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(54) REARWARD ACOUSTIC DIFFUSION FOR ULTRASOUND-ON-A-CHIP TRANSDUCER ARRAY

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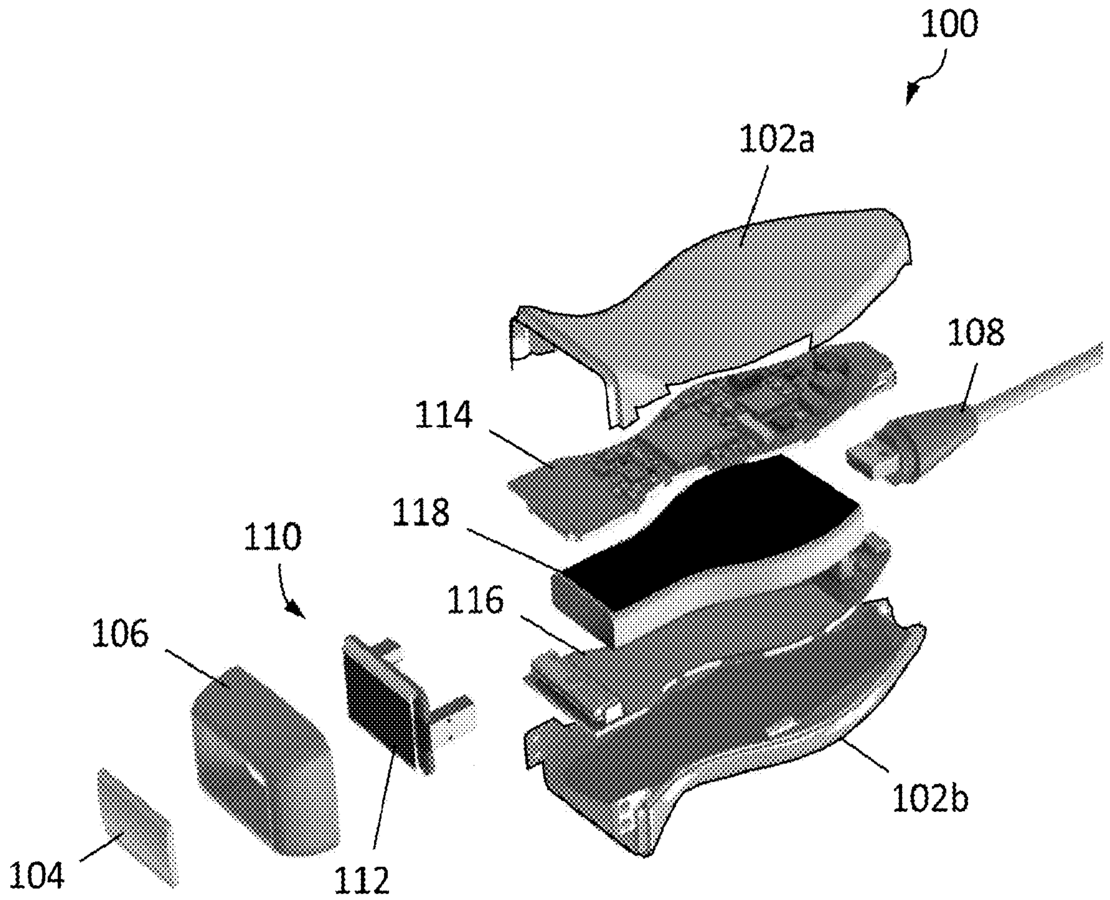
(57) ABSTRACT

A heat sink device has a non-planar mounting surface and an ultrasonic transducer substrate attached to the non-planar mounting surface. The non-planar mounting surface of the heat sink device is configured to diffuse acoustic waves that are incident thereupon.



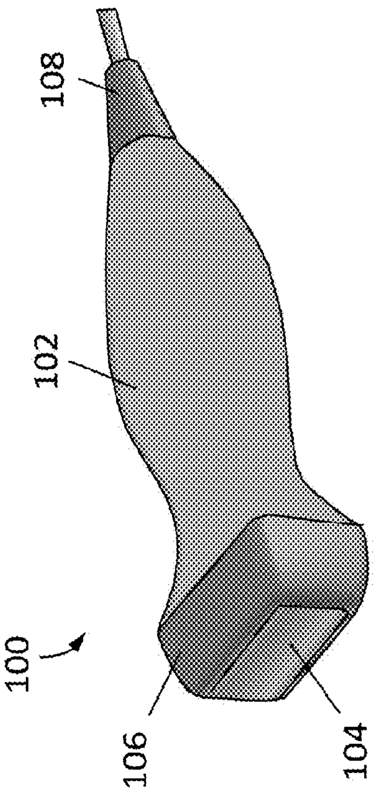

100
106
104
102
108

FIG. 1

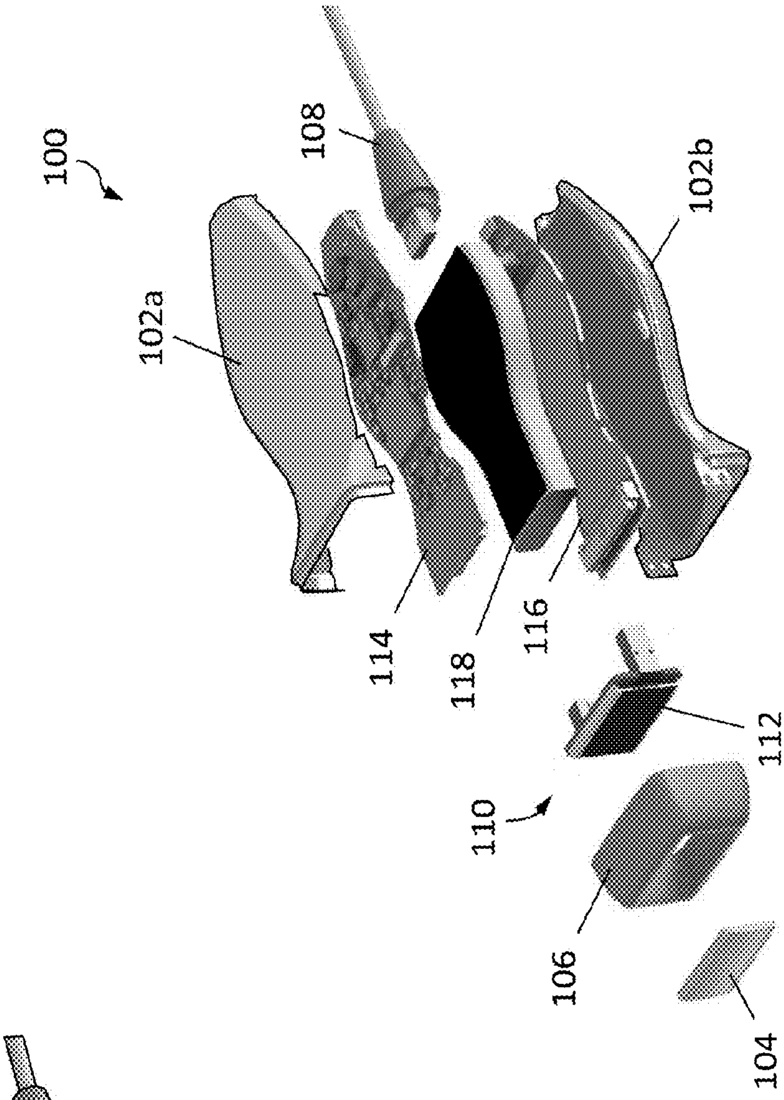

100
108
102a
102b
114
118
116
112
110
106
104

FIG. 2

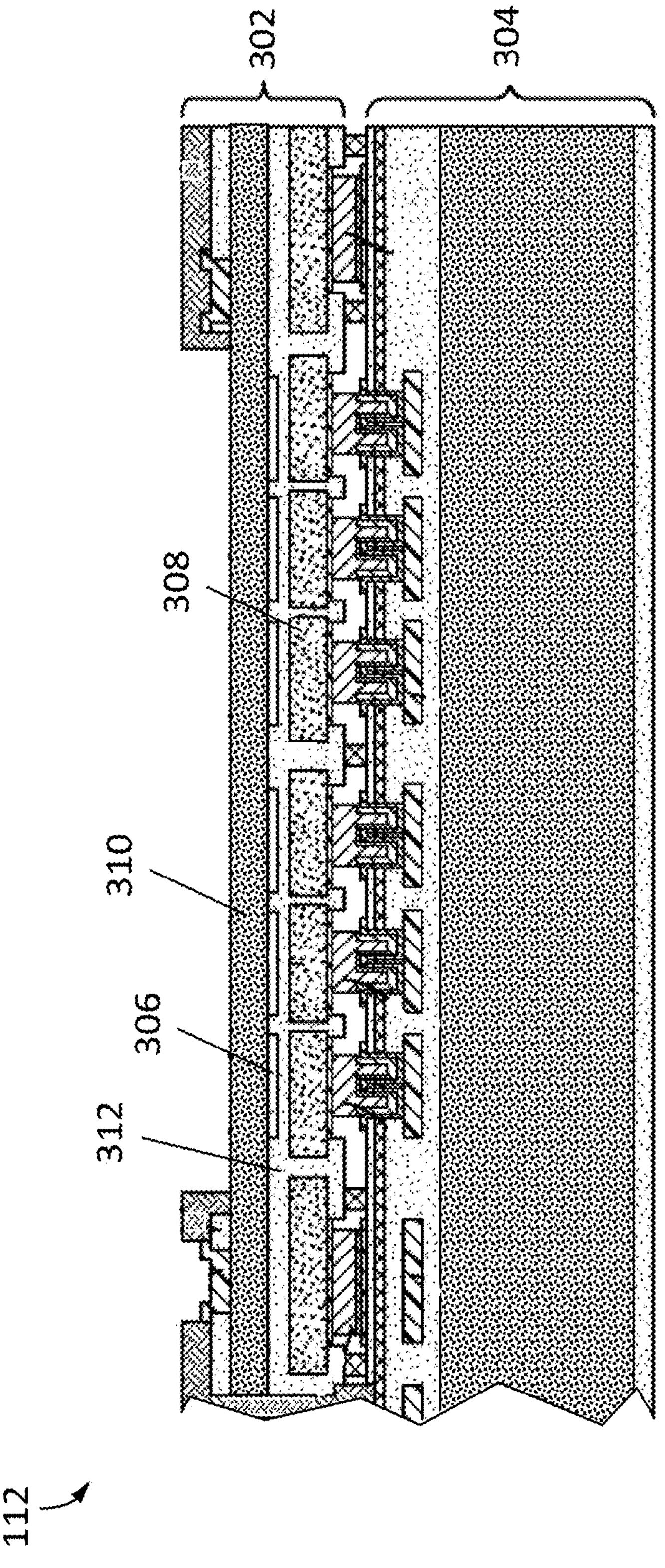


FIG. 3

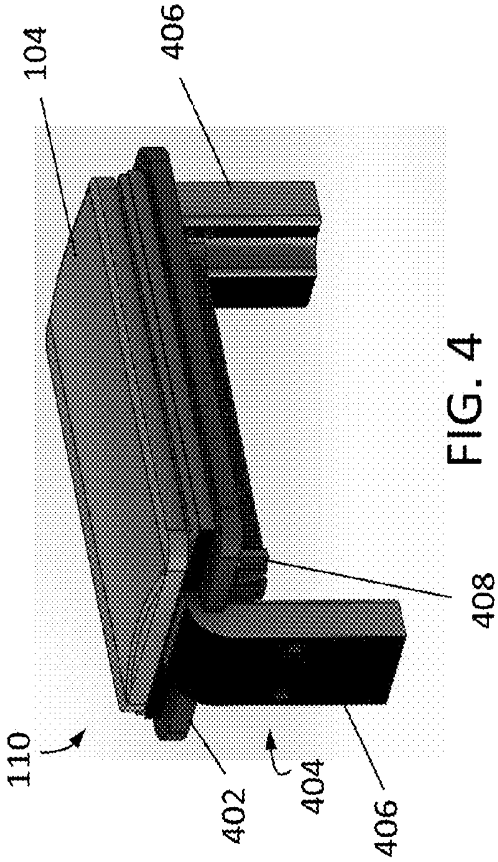


FIG. 4

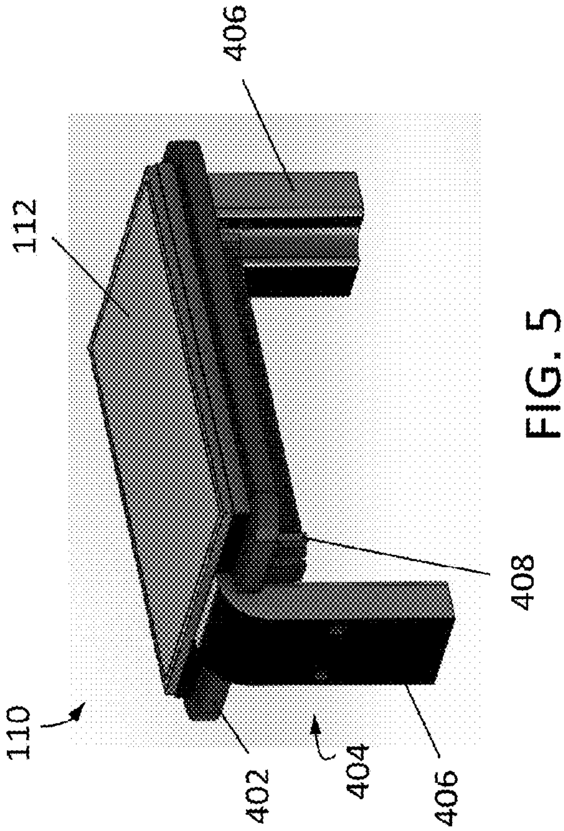


FIG. 5

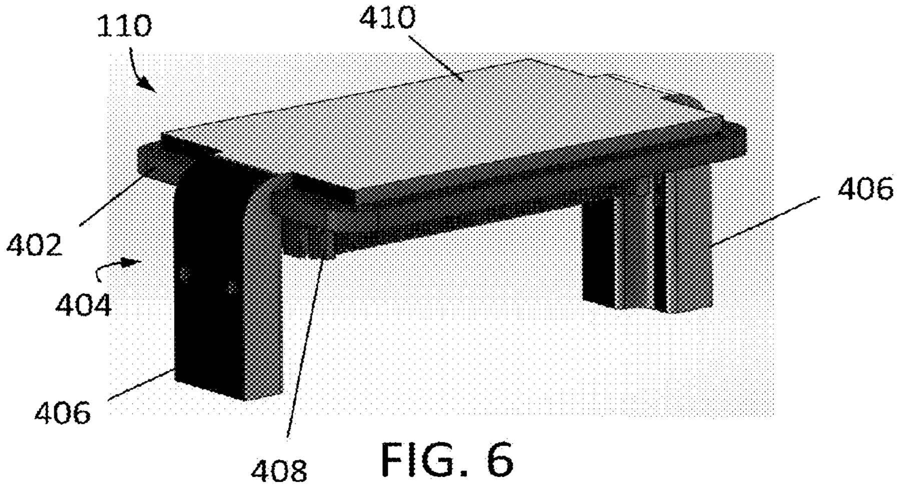


FIG. 6

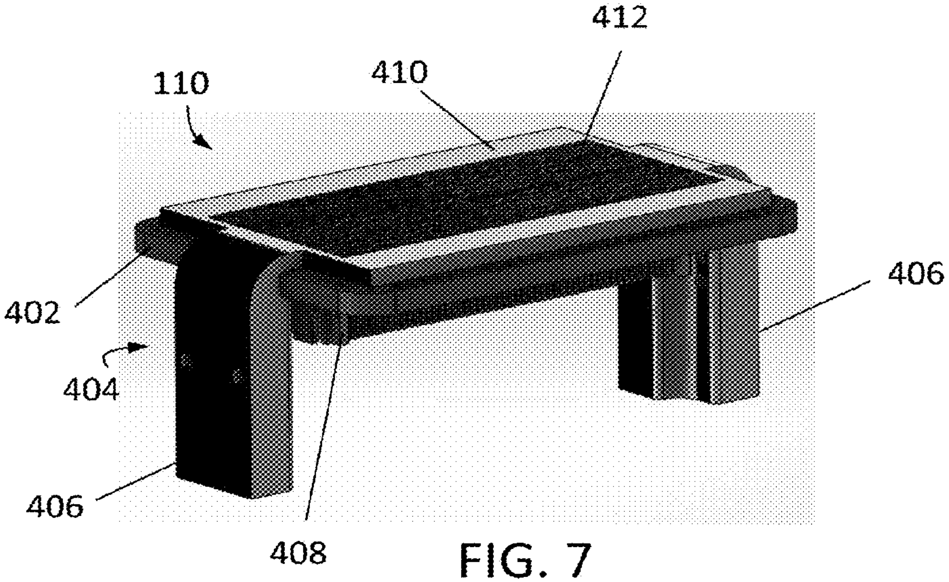


FIG. 7

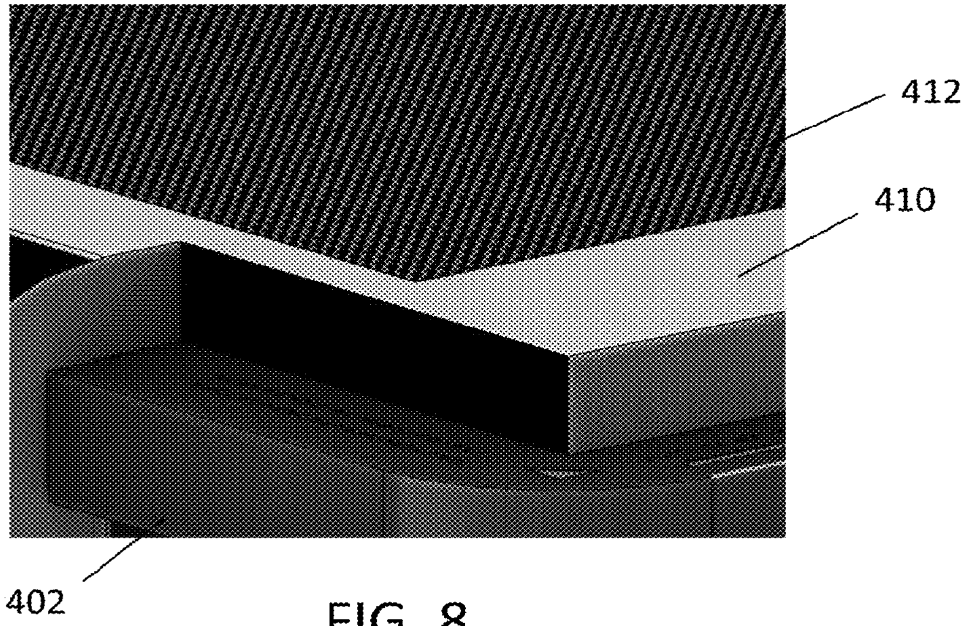


FIG. 8

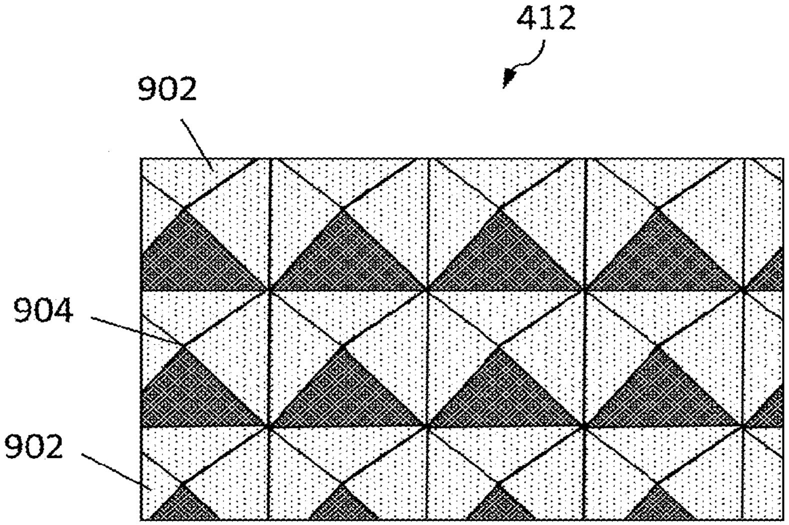


FIG. 9

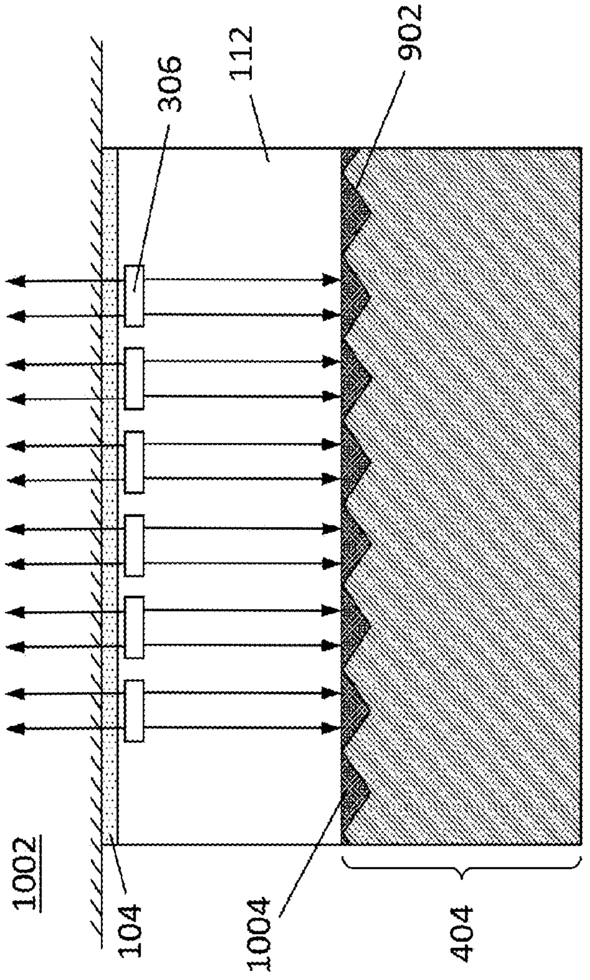


FIG. 10

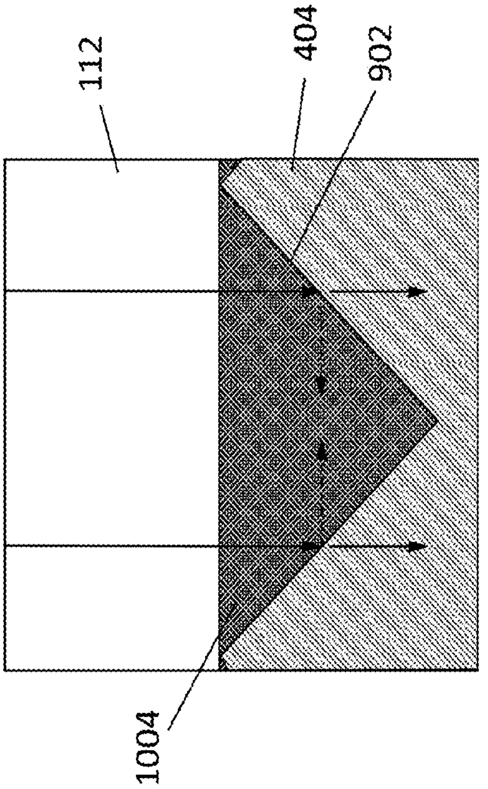


FIG. 11

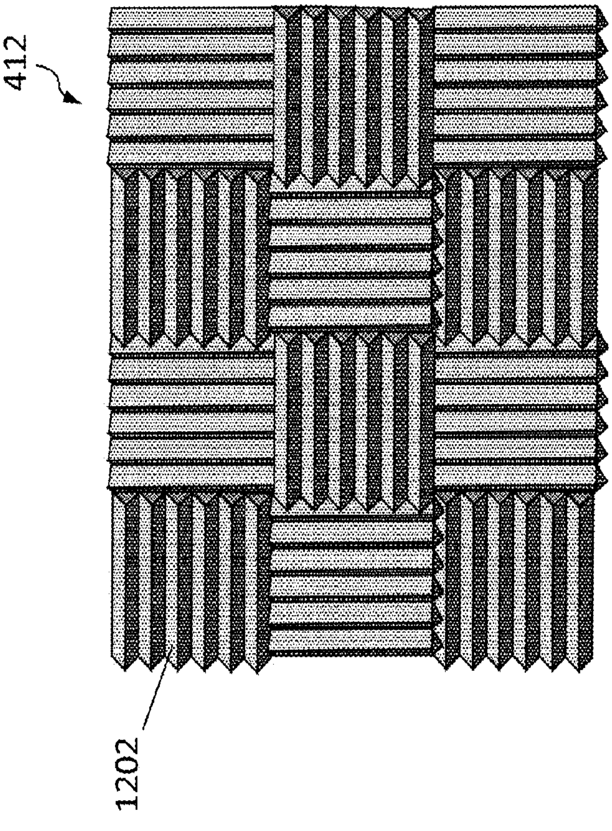


FIG. 12

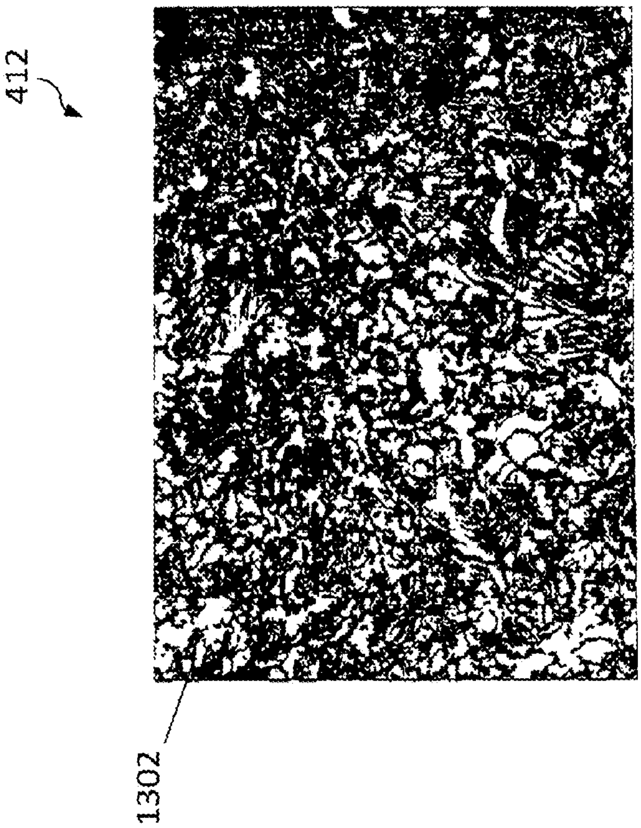


FIG. 13

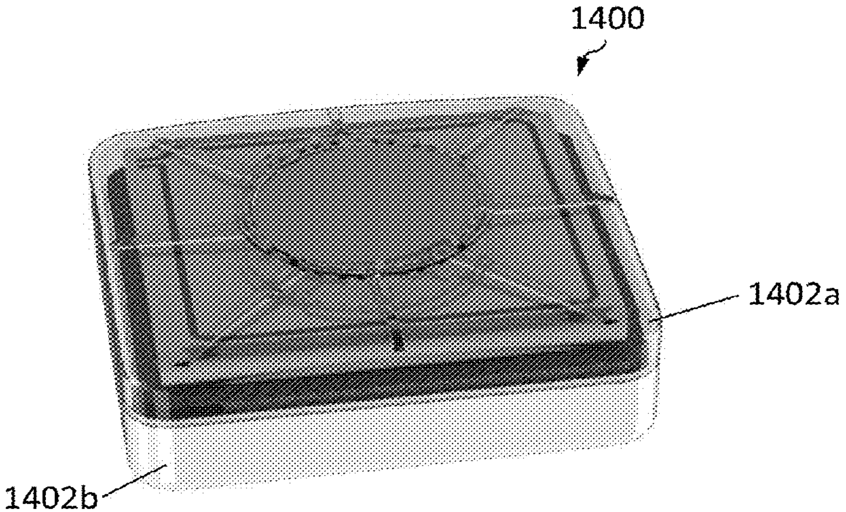


FIG. 14

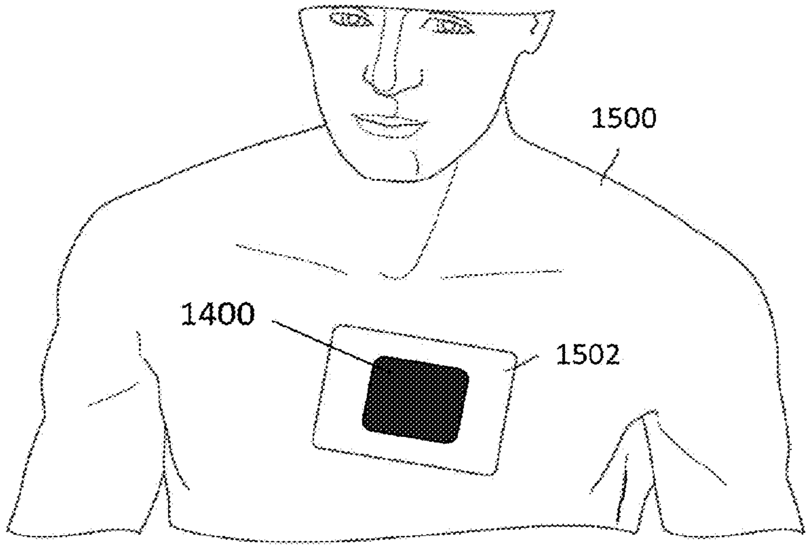


FIG. 15

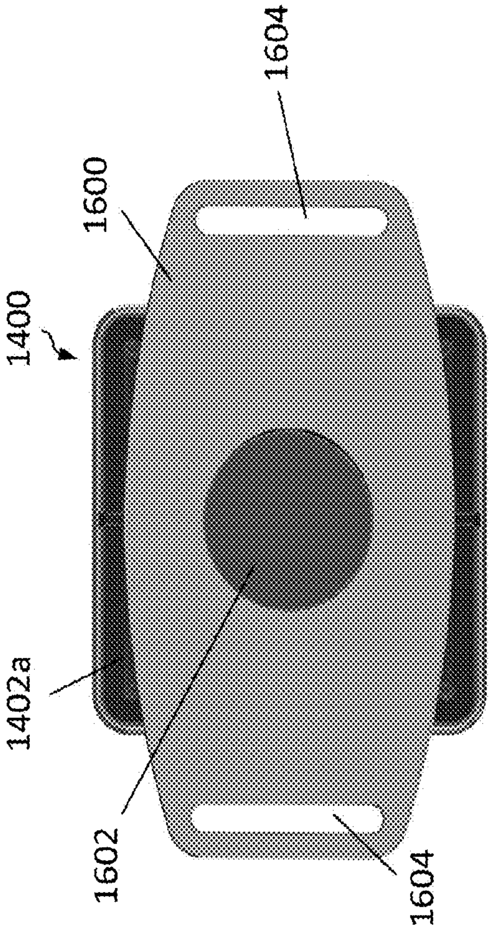


FIG. 16

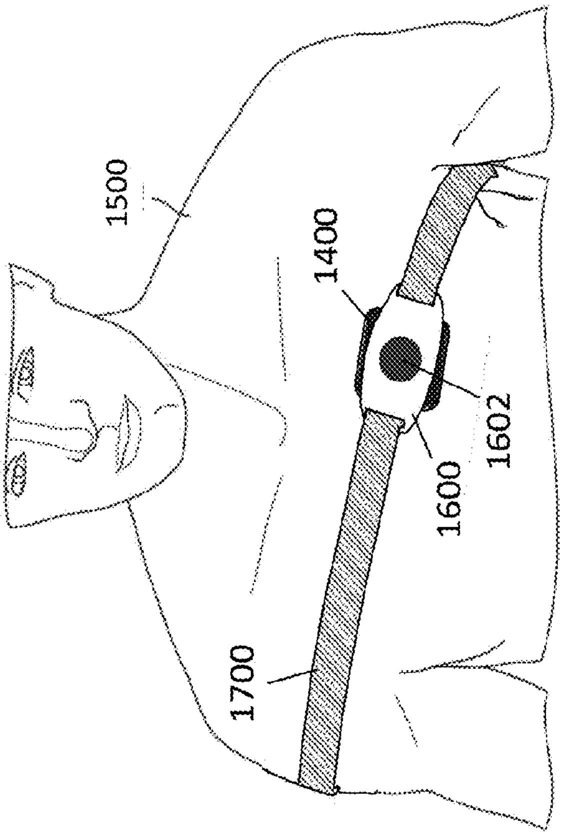


FIG. 17

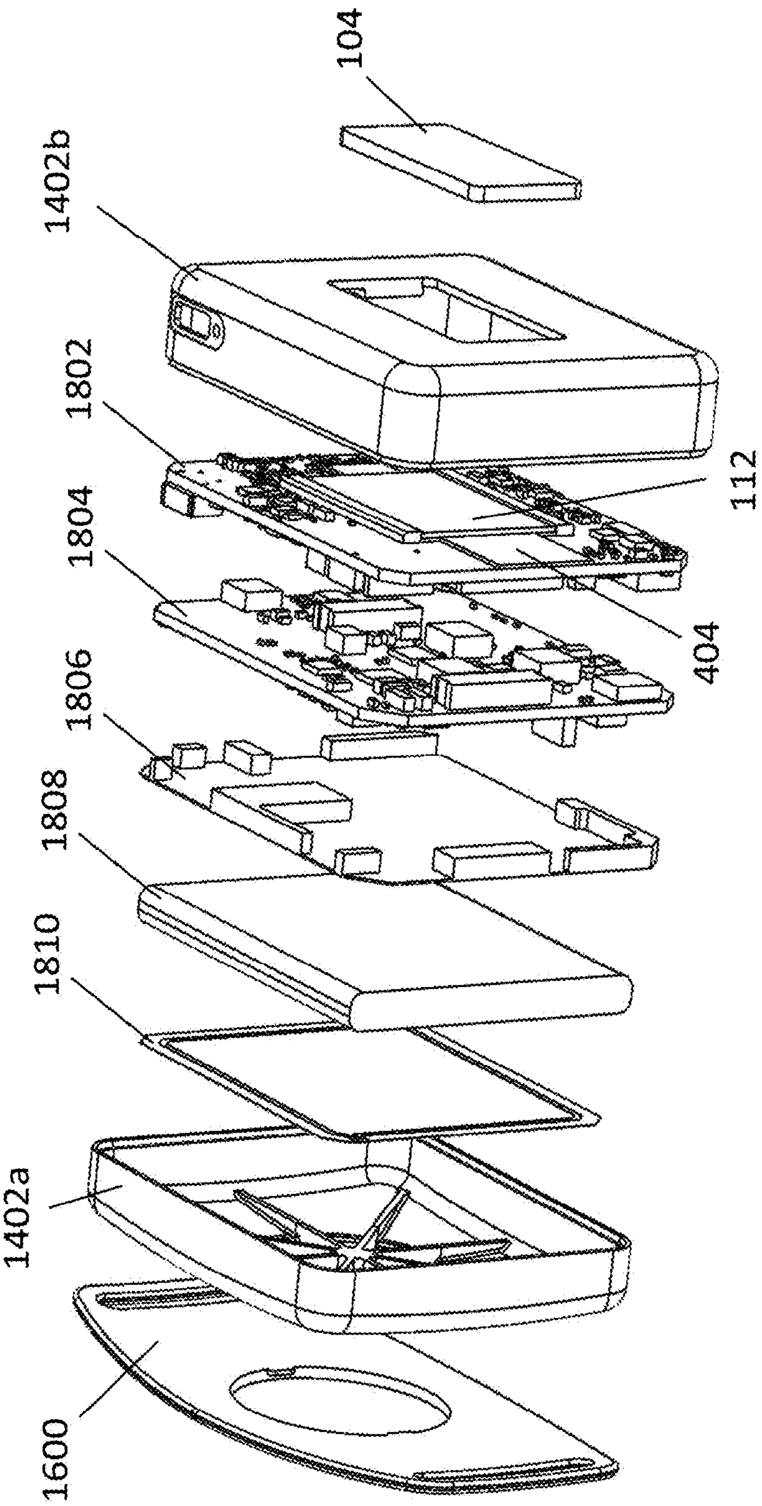


FIG. 18

REARWARD ACOUSTIC DIFFUSION FOR ULTRASOUND-ON-A-CHIP TRANSDUCER ARRAY

BACKGROUND

[0001] The present disclosure relates generally to ultrasound technology. In particular, the present disclosure relates to an apparatus and method for rearward acoustic diffusion for an ultrasound-on-chip transducer array.

[0002] Ultrasound devices may be used to perform diagnostic imaging and/or treatment, using sound waves with frequencies that are higher with respect to those audible to humans. Ultrasound imaging may be used to see internal soft tissue body structures, for example to find a source of disease or to exclude any pathology. When pulses of ultrasound are transmitted into tissue (e.g., by using a probe), sound waves are reflected off the tissue with different tissues reflecting varying degrees of sound. These reflected sound waves may then be recorded and displayed as an ultrasound image to the operator. The strength (amplitude) of the sound signal and the time it takes for the wave to travel through the body provide information used to produce the ultrasound image. Many different types of images can be formed using ultrasound devices, including real-time images. For example, images can be generated that show two-dimensional cross-sections of tissue, blood flow, motion of tissue over time, the location of blood, the presence of specific molecules, the stiffness of tissue, or the anatomy of a three-dimensional region.

SUMMARY

[0003] In one embodiment, a heat sink device has a non-planar mounting surface and an ultrasound-on-chip device attached to the non-planar mounting surface, the ultrasound-on-chip device including an ultrasonic transducer substrate bonded to an integrated circuit substrate. The non-planar mounting surface of the heat sink device is configured to diffuse acoustic waves that are incident thereupon.

[0004] In another embodiment, an ultrasound probe includes a housing and an ultrasonic transducer assembly disposed within the housing, the ultrasonic transducer assembly further including a metal heat sink device having a non-planar mounting surface, and an ultrasonic transducer substrate attached to the non-planar mounting surface of the heat sink device. The non-planar mounting surface of the heat sink device may be configured to diffuse acoustic waves that are incident thereupon.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] Various aspects and embodiments of the disclosed technology will be described with reference to the following Figures. It should be appreciated that the figures are not necessarily drawn to scale. Items appearing in multiple figures are indicated by the same reference number in all the figures in which they appear, and where:

[0006] FIG. **1** is a perspective view of a handheld ultrasound probe suitable for use with exemplary embodiments;

[0007] FIG. **2** is an exploded perspective view of the ultrasound probe of FIG. **1**;

[0008] FIG. **3** is a partial cross-sectional view of an exemplary ultrasound-on-chip device suitable for use with exemplary embodiments;

[0009] FIG. **4** is perspective view of the ultrasonic transducer assembly shown in FIG. **2**;

[0010] FIG. **5** illustrates the ultrasonic transducer assembly shown in FIG. **2**, with the acoustic lens removed; and

[0011] FIG. **6** illustrates the ultrasonic transducer assembly shown in FIG. **5**, with the ultrasound-on-chip device removed to reveal a heat sink having a planar mounting surface;

[0012] FIG. **7** illustrates a heat sink design in accordance with an exemplary embodiment, including a non-planar mounting surface;

[0013] FIG. **8** is an enlarged view of the heat sink design shown in FIG. **7**;

[0014] FIG. **9** is a top view illustrating the pattern of the non-planar mounting surface;

[0015] FIG. **10** is a schematic cross-sectional view illustrating transmission of acoustic energy by an ultrasonic transducer assembly, according to embodiments, in forward and rearward directions;

[0016] FIG. **11** is an enlarged view of an ultrasound-on-chip/heat sink interface in FIG. **10**;

[0017] FIG. **12** illustrates an alternative embodiment of the pattern of the non-planar mounting surface;

[0018] FIG. **13** illustrates another alternative embodiment of the pattern of the non-planar mounting surface;

[0019] FIG. **14** is a perspective view of another type of ultrasound probe suitable for use with exemplary embodiments;

[0020] FIG. **15** illustrates the ultrasound probe of FIG. **14** affixed to a patient;

[0021] FIG. **16** is a top view illustrating an alternative fastening mechanism for the ultrasound probe of FIG. **14**;

[0022] FIG. **17** illustrates the ultrasound probe of FIG. **14** affixed to the patient; and

[0023] FIG. **18** is an exploded perspective view of the ultrasound probe of FIG. **16**.

DETAILED DESCRIPTION

[0024] Medical ultrasound imaging transducers are used to transmit acoustic pulses that are coupled into a patient through one or more acoustic matching layers. After sending each pulse, the transducers then detect incoming body echoes. The echoes are produced by acoustic impedance mismatches of different tissues (or tissue types) within the patient which enable both partial transmission and partial reflection of the acoustic energy. Exemplary types of ultrasonic transducers include those formed from piezoelectric materials or, more recently, capacitive micromachined ultrasonic transducers (CMUTs) that are formed using a semiconductor substrate.

[0025] In the case of a CMUT device, a flexible membrane is suspended above a conductive electrode by a small gap. When a voltage is applied between the membrane and the electrode, Coulombic forces attract the flexible membrane to the electrode. As the applied voltage varies over time, so does the membrane position, thereby generating acoustic energy that radiates from the face of the transducer as the membrane moves. However, in addition to transmitting acoustic energy in a forward direction toward the body being imaged, the transducers simultaneously transmit acoustic energy in a backward direction away from the patient being imaged. That is, some portion of the acoustic energy is also propagated back through the CMUT support structure(s), such as a silicon wafer for example.

[0026] When an incident ultrasound pulse encounters a large, smooth interface of two body tissues with different acoustic impedances, the sound energy is reflected back to the transducer. This type of reflection is called specular reflection, and the echo intensity generated is proportional to the acoustic impedance gradient between the two mediums. The same holds true for structures located in a direction away from the patient being imaged, such as a semiconductor chip/metal heat sink interface. If an incident ultrasound beam reaches an acoustic interface at substantially a normal angle (90°), almost all of the generated echo will travel back toward the originating transducer.

[0027] Typically, for both piezoelectric and capacitive transducer devices, an acoustic backing material is positioned on a back side of an ultrasonic transducer array in order to absorb and/or scatter as much of the backward transmitted acoustic energy as possible and prevent such energy from being reflected by any support structure(s) back toward the transducers and reducing the quality of the acoustic image signals obtained from the patient by creating interference. In general, however, materials that have good acoustic attenuating and scattering properties may also have poor thermal conductivity and/or coefficient of thermal expansion (CTE) mismatches with respect to the transducer substrate material. Accordingly, exemplary embodiments disclosed herein introduce a heat sink device on which an ultrasonic transducer may be attached that provides both acoustic attenuation/scattering capability, as well as thermal dissipation capability. In one embodiment, a metal heat sink device (e.g., copper) may have a non-planar mounting surface and an ultrasound-on-chip substrate attached to the non-planar mounting surface of the heat sink device.

[0028] As compared to a planar surface, the non-planar mounting surface of the heat sink device can be configured to reduce the amount of acoustic energy reflected off the face of the heat sink device and directed back through the body of the semiconductor substrate toward the transducers. Where the angle of incidence with a specular boundary is less than 90°, the echo will not return to the originating transducer; rather, it is reflected at an angle equal to the angle of incidence (similar to visible light reflecting in a mirror). Moreover, in contrast to an acoustic backing that physically separates the transducer substrate from the heat sink surface, a portion of the exemplary heat sink surface may have direct physical contact with the chip surface. Although heat sinking performance may be optimized using a planar surface with maximum surface area contact between the heat sink and the substrate, this comes at a cost of acoustic performance. Therefore, with such a tradeoff, both the benefits of rearward acoustic diffusion and heat dissipation may be achieved.

[0029] Embodiments of the present disclosure are described below with reference to the accompanying drawings, in which some, but not all, embodiments of the present disclosure are shown. The present disclosure can be embodied in many different forms and should not be construed as limited to the embodiments set forth herein. Rather, these embodiments are provided so that this disclosure clearly satisfies applicable legal requirements. Like numbers refer to like elements throughout.

[0030] Referring initially to FIG. **1** and FIG. **2**, an exemplary ultrasound probe **100** is depicted in a perspective view and an exploded perspective view, respectively. It should be understood, however, that the ultrasound probe **100** depicted in FIG. **1** and FIG. **2** represents one exemplary application for the acoustic attenuation features described herein, and other form factors, applications and devices are also contemplated. As shown in FIG. **1**, the exemplary ultrasound probe **100** is a handheld probe that includes a probe housing **102** having an acoustic lens **104** and shroud **106** disposed at a first end thereof, and a cable assembly **108** disposed at a second end thereof. The shroud **106** prevents direct contact between an ultrasonic transducer assembly **110** (FIG. **2**) and a patient (not shown) when the ultrasound probe **100** is used to image the patient.

[0031] In addition to imaging, the acoustic lens **104** may also be configured to focus acoustic energy to spots having areas of the size required for high-intensity focused ultrasound (HIFU) procedures. Furthermore, the acoustic lens **104** may acoustically couple the ultrasonic transducer assembly **110** to the patient (not shown) to minimize acoustic reflections and attenuation. In some embodiments, the acoustic lens **104** may be fabricated with materials providing impedance matching between ultrasonic transducer assembly **110** and the patient. In still other embodiments, the acoustic lens **104** may provide electric insulation and may include shielding to prevent electromagnetic interference (EMI). Additionally, the shroud **106** and acoustic lens **104** may provide a protective interface to absorb or reject stress between the ultrasonic transducer assembly **110** and the acoustic lens **104**.

[0032] As also shown in FIG. **2**, the ultrasonic transducer assembly **110** includes an ultrasound-on-chip device **112** having an ultrasonic transducer array that is covered by the acoustic lens **104** when the ultrasound probe **100** is assembled. An interior region of the ultrasound probe **100**, encapsulated by upper probe housing section **102***a* and lower probe housing section **102***b*, may also include components such as a first circuit board **114**, a second circuit board **116** and a battery **118**. The circuit boards **114** and **116** may include circuitry configured to operate the ultrasonic transducer arrangement **110** in a transmit mode to transmit ultrasound signals, or receive mode, to convert received ultrasound signals into electrical signals. Additionally, such circuitry may provide power to the ultrasonic transducer assembly **110**, generate drive signals for the ultrasonic transducer assembly **110**, process electrical signals produced by the ultrasonic transducer assembly **110**, or perform any combination of such functions. The cable assembly **108** may carry any suitable analog and/or digital signals to and from circuit boards **114** and **116**.

[0033] An exemplary configuration for the ultrasound-on-chip device **112** is illustrated in the partial cross-sectional view of FIG. **3**. In the embodiment depicted, the ultrasound-on-chip device **112** includes an ultrasonic transducer substrate **302** bonded to an integrated circuit substrate **304**, such as a complementary metal oxide semiconductor (CMOS) substrate. The ultrasonic transducer substrate **302** may have a plurality of cavities **306** formed therein, and is an example of a CMUT device as described above. The cavities **306** are formed between a first silicon device layer **308** and a second silicon device layer **310**. A silicon oxide layer **312** (e.g., a thermal silicon oxide such as a silicon oxide formed by thermal oxidation of silicon) may be formed between the first and second silicon device layers **308** and **310**, with the cavities **306** being formed therein. In this non-limiting example, the first silicon device layer **308** may be configured as a bottom electrode and the second silicon device layer **310**

may be configured as a membrane. Thus, the combination of the first silicon device layer **308**, second silicon device layer **310**, and cavities **306** may form an ultrasonic transducer (e.g., a CMUT), of which six are illustrated in this non-limiting cross-sectional view. To facilitate operation as a bottom electrode or membrane, one or both of the first silicon device layer **308** and second silicon device layer **310** may be doped to act as conductors, and in some cases are highly doped (e.g., having a doping concentration greater than 10^{15} dopants/cm^3 or greater).

[0034] In terms of the aforementioned forward direction toward a subject being imaged, this would be in the upward direction with respect to the view in FIG. **3**, whereas the backward direction away from the subject being imaged would be in the downward direction with respect to the view in FIG. **3**. Additional information regarding the fabrication and integration of CMUTs with CMOS wafers may be found, for example, in U.S. Pat. No. 9,067,779, assigned to the assignee of the present application, the contents of which are incorporated by reference herein in their entirety. Again however, it should be appreciated that the ultrasonic transducer substrate **302**/CMOS substrate **304** embodiment represents just one possible configuration for the ultrasound-on-chip device **112**. Other configurations are also possible including, but not limited to, a side-by-side arrangement where transducers and CMOS circuitry are formed on a same substrate, as well as arrays formed from piezoelectric micromachined ultrasonic transducers (PMUTs), or other suitable types of ultrasonic transducers. In still other embodiments, the ultrasound-on-chip device **112** may include an ultrasonic transducer array by itself (i.e., an ultrasonic transducer chip), where CMOS circuitry is located on a different substrate or circuit board altogether.

[0035] Referring now to FIG. **4**, a perspective view of the ultrasonic transducer assembly **110** is illustrated in further detail. In the embodiment shown, the ultrasonic transducer assembly **110** includes an interposer circuit board **402** and a heat sink **404** formed from a thermally conductive material such as copper, for example. In the particular view of FIG. **4**, only side tabs **406** of the heat sink **404** are most clearly depicted, as both the top (mounting) surface of the heat sink **404** and the ultrasound-on-chip device **112** are covered by the acoustic lens **104** for illustration purposes. Subsequent views depict these obscured components in further detail, however. For example, FIG. **5** depicts the ultrasonic transducer assembly **110** of FIG. **4**, with the acoustic lens **104** removed to reveal the ultrasound-on-chip device **112**. The interposer circuit board **402** serves as an electrical interface between the ultrasound-on-chip device **112** and the first and second circuit boards **114**, **116** shown in FIG. **2**. Connections between a mounting surface of the ultrasound-on-chip device **112** and a first side of the interposer circuit board **402** may be made, for example, using individual wire bonds (not shown) that may in turn be encapsulated by an encapsulant material (not shown). In addition, the interposer circuit board **402** may include one or more connectors **408** configured to mate with corresponding connectors of the first and second circuit boards **114**, **116**.

[0036] FIG. **6** illustrates the ultrasonic transducer assembly **110** with the ultrasound-on-chip device **112** removed to reveal a planar mounting surface **410** of a heat sink **404**. Although the heat sink **404** shown in FIG. **6** provides desired thermal dissipation heat generated by the ultrasound-on-chip device **112**, the properties of the heat sink metal affect how much acoustic energy is reflected and how much is absorbed. In this case, the planar (flat) mounting surface **410** may act as an acoustic reflector that redirects unabsorbed acoustic waves back toward the transducers of the ultrasound-on-chip device **112**. This is undesirable, since such reflected acoustic waves can contribute to false image data.

[0037] Accordingly, FIG. **7** illustrates a heat sink design in accordance with an exemplary embodiment, in which a substantial portion of the mounting surface **410** of the heat sink **404** is a non-planar surface **412**. Where geometric features of the mounting surface **410** of the heat sink **404** are made non-planar (as opposed to planar), acoustic sound waves are incident at a non-normal angle with respect to the heat sink surface. Those waves that are not absorbed by the heat sink **406** may be reflected in a direction other than toward the originating transducer and may, in some instances, cancel with one another or at least be scattered in a direction where they may have relatively longer travel times. This in turn may allow for more absorption by the heat sink **406**, reducing interference with acoustic waves being detected from the imaged patient. The non-planar surface **412** may, in one embodiment, encompass an area of the mounting surface **410** corresponding to locations of the ultrasonic transducers of the ultrasound-on-chip device **112** when attached to the heat sink **404**.

[0038] FIG. **8** is an enlarged view of a portion of the heat sink **404** in FIG. **7**. The non-planar surface **412** may be defined by forming patterned features in the mounting surface **410**. Exemplary techniques for forming the patterned features of the non-planar surface **412** techniques include, but are not limited to, stamping, molding, etching or other microfabrication techniques. The non-planar pattern may include regular features, such as illustrated in FIG. **9**, or irregular features as described in further detail hereinafter. The exemplary pattern for the non-planar surface **412** in FIG. **9** includes a plurality of pyramid structures, each having triangular surfaces **902** converging to a single point **904**. Other patterns are also contemplated, however.

[0039] FIG. **10** schematically illustrates the propagation of acoustic waves from an ultrasound-on-chip device **112** attached to the heat sink **404**. It should be noted that the device **112** shown in FIG. **10** is a simplified schematic for illustrative purposes, and does differentiate between the transducer portion and the CMOS integrated circuit portion of the device **112**, other than depicting the CMUT cavities **306**. As will be noted, acoustic waves are transmitted from the transducers in a forward direction into the tissue **1002** of a patient via the acoustic lens **104**, as well as in a backward direction through the substrate material of ultrasound-on-chip device **112** toward the interface with the heat sink **404**.

[0040] An adhesive material **1004** may be used to securely attach the ultrasound-on-chip device **112** to the interface with the heat sink **404**. The adhesive material **1004** may be any suitable material known in the art, such as an epoxy material, and optionally a tungsten filled epoxy material or epoxy mixture (with tungsten and/or additional elements) selected for acoustic dampening capabilities. In the enlarged view of FIG. **11**, some of the incident acoustic energy incident upon the surfaces **902** may be transmitted through the interface and into the heat sink **404**, and some of the incident acoustic energy incident upon the surfaces **902** may be reflected (scattered) in directions away from the transducers. In some cases, reflected acoustic waves may cancel with other reflected acoustic waves.

[0041] As indicated above, other patterns are also possible for a non-planar surface **412** of the heat sink **404**. For example, FIG. **12** illustrates an alternative embodiment of the pattern of the non-planar mounting surface **412**. Similar to the embodiment of FIG. **9**, a pattern of prism structures **1202** (also referred to as wedge structures) may be formed (e.g., by stamping) on the mounting surface of the heat sink. The structures **1202** may, for example, be formed in groups of repeating arrangements, where structures in adjacent groups have longitudinal apexes disposed orthogonal to one another. Still another embodiment for a non-planar heat sink surface **412** is illustrated in FIG. **13**. In this embodiment, the non-planar surface **412** is a sintered surface **1302**, which may be formed using a metallic powder to create an irregular surface. Optionally, a tungsten filled epoxy material may also be applied in bonding an ultrasound-on-chip device **112** to the non-planar surfaces **412** of either FIG. **12** or FIG. **13**.

[0042] In addition to handheld probe embodiments such as depicted in FIG. **1** and FIG. **2**, it is further contemplated that other ultrasound probe form factors may incorporate the above described acoustically diffusing heat sink embodiments. For example, FIG. **14** is a perspective view illustrating an ultrasound probe **1400** that is embodied in a patch configuration, and having an upper housing **1402***a* and a lower housing **1402***b*. The probe **1400** is shown coupled to a patient **1500** in FIG. **15**, and may be configured to transmit, wirelessly for example, collected ultrasound data to one or more external devices (not shown) for further processing. In the example depicted, the probe **1400** may also be provided with dressing **1502** that provides an adhesive surface for both the probe housing as well as to the skin of the patient. One non-limiting example of such a dressing **1502** is Tegaderm™, a transparent medical dressing available from 3M Corporation. Although not specifically shown in FIG. **15**, the lower housing **1402***b* may include an opening that aligns with a corresponding opening in the dressing **1502** so that transducer elements of the ultrasound probe **1400** may be acoustically coupled to the patient **1500**.

[0043] Referring to FIG. **16**, an alternative fastening mechanism for the ultrasound probe **1400** is illustrated. In the embodiment shown, the ultrasound probe **1400** further includes a buckle **1600** affixed to the upper housing **1402***a* via a post **1602** using, for example, a threaded engagement between the buckle **1600** and the post **1602**. Other attachment configurations are also contemplated, however. As further shown in FIG. **16**, the buckle **1600** includes a pair of slots **1604** that in turn accommodate a strap **1700** (FIG. **17**). In this example, the strap **1700** is wrapped around the patient **1500** and appropriately tightened in order to secure the ultrasound probe **1400** to a desired location on the patient **1500** for acquisition of desired ultrasound data.

[0044] FIG. **18** illustrates an exploded perspective view of the ultrasound probe **1400** of FIG. **16**. For ease of illustration and comparison, similar components with respect to the embodiment of FIG. **1** and FIG. **2** are designated with similar reference numerals. For example, in addition to the upper housing **1402***a*, lower housing **1402***b* and buckle, the ultrasound probe **1400** further includes an acoustic lens **104** to cover the ultrasound-on-chip device **112**, which in turn is attached to a heat sink device **404**. Although not specifically shown in FIG. **18**, the mounting surface of the heat sink device **404** may be provided with any of the acoustically diffusing features discussed above, such as for example in any of the embodiments of FIGS. **7**, **12** and **13**.

[0045] In contrast to the handheld probe embodiment of FIGS. **1-8** in which the ultrasonic transducer assembly **110** includes an interposer circuit board **402**, the ultrasound-on-chip device **112** and heat sink device **404** are attached directly to a first circuit board **1802**. In addition, the ultrasound probe **1400** further includes, by way of example, a second circuit board **1804** (e.g., for power supply components), an insulator board **1806**, battery **1808** and antenna **1810** (e.g., to enable wireless communication to and from the ultrasound probe **1400**). In any case, it will be appreciated that the above described thermal and acoustic benefits provided by the heat sink device **404** are applicable to ultrasound probes of various form factors.

[0046] The techniques described herein are exemplary, and should not be construed as implying any particular limitation on the present disclosure. It should be understood that various alternatives, combinations and modifications could be devised by those skilled in the art from the present disclosure. For example, steps associated with the processes described herein can be performed in any order, unless otherwise specified or dictated by the steps themselves. The present disclosure is intended to embrace all such alternatives, modifications and variances that fall within the scope of the appended claims.

What is claimed is:

1. An apparatus, comprising:

a heat sink device having a non-planar mounting surface; and

an ultrasonic transducer substrate attached to the non-planar mounting surface of the heat sink device;

wherein the non-planar mounting surface of the heat sink device is configured to diffuse acoustic waves that are incident thereupon.

2. The apparatus of claim **1**, wherein the ultrasonic transducer substrate comprises a portion of an ultrasound-on-chip device attached to the non-planar mounting surface of the heat sink device, the ultrasound-on-chip device further comprising the ultrasonic transducer substrate bonded to an integrated circuit substrate.

3. The apparatus of claim **1**, wherein the non-planar mounting surface of the heat sink device comprises a pattern.

4. The apparatus of claim **3**, wherein the pattern comprises a plurality of pyramid structures.

5. The apparatus of claim **3**, wherein the pattern comprises a plurality of prism structures.

6. The apparatus of claim **1**, wherein the non-planar mounting surface of the heat sink device comprises a plurality of irregular features.

7. The apparatus of claim **6**, wherein plurality of irregular features comprises a sintered surface.

8. The apparatus of claim **1**, further comprising an adhesive material that attaches the ultrasound-on-chip device to the non-planar mounting surface of the heat sink device.

9. The apparatus of claim **8**, wherein the adhesive material comprises an epoxy material.

10. The apparatus of claim **8**, wherein the adhesive material comprises a tungsten filled epoxy material.

11. The apparatus of claim **1**, wherein the ultrasound transducer substrate is further configured to accommodate a solid state monolithic ultrasound transducer.

12. An ultrasound probe, comprising:

a housing; and

an ultrasonic transducer assembly disposed within the housing, the ultrasonic transducer assembly further comprising a metal heat sink device having a non-planar mounting surface, and an ultrasonic transducer substrate attached to the non-planar mounting surface of the heat sink device;

wherein the non-planar mounting surface of the heat sink device is configured to diffuse acoustic waves that are incident thereupon.

13. The ultrasound probe of claim **12**, wherein the ultrasonic transducer substrate comprises a portion of an ultrasound-on-chip device attached to the non-planar mounting surface of the heat sink device, the ultrasound-on-chip device further comprising the ultrasonic transducer substrate bonded to an integrated circuit substrate.

14. The ultrasound probe of claim **13**, wherein the non-planar mounting surface of the heat sink device comprises a stamped pattern.

15. The ultrasound probe of claim **14**, wherein the stamped pattern comprises a plurality of pyramid structures.

16. The ultrasound probe of claim **14**, wherein the stamped pattern comprises a plurality of prism structures.

17. The ultrasound probe of claim **12**, wherein the non-planar mounting surface of the heat sink device comprises a plurality of irregular features.

18. The ultrasound probe of claim **17**, wherein the plurality of irregular features comprises a sintered surface.

19. The ultrasound probe of claim **12**, further comprising an adhesive material that attaches the ultrasound-on-chip device to the non-planar mounting surface of the heat sink device.

20. The ultrasound probe of claim **19**, wherein the adhesive material comprises an epoxy material.

21. The ultrasound probe of claim **19**, wherein the adhesive material comprises a tungsten filled epoxy material.

22. The ultrasound probe of claim **12**, wherein the housing comprises a handheld probe.

23. The ultrasound probe of claim **12**, wherein the housing comprises a patch configured to be affixed to a patient.

24. The ultrasound probe of claim **12**, wherein the ultrasound transducer assembly further comprises a solid state monolithic ultrasound transducer.

25. The apparatus of claim **24**, wherein the solid state monolithic ultrasound transducer further comprises a plurality of capacitive ultrasound transducers bonded with an integrated circuit.

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专利名称(译)	用于片上超声换能器阵列的后向声扩散		
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申请(专利权)人(译)	蝶形网络，INC.		
当前申请(专利权)人(译)	蝶形网络，INC.		
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摘要(译)

散热装置具有非平面安装表面和附接到非平面安装表面的超声换能器基板。散热装置的非平面安装表面被配置为扩散入射在其上的声波。