transducer, and install a second set of wires between the ASIC and the substrate
410
Deposit an encapsulating material in the ASIC cavity to completely cover the ASIC and the second set of wires
412

Figure 4

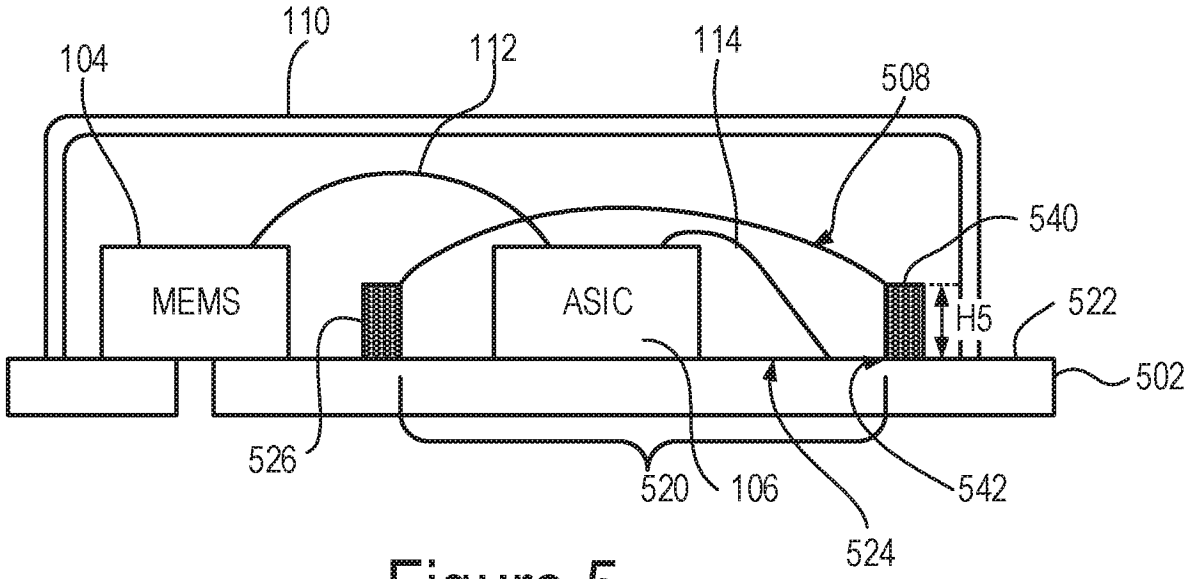


Figure 5

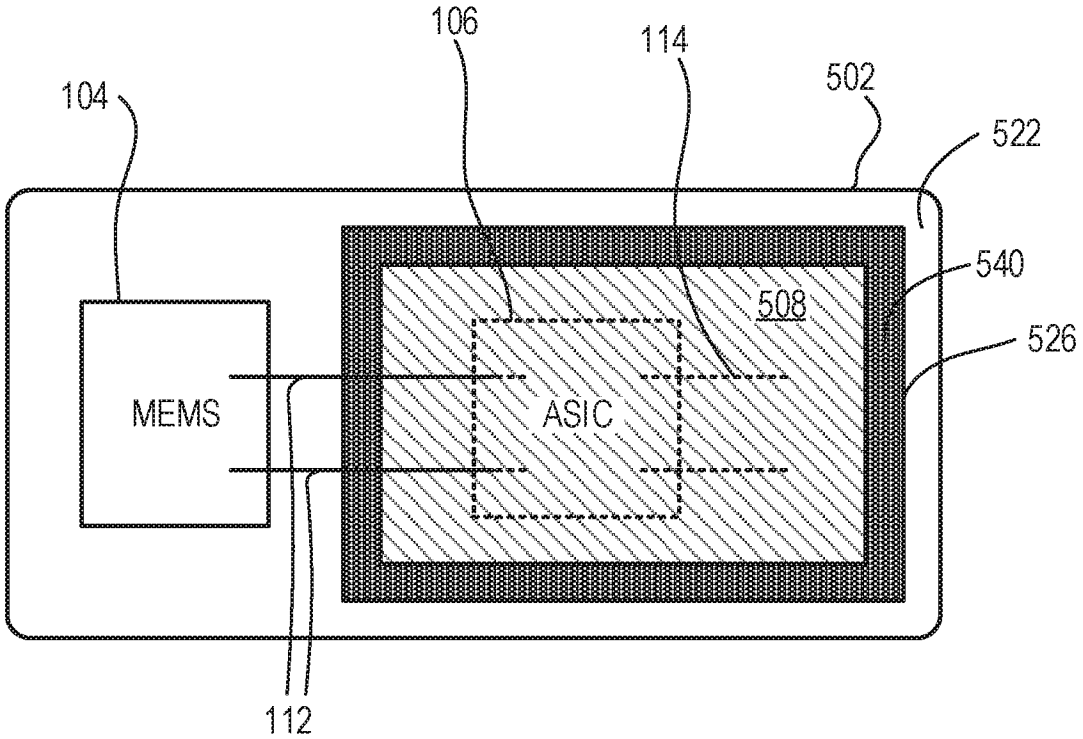


Figure 6

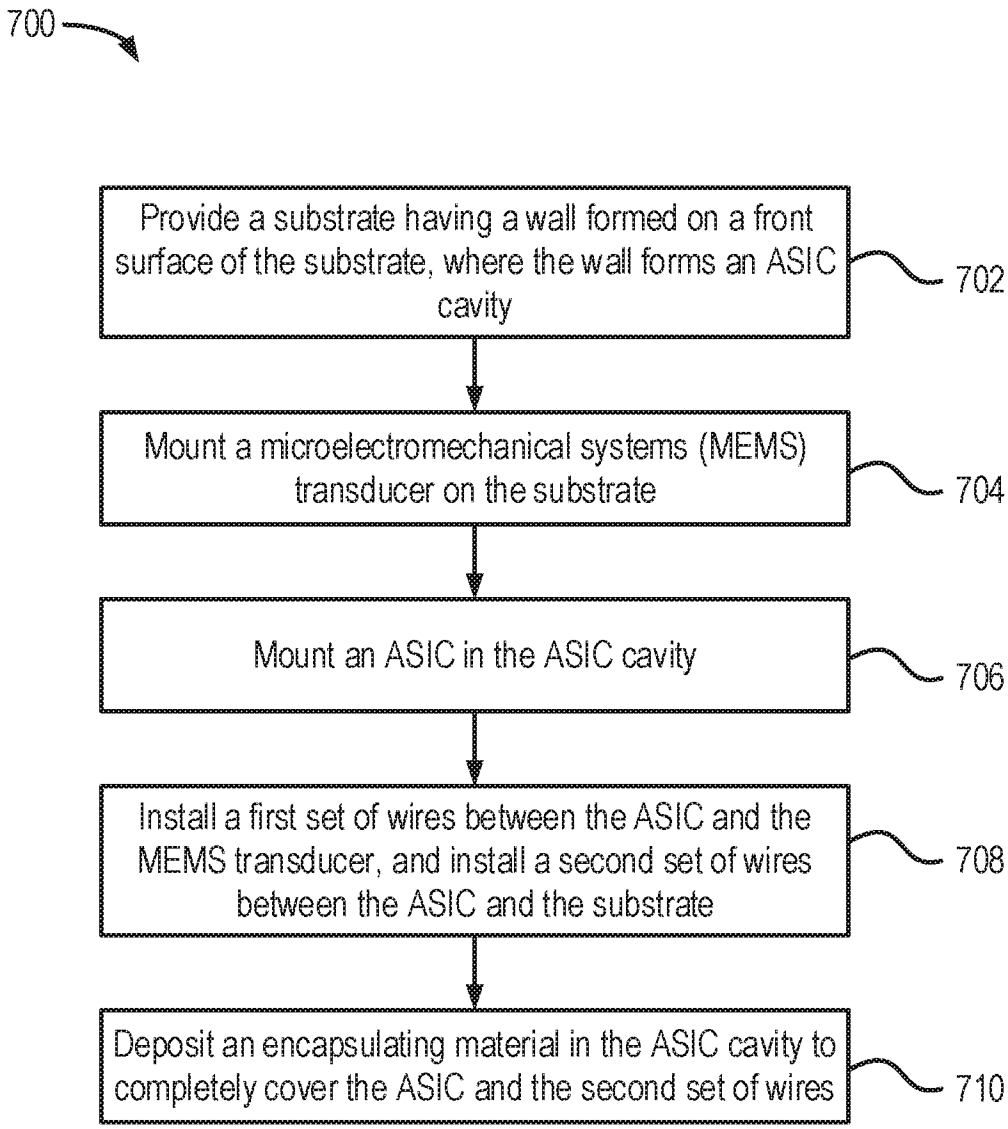

700
Provide a substrate having a wall formed on a front surface of the substrate, where the wall forms an ASIC cavity
702
Mount a microelectromechanical systems (MEMS) transducer on the substrate
704
Mount an ASIC in the ASIC cavity
706
Install a first set of wires between the ASIC and the MEMS transducer, and install a second set of wires between the ASIC and the substrate
708
Deposit an encapsulating material in the ASIC cavity to completely cover the ASIC and the second set of wires
710

Figure 7

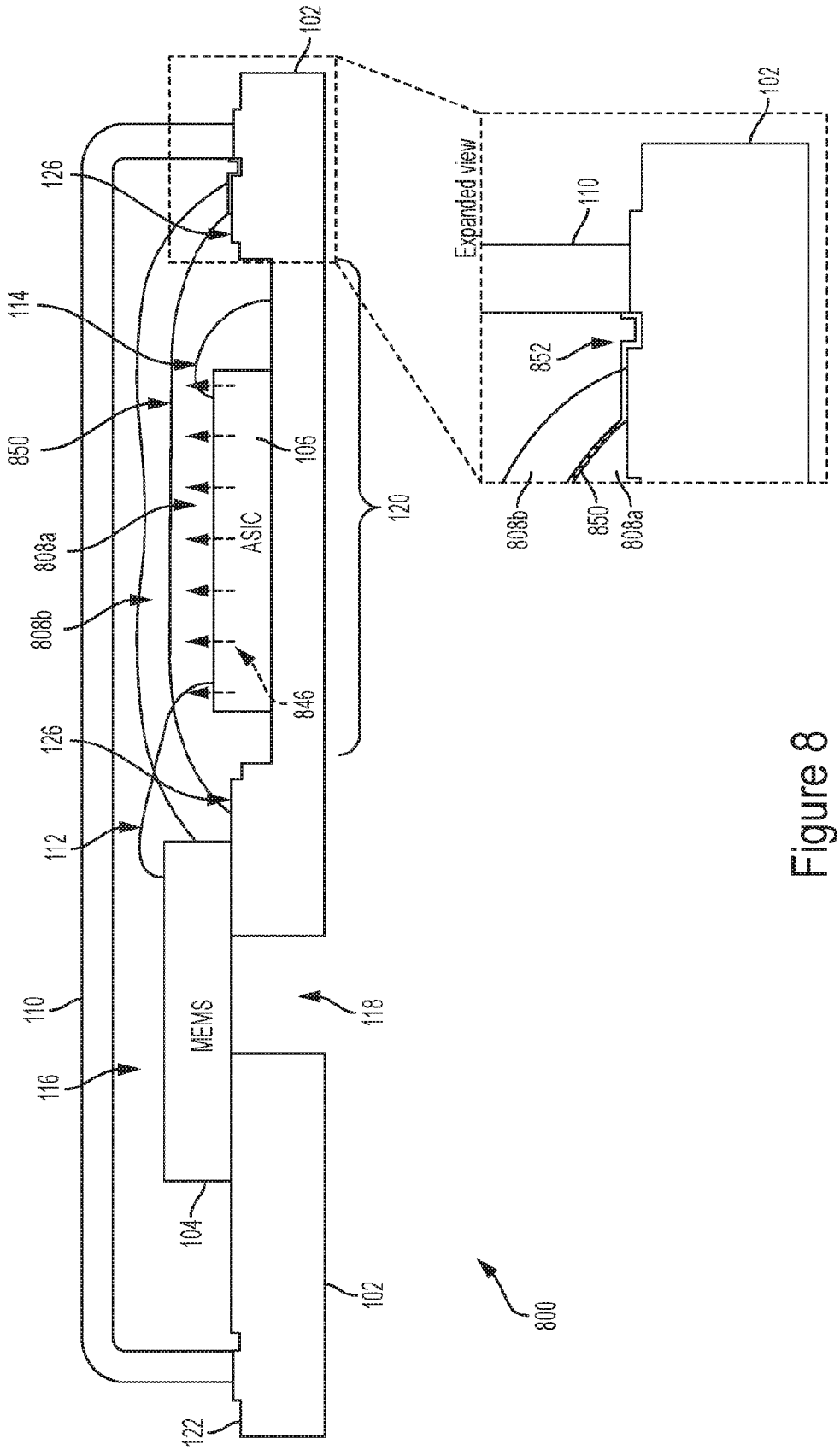

102
126
114
850
808a
808b
126
112
110
116
104
102
122
ASIC
MEMS
106
846
120
118
800
Expanded view
102
110
852
808b
850
808a

Figure 8

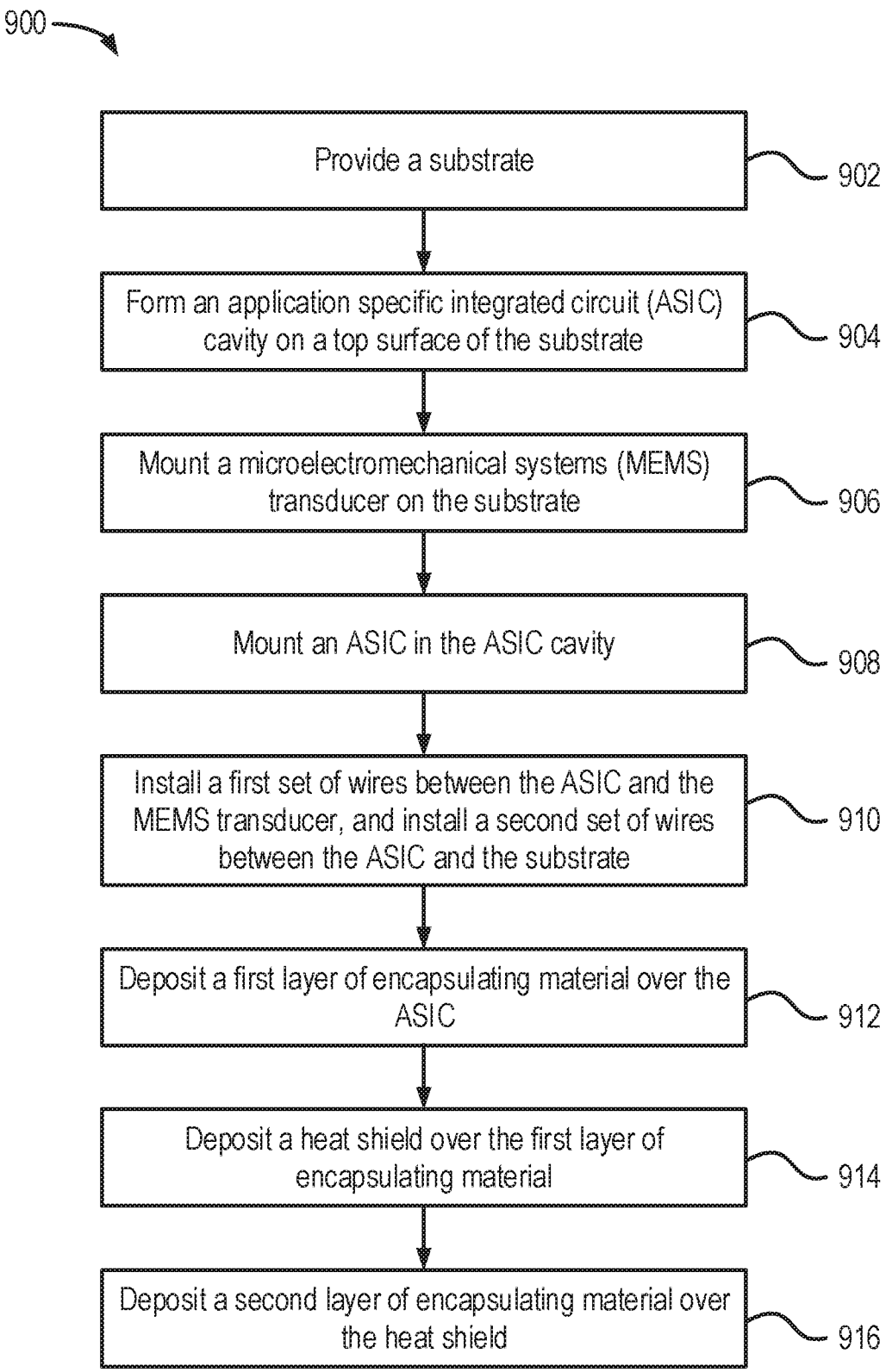

900
Provide a substrate
902
Form an application specific integrated circuit (ASIC) cavity on a top surface of the substrate
904
Mount a microelectromechanical systems (MEMS) transducer on the substrate
906
Mount an ASIC in the ASIC cavity
908
Install a first set of wires between the ASIC and the MEMS transducer, and install a second set of wires between the ASIC and the substrate
910
Deposit a first layer of encapsulating material over the ASIC
912
Deposit a heat shield over the first layer of encapsulating material
914
Deposit a second layer of encapsulating material over the heat shield
916

Figure 9

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2018/034475

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04R1/04
ADD. H01L23/28 B81B7/00

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H04R B81B H01L

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2016/100256 A1 (WATSON JOSHUA [US] ET AL) 7 April 2016 (2016-04-07)	27,29,31
A	abstract; figure 1	1,16
A	US 2013/105952 A1 (FONTANA FULVIO VITTORIO [IT] ET AL) 2 May 2013 (2013-05-02) paragraphs [0002], [0041], [0066] - paragraph [0071]; figures 2, 6a, 6b	1-35
Y	US 2008/056524 A1 (SAKAKIBARA SHINGO [JP] ET AL) 6 March 2008 (2008-03-06)	27,29, 31,32, 34,35
A	paragraphs [0013], [0035] - paragraph [0071]; figures 2,3 paragraph [0041] - paragraph [0061]; figure 4	28,30,33

-/--

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
17 October 2018	25/10/2018

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

2

Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2018/034475

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 9 640 531 B1 (OR-BACH ZVI [US] ET AL) 2 May 2017 (2017-05-02)	32,34,35
A	column 10, last paragraph - column 11, line 7; figures 3, 5, 15A column 19, line 11 - line 23	2-15, 17-26

2

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2018/034475

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2016100256 A1	07-04-2016	NONE	
US 2013105952 A1	02-05-2013	US 2013105952 A1	02-05-2013
		US 2015217993 A1	06-08-2015
US 2008056524 A1	06-03-2008	CN 101141838 A	12-03-2008
		EP 1898667 A2	12-03-2008
		JP 2008066983 A	21-03-2008
		KR 20080022509 A	11-03-2008
		TW 200822779 A	16-05-2008
		US 2008056524 A1	06-03-2008
US 9640531 B1	02-05-2017	NONE	