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(54) **ULTRASOUND TRANSDUCER ARRAYS**

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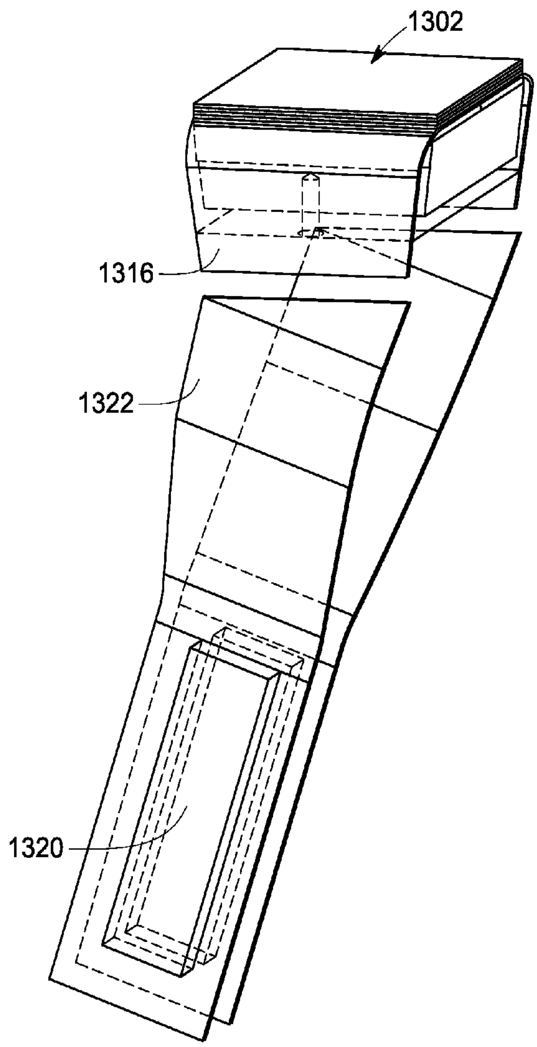
(57) **ABSTRACT**

An ultrasound transducer array for an ultrasound probe is presented. The ultrasound transducer array includes a support structure. Further, the ultrasound transducer array includes a plurality of electro-acoustic modules coupled to the support structure, wherein each of the plurality of electro-acoustic modules comprises at least one matrix acoustic array and an interconnect element, wherein each of the plurality of electro-acoustic modules is interchangeable on the support structure so as to adapt to one or more shapes of the ultrasound probe, and wherein each of the plurality of electro-acoustic modules operates in a manner substantially identical to each other of the plurality of electro-acoustic modules.



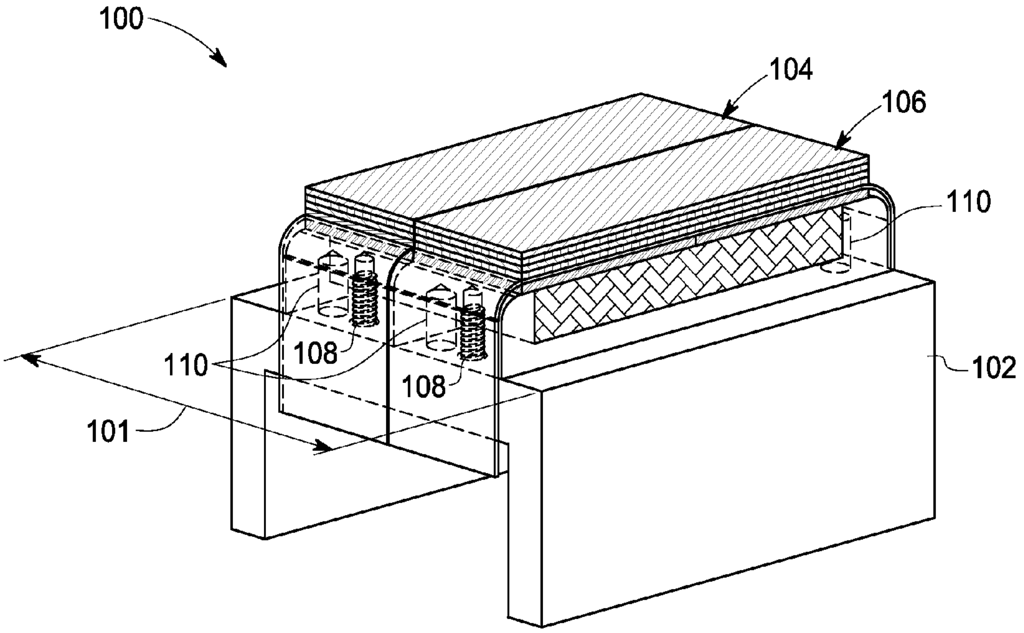



FIG. 1

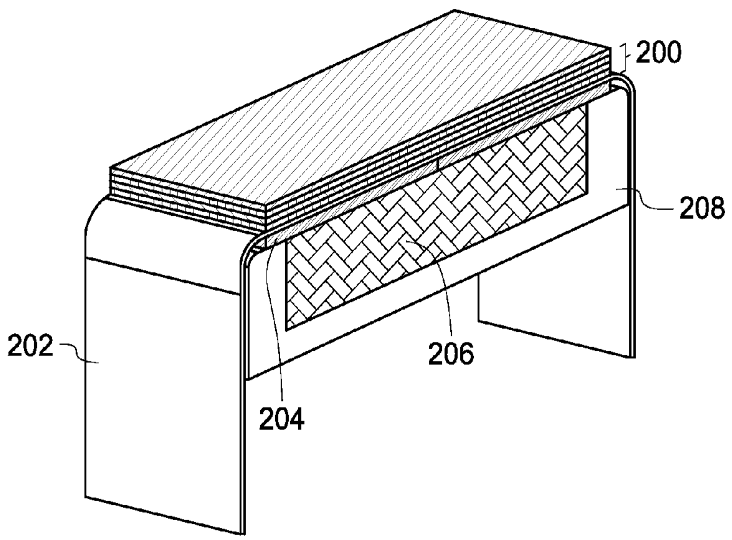



FIG. 2

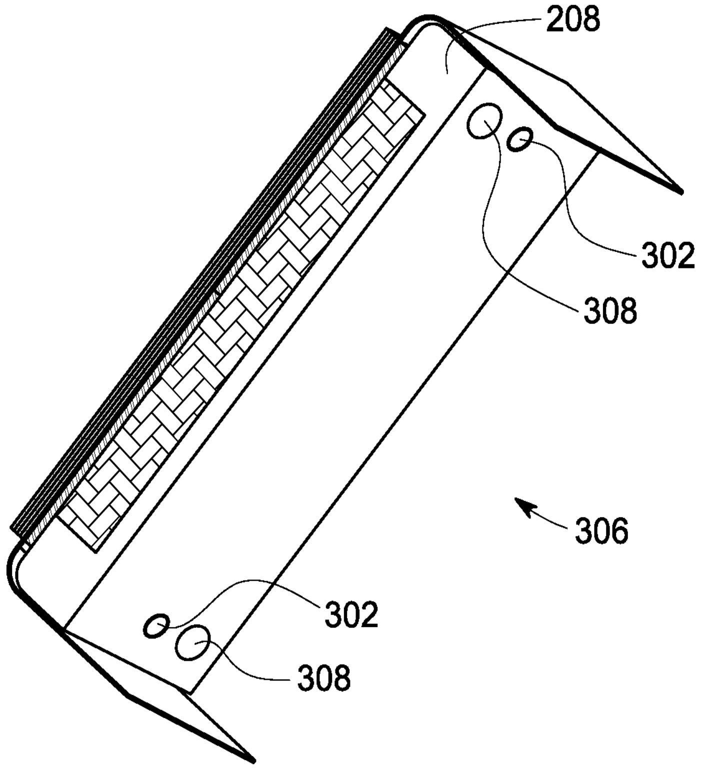



FIG. 3

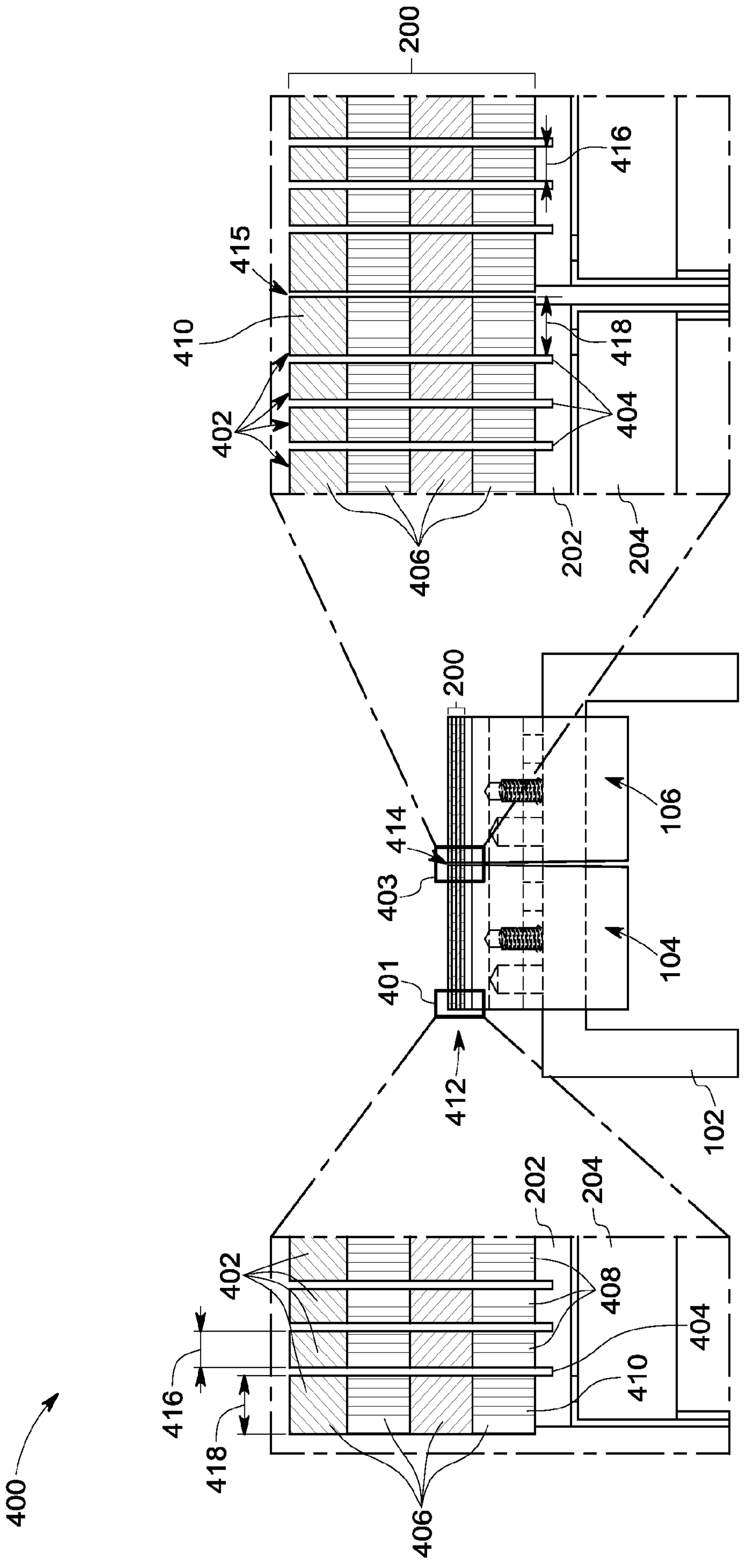

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FIG. 4

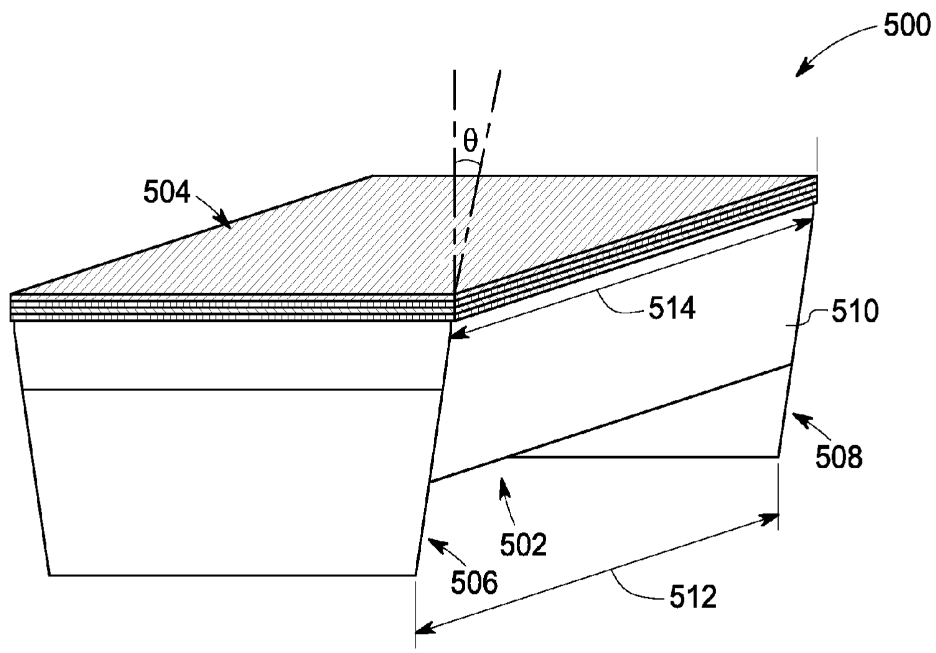


FIG. 5

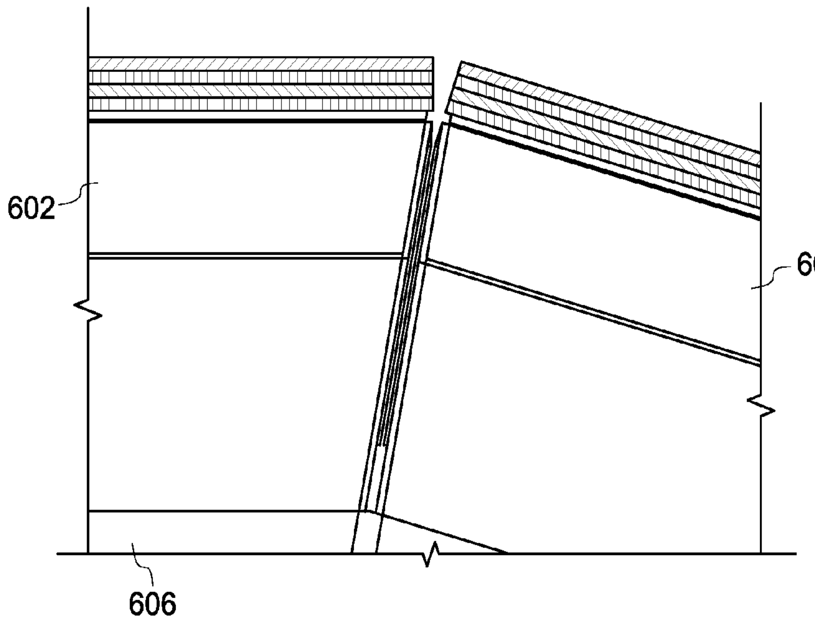


FIG. 6

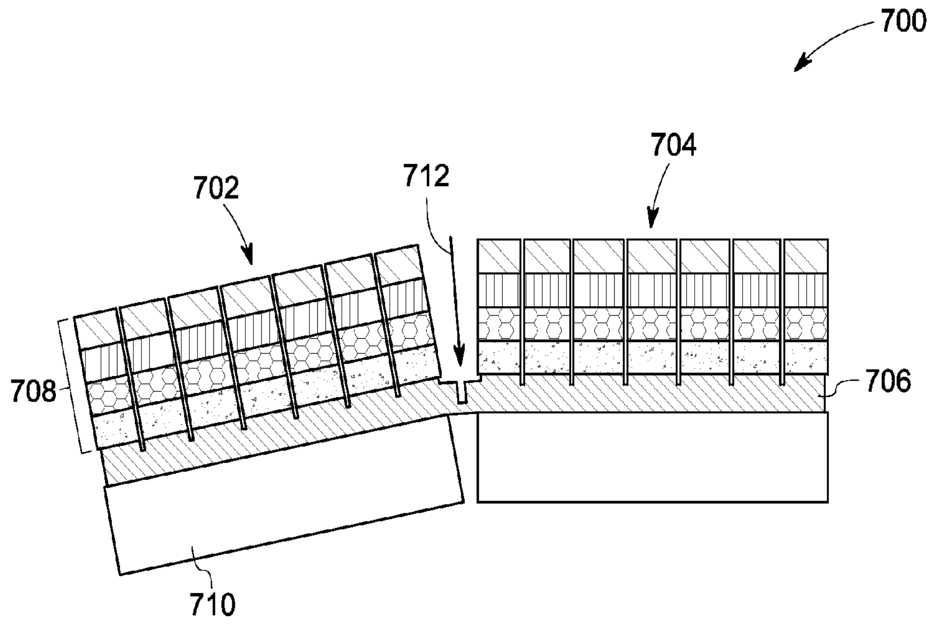


FIG. 7

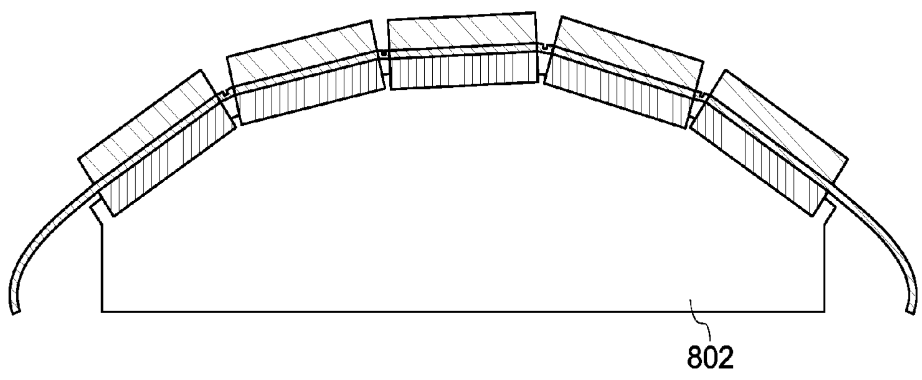


FIG. 8

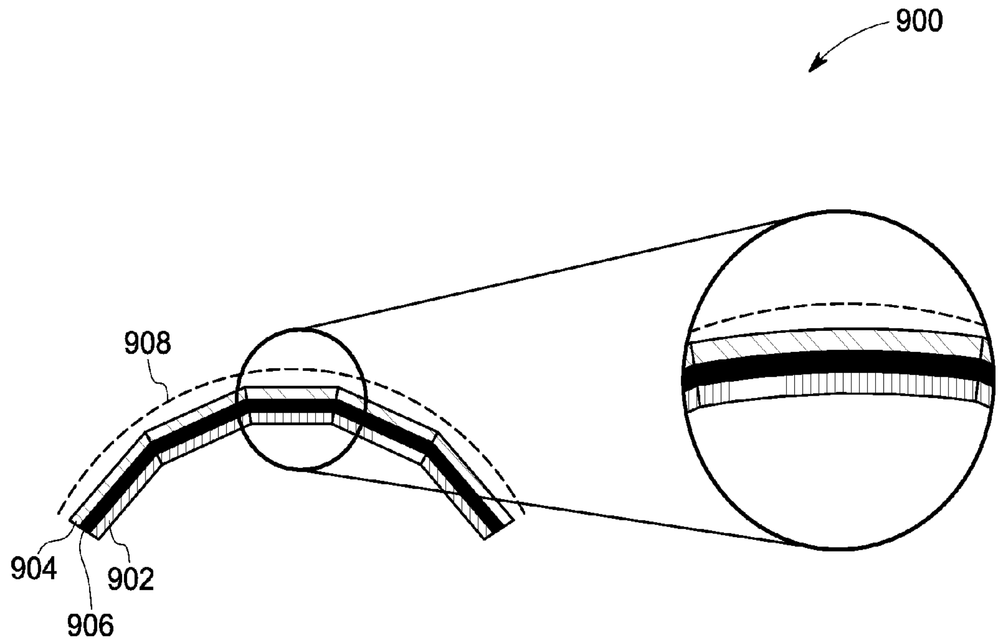


FIG. 9

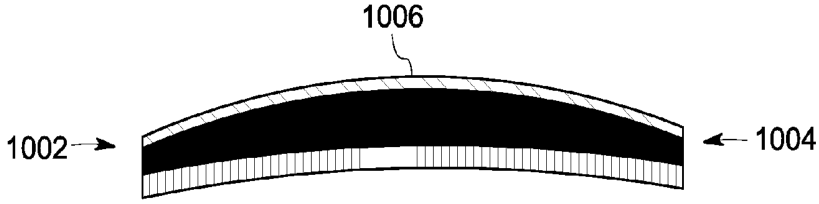


FIG. 10

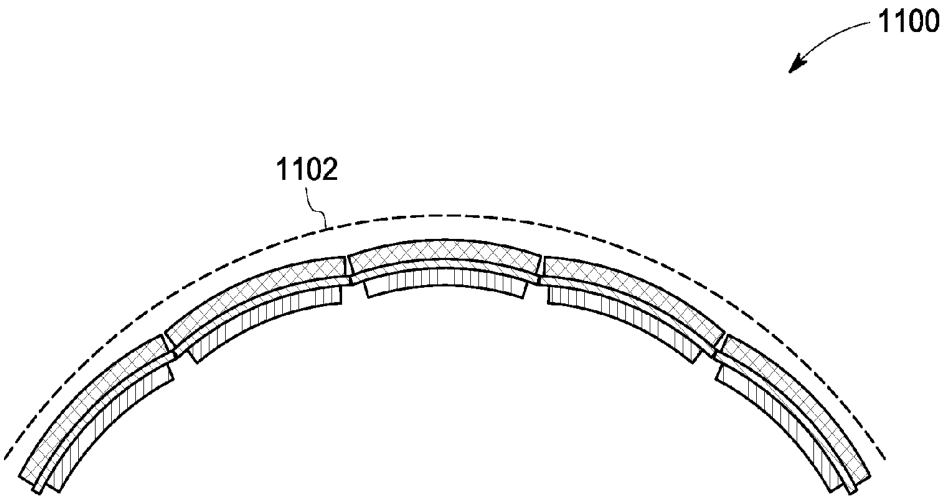


FIG. 11

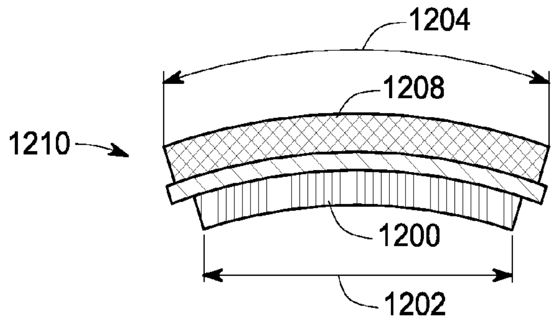


FIG. 12

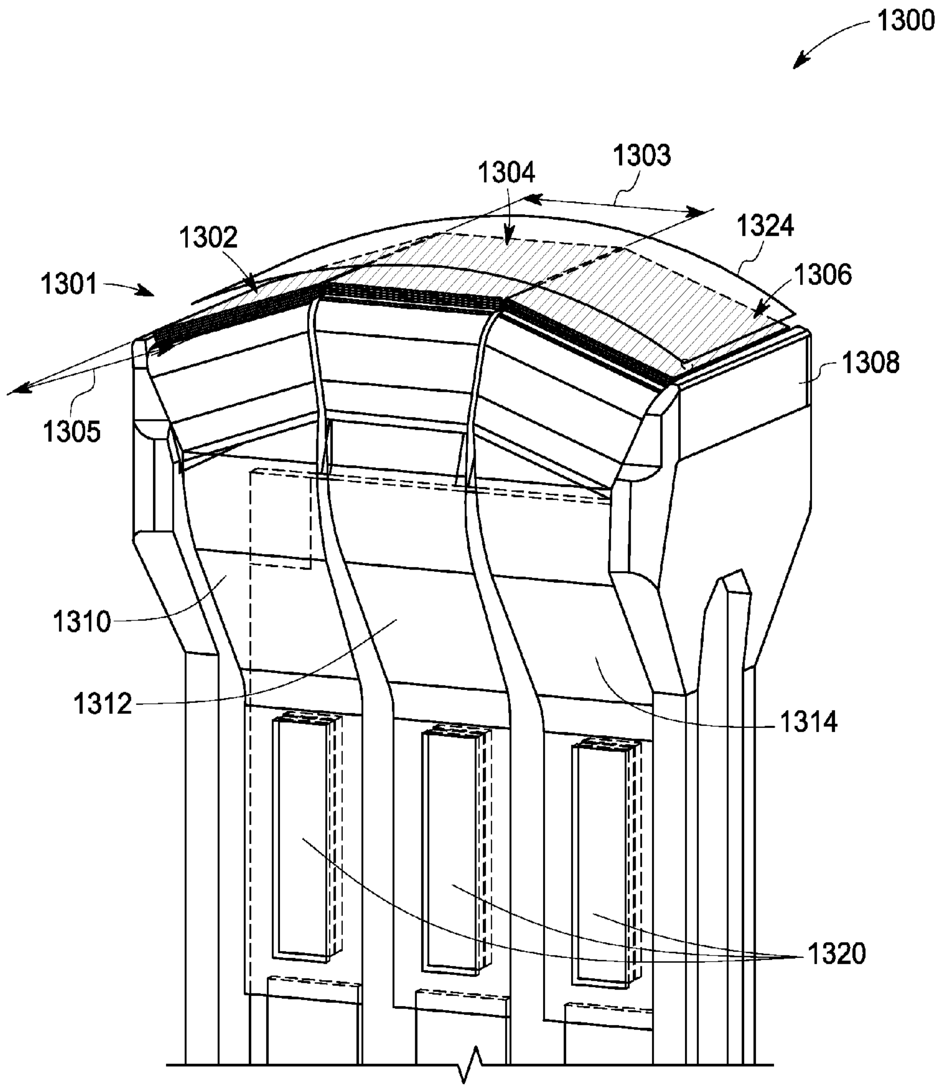
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FIG. 13

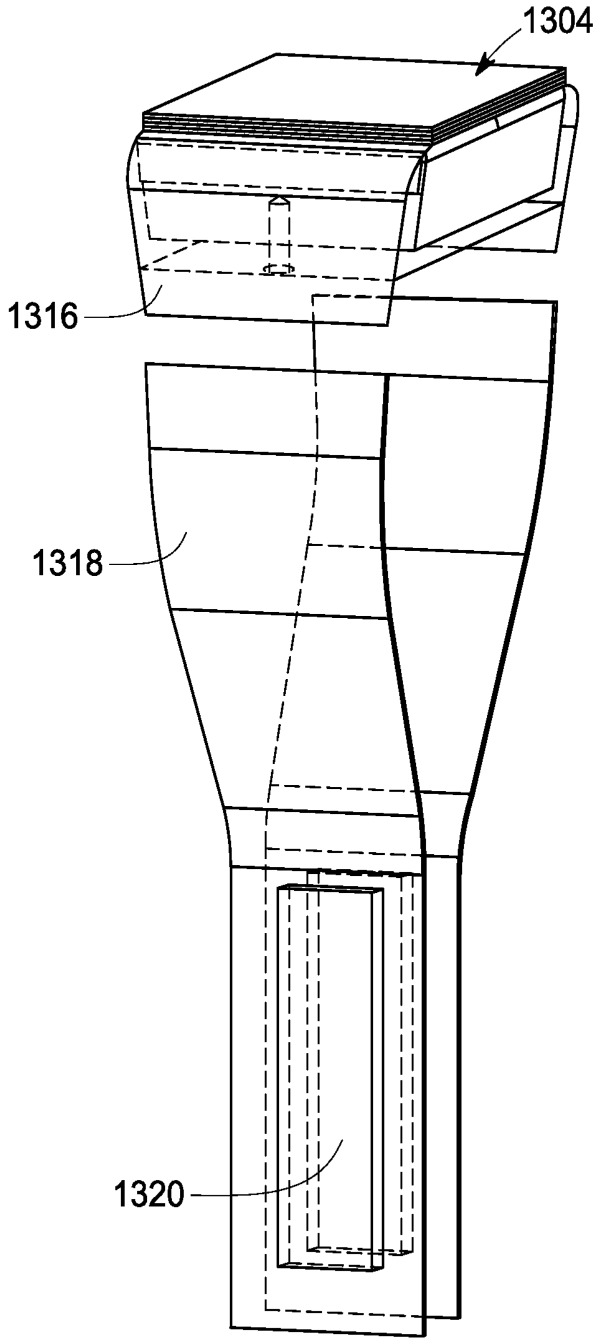


FIG. 14

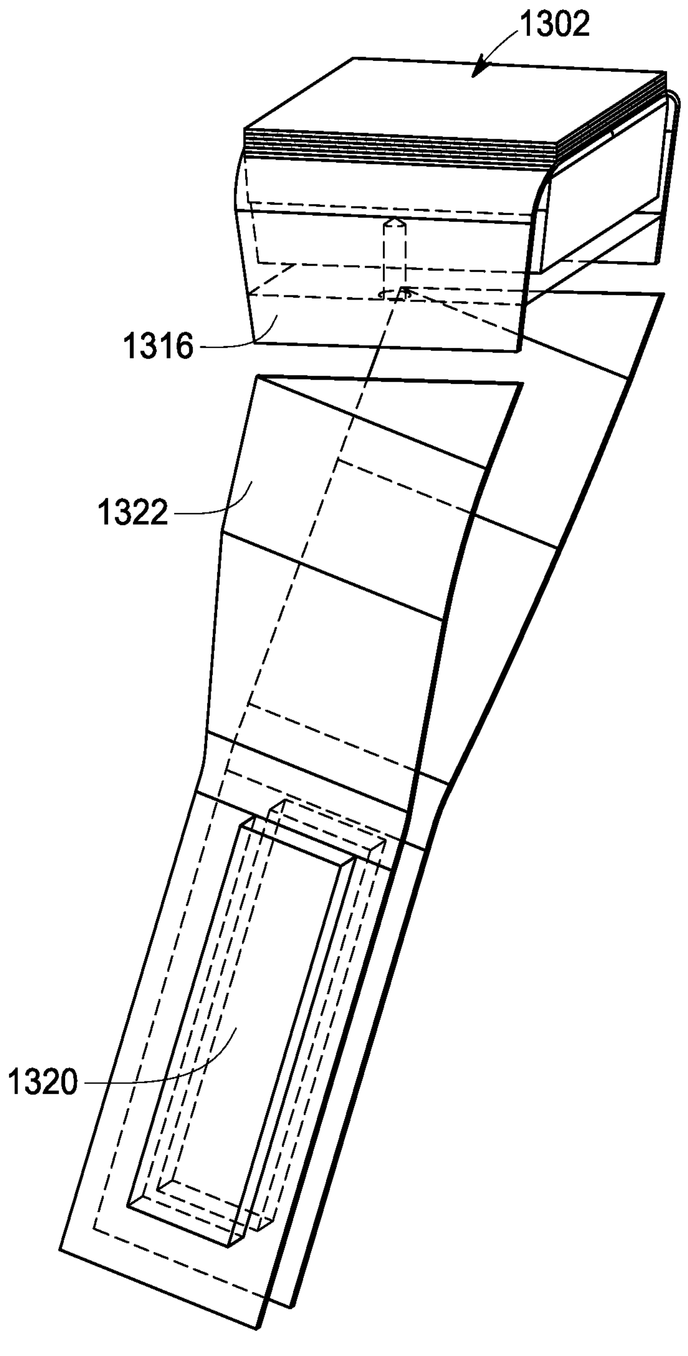


FIG. 15

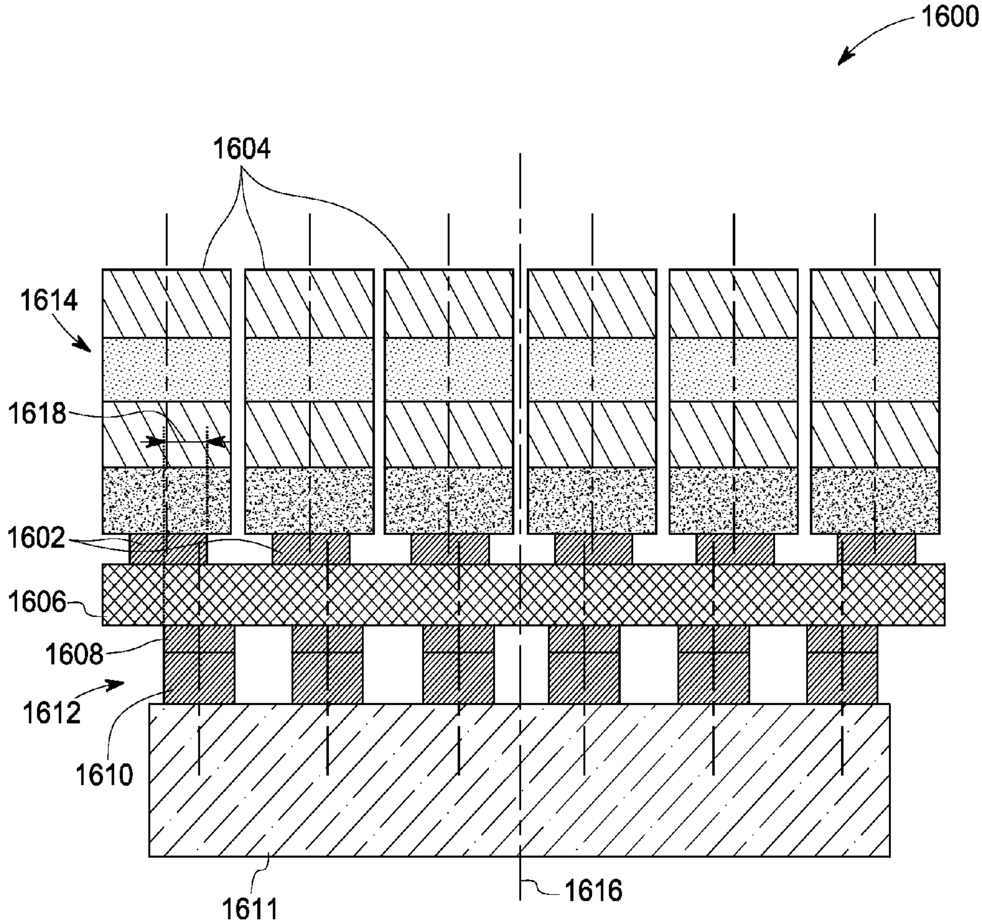


FIG. 16

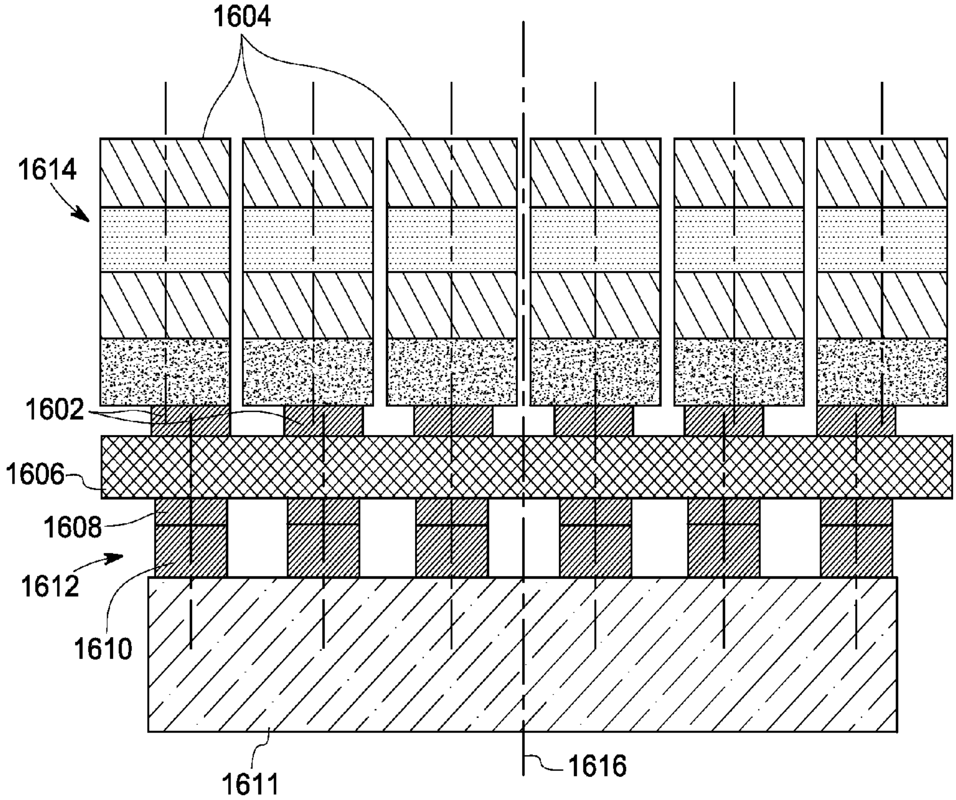


FIG. 17

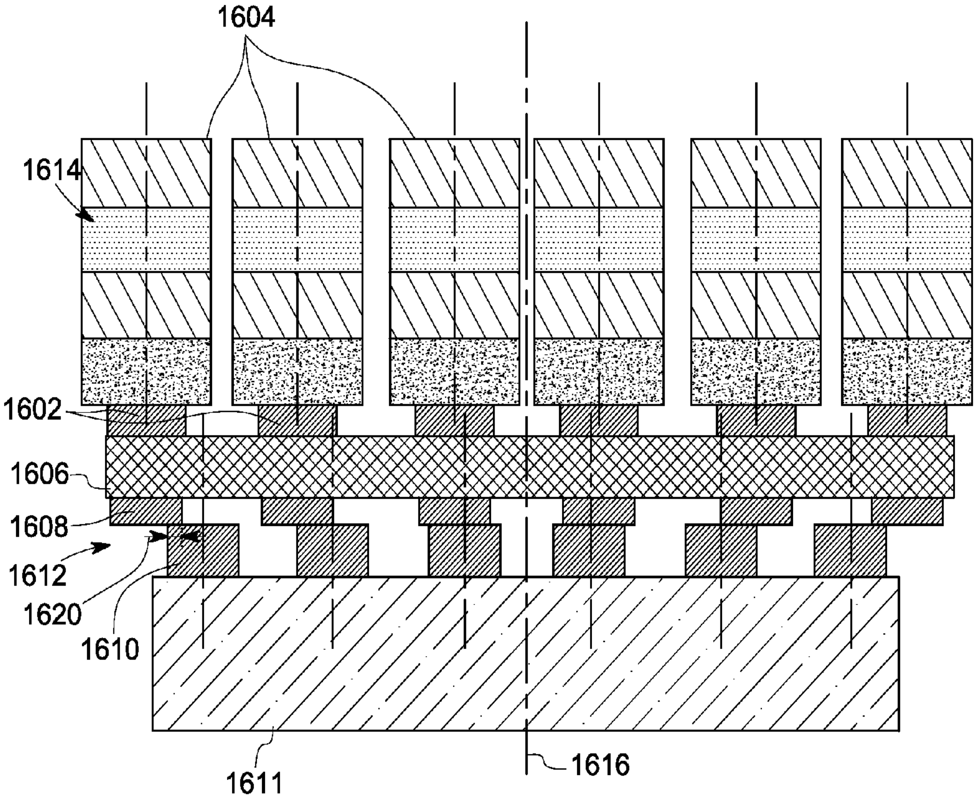


FIG. 18

# ULTRASOUND TRANSDUCER ARRAYS

## BACKGROUND

**[0001]** Embodiments of the present disclosure relate generally to ultrasound transducers, and more particularly to a system and method for assembling an ultrasound transducer array using electro-acoustic modules.

**[0002]** Ultrasound transducers are used extensively for ultrasound imaging of an object. Particularly, in a medical field, the ultrasound transducers are typically used to obtain a high quality image of a region within a patient. Further, this high quality image may be used for diagnosing the patient.

**[0003]** An ultrasound transducer typically includes transducer arrays that are generally used for transmission and reception of ultrasonic or acoustic waves. These acoustic waves are further processed to obtain the image of the object. In general, the transducer arrays may be flat transducer arrays or convex transducer arrays. The flat transducer arrays are commonly used in cardiac imaging while, the convex transducer arrays are used in other diagnostic applications, such as abdominal imaging.

**[0004]** In a conventional ultrasound transducer, the flat transducer arrays are formed by fabricating large arrays on a single substrate. However, this type of fabricating process includes additional steps, such as lamination and dicing of large parts, which further results in more scrap materials. This in turn increases the cost of the ultrasound transducers.

**[0005]** In addition, the convex transducer arrays are formed by fabricating a large array in a flat configuration and subsequently bending the large array into its final form. Typically, the large array is in direct contact with beam forming electronics or an application specific integrated circuit (ASIC). Thus, while bending the large array, the beam forming electronics or ASIC are also bent along with the large array. Further, bending the beam forming electronics or ASIC may induce sufficient internal stresses, which in turn alters the ASIC functionality and/or reliability. Therefore, it is preferred to fabricate or form the convex transducer array without bending the electronics or ASICs.

**[0006]** Thus, there is need for an improved method and system for fabricating/assembling ultrasound transducer arrays.

## BRIEF DESCRIPTION

**[0007]** In accordance with one embodiment described herein, an ultrasound transducer array for an ultrasound probe is presented. The ultrasound transducer array includes a support structure. Further, the ultrasound transducer array includes a plurality of electro-acoustic modules coupled to the support structure, wherein each of the plurality of electro-acoustic modules comprises at least one matrix acoustic array and an interconnect element, wherein each of the plurality of electro-acoustic modules is interchangeable on the support structure so as to adapt to one or more shapes of the ultrasound probe, and wherein each of the plurality of electro-acoustic modules operates in a manner substantially identical to each other of the plurality of electro-acoustic modules.

**[0008]** In accordance with a further aspect of the present disclosure, an electro-acoustic module for an ultrasound transducer array is presented. The electro-acoustic module includes a base unit including an acoustic backing and a heat sink, wherein the heat sink is configured to detachably couple to a support structure of the ultrasound transducer array. Further, the electro-acoustic module includes an ASIC layer individually coupled to the base unit. Also, the electro-acoustic module includes a flex interconnect disposed on the ASIC layer and electrically coupled to a circuit board. In addition, the electro-acoustic module includes a matrix acoustic array disposed on the flex interconnect and comprising a plurality of stack elements at least partially separated by a vertical gap, wherein at least one narrow stack element is positioned between two wide stack elements, wherein the at least one narrow stack element has a width extending horizontally between the vertical gaps that is lesser than a width of the wide stack elements.

## DRAWINGS

**[0009]** These and other features, aspects, and advantages of the present invention will become better understood when the following detailed description is read with reference to the accompanying drawings in which like characters represent like parts throughout the drawings, wherein:

**[0010]** FIG. **1** is a perspective view of a transducer array having electro-acoustic modules, in accordance with aspects of the present disclosure;

**[0011]** FIG. **2** is a perspective view of an electro-acoustic module, in accordance with aspects of the present disclosure;

**[0012]** FIG. **3** is a bottom view of the electro-acoustic module, in accordance with aspects of the present disclosure;

**[0013]** FIG. **4** is a side view of the transducer array depicting an enlarged portion of an acoustic array, in accordance with aspects of the present disclosure;

**[0014]** FIG. **5** is a side view of the electro-acoustic module, in accordance with one embodiment of the present disclosure;

**[0015]** FIG. **6** is a side view of electro-acoustic modules assembled on a non-planar support structure, in accordance with one embodiment of the present disclosure;

**[0016]** FIG. **7** is a cross section of the electro-acoustic module, in accordance with aspects of the present disclosure;

**[0017]** FIG. **8** is a side view of a transducer array mounted on a convex support structure, in accordance with aspects of the present disclosure;

**[0018]** FIG. **9** is a diagrammatical representation of the transducer array, in accordance with one embodiment of the present disclosure;

**[0019]** FIG. **10** is a diagrammatical representation of an electro-acoustic module, in accordance with one embodiment of the present disclosure;

**[0020]** FIG. **11** is a diagrammatical representation of the transducer array, in accordance with another embodiment of the present disclosure

**[0021]** FIG. **12** is a diagrammatical representation of an electro-acoustic module, in accordance with another embodiment of the present disclosure;

**[0022]** FIG. **13** is a perspective view of an ultrasound probe, in accordance with aspects of the present disclosure;

**[0023]** FIG. **14** illustrates an electro-acoustic module having one design of an elongated flex interconnect, in accordance with aspects of the present disclosure;

**[0024]** FIG. **15** illustrates an electro-acoustic module having another design of an elongated flex interconnect, in accordance with aspects of the present disclosure;

**[0025]** FIG. **16** illustrates a side view of an electro-acoustic module illustrating elements of an acoustic array, in accordance with one embodiment of the present disclosure;

**[0026]** FIG. **17** illustrates a side view of an electro-acoustic module illustrating elements of an acoustic array, in accordance with another embodiment of the present disclosure; and

**[0027]** FIG. **18** illustrates a side view of an electro-acoustic module illustrating elements of an acoustic array, in accordance with yet another embodiment of the present disclosure.

## DETAILED DESCRIPTION

**[0028]** As will be described in detail hereinafter, various embodiments of ultrasound transducer arrays and methods for fabricating the same are presented. The transducer arrays may comprise electro-acoustic modules that are interchangeable and adaptable to a shape of an ultrasound probe. Also, the formation of these transducer arrays yields minimal scrap material, thus reducing the manufacturing cost of the ultrasound probe. Moreover, the transducer arrays can be assembled on a convex structure without bending the electronics or ASIC, which in turn improves the functionality and/or reliability of the ASIC.

**[0029]** Turning now to the drawings and referring to FIG. **1**, a transducer array having electro-acoustic modules, in accordance with aspects of the present disclosure, is depicted. The transducer array **100** is typically used to transmit ultrasonic or acoustic waves towards an object (not shown in FIG. **1**). In response to transmitting the ultrasonic waves, the transducer array **100** may receive reflected or attenuated ultrasonic waves from the object. Further, these received ultrasonic waves are processed to obtain an ultrasonic image of the object. In one embodiment, the object may be a region of interest in a patient.

**[0030]** In a presently contemplated configuration, the transducer array **100** includes a support structure **102** and one or more electro-acoustic modules **104**, **106** that are coupled to the support structure **102**. Each of these electro-acoustic modules **104**, **106** may be interchangeable on the support structure **102**, and thus, the electro-acoustic modules **104**, **106** may not be required to be located in a particular position on the support structure **102**. Also, each of the electro-acoustic modules **104**, **106** may be similar in size, which aids in easy extensibility, replaceablity, and/or flexibility during design and manufacture of an ultrasound probe. Moreover, the electro-acoustic modules **104**, **106** may be tiled or aligned on a planar or non-planar portion of a support structure so as to adapt to a shape of an ultrasound probe. In addition, if one of these electro-acoustic modules **104**, **106** is affected or damaged then it may be replaced by a new electro-acoustic module.

**[0031]** In the embodiment of FIG. **1**, the transducer array **100** includes two electro-acoustic modules **104**, **106** that are detachably coupled to a portion **101** of the support structure **102**. The portion **101** of the support structure **102** may be a planar structure that acts as a base or spine for the electro-acoustic modules **104**, **106**. In one embodiment, the support structure **102** may be a non-planar structure, such as a convex structure. Further, the electro-acoustic modules **104**, **106** may be smaller in size compared to the support structure **102**, which in turn aids in designing and manufacturing a desired ultrasound probe. For example, the electro-acoustic modules **104**, **106** may be arranged on the support structure **102** to form a portable ultrasound probe.

**[0032]** In addition, the electro-acoustic modules **104**, **106** may be arranged on one or more types of the support structure to conform to the shape of the ultrasound probe. For example, if the electro-acoustic modules **104**, **106** are arranged on a flat portion **101** of the support structure **102**, a flat transducer array may be formed. In another example, if the electro-acoustic modules **104**, **106** are arranged on a convex portion of the support structure, a convex transducer array may be formed (see FIG. **8**). In addition, the support structure **102** includes protruding members **108** and pins **110** that are used for coupling the electro-acoustic modules **104**, **106** to the support structure **102**. The aspect of coupling the electro-acoustic modules **104**, **106** to the support structure **102** is explained in greater detail with reference to FIG. **3**. It should be noted that the transducer array **100** may include any number of electro-acoustic modules, and is not limited to the number of electro-acoustic modules shown in FIG. **1**.

**[0033]** Furthermore, as depicted in FIG. **2**, each of the electro-acoustic modules **104**, **106** includes a matrix acoustic array **200**, a flex interconnect **202**, one or more application-specific integrated circuits (ASIC) **204**, an acoustic backing **206**, and a heat sink **208**. The matrix acoustic array **200** is configured to send one or more acoustic waves towards the object. In response, the matrix acoustic array **200** may receive the reflected acoustic waves from the object. These acoustic waves may have a frequency in a range from about 0.5 MHz to about 25 MHz. In one embodiment, the matrix acoustic array **200** includes single or multiple rows of electrically and acoustically isolated transducer elements. Each of these transducer elements may be a layered structure including at least a piezoelectric layer and an acoustic matching layer. In one embodiment, the matrix acoustic array **200** may include micromachined ultrasound transducers, such as capacitive micromachined ultrasonic transducers (cMUTs) and/or piezoelectric micromachined ultrasonic transducers (pMUTs).

**[0034]** As will be appreciated, an electrical pulse is applied to electrodes of the piezoelectric layer, causing a mechanical change in the dimension of the piezoelectric layer. This in turn generates an acoustic wave that is transmitted towards the object. Further, when the acoustic waves are reflected back from the object, a voltage difference is generated across the electrodes that are then detected as a received signal. Thereafter, the received signal from each of the transducer elements in the acoustic array **200** is combined and processed by the ASIC **204**.

**[0035]** Moreover, the matrix acoustic array **200** is coupled to the flex interconnect **202** that is used for providing electrical connection between the acoustic array and signal processing electronics or circuit board (not shown in FIG. **2**) that is disposed within a body of the ultrasound probe. In one example, the flex interconnect **202** may be used to communicate the electrical pulses between the piezoelectric layer and the signal processing electronics.

**[0036]** Further, the ASIC **204** is coupled to the acoustic backing **206** and the heat sink **208**, as depicted in FIG. **2**. The acoustic backing **206** may be configured to absorb and/or scatter the acoustic waves or energy that is transmitted in a direction away from the object being scanned. Particularly, the acoustic waves are generated by the piezoelectric layer. Further, a portion of the generated acoustic waves may be reflected from structures or interfaces behind the transducer array. These acoustic waves may combine with the acoustic waves that are reflected from the object, which in turn reduces the quality of the ultrasonic image of the object.

**[0037]** To avoid the above problem, the acoustic backing **206** may be positioned beneath the ASIC **204** to attenuate or absorb the acoustic waves that are propagated in the reverse direction to the object. In one example, the acoustic backing **206** may include acoustic backing materials that are combinations of a high-density acoustic scatterer, such as tungsten metal, and/or a soft acoustic absorbing material, such as silicone, in a matrix of an epoxy or a polyurethane. In another example, the backing material may comprise an epoxy filled graphite foam which has the added advantage of having a high thermal conductivity to draw heat away from the ASIC. Also, the heat sink **208** may be configured to absorb or dissipate the heat generated in the electro-acoustic module. In one embodiment, the heat sink **208** along with the acoustic backing **206** may be configured to absorb the heat generated in the electro-acoustic module.

**[0038]** In one embodiment, the heat sink **208** includes one or more apertures **302** on a bottom surface **306** of the heat sink **208**, as depicted in FIG. **3**. The one or more apertures **302** are configured to receive protruding members **108** from the support structure **102** and in one embodiment the apertures **302** may be threaded. In one example, the protruding members **108** may include screws that are inserted into apertures **302** that are threaded for coupling the electro-acoustic module **104** to the support structure **102**. Also, the heat sink **208** includes one or more alignment apertures **308** on the bottom surface **306** for receiving one or more pins **110** from the support structure **102**. Particularly, while coupling the electro-acoustic module **104** to the support structure **102**, tool pins **110** on a top side of the support structure **102** are inserted into corresponding alignment apertures **308** on the bottom surface **306** of the heat sink **208**. Thereafter, the electro-acoustic module **104** may be adjusted to avoid any misalignment of the transducer array **100**. After adjusting or aligning the position of the electro-acoustic module **104** on the support structure **102**, the protruding members **108**, such as screws are inserted into the apertures **302** of the heat sink **208** to fasten the electro-acoustic module **104** to the support structure **102**. In another embodiment, the electro-acoustic module may include one or more protruding members and the support structure may include one or more apertures. Further, each of the protruding members may be inserted into a corresponding aperture to fasten and/or align the electro-acoustic module to the support structure. In yet another embodiment, the electro-acoustic module may be coupled to the support structure by using a glue film/layer between the electro-acoustic module and the support structure. Also, in one more embodiment, the support structure may have a receiving pocket shape that matches with a shape of the heat sink in the electro-acoustic module. Further, when the electro-acoustic module is placed on the support structure, the heat sink may be secured to the support structure so as to fasten the electro-acoustic module to the support structure. Additionally, in one other embodiment, the electro-acoustic modules may be magnetically coupled to the support structure. It may be noted that the electro-acoustic modules may be coupled to the support structure by using any similar fastening/coupling mechanism, and is not limited to the mechanism described above.

**[0039]** Thus, by using the electro-acoustic modules **104**, **106**, the transducer array **100** may be assembled and conformed to the shape of the ultrasound probe. Also, the electro-acoustic modules **104**, **106** may be easily adjusted on the support structure **102** to avoid any misalignment of the transducer array **100**.

**[0040]** Referring to FIG. **4**, a side view of a transducer array **400** illustrating elements of an acoustic array, in accordance with aspects of the present disclosure, is depicted. For ease of understanding, the transducer array **400** is described with reference to the components of transducer array **100** of FIGS. **1-3**. The transducer array **400** includes two electro-acoustic modules **104**, **106** that are disposed adjacent to each other on a support structure **102**. Portions **401**, **403** of these two electro-acoustic modules **104**, **106** are enlarged to illustrate a structure of a matrix acoustic array **200**. Particularly, the enlarged portions **401**, **403** depict the matrix acoustic array **200**, a flex interconnect **202**, and an ASIC **204**.

**[0041]** Further, the matrix acoustic array **200** includes acoustic elements **402** that are separated by a vertical gap **404**, as depicted in FIG. **4**. Each of the acoustic elements **402** is formed by a stack of layers **406** that are used for sending acoustic waves towards an object and receiving the reflected acoustic waves from the object. Furthermore, the acoustic elements **402** include narrow stack elements **408** and wide stack elements **410**. Also, the width **416** of the narrow stack elements **408**, which is extended horizontally between the vertical gap **404**, is lesser than the width **418** of the wide stack elements **410**.

**[0042]** Moreover, the wide stack elements **410** are positioned at sides of the acoustic array **104**, while the narrow stack elements **408** are positioned between the two wide stack elements **410**. For example, a first wide stack element **410** is disposed at a left edge **412** of the acoustic array **104** and the second wide stack element **410** may be disposed at a right edge **414** of the acoustic array **104**. Further, the narrow stack elements **408** are placed between the first and second wide stack elements **410**, as depicted in FIG. **4**. In one embodiment, the wide stack elements **410** are placed at the edges **412**, **414** to reduce a vertical gap **415** between adjacent electro-acoustic modules **104**, **106** when the electro-acoustic modules **104**, **106** are disposed on the support structure **102**. By reducing the width of the vertical gap **415**, the electro-acoustic modules **104**, **106** may receive the reflected acoustic waves with minimal or no signal loss. This in turn improves the quality of the ultrasonic image of the object.

**[0043]** In another embodiment, the two wide stack elements **410** are placed at the edges **412**, **414** of the matrix acoustic array **104** such that the two wide stack elements **410** overhang the ASIC **204** in the corresponding electro-acoustic module **104**. Particularly, while preparing an individual electro-acoustic module **104**, the edges **412**, **414** of the electro-acoustic module **104** would otherwise need to be trimmed by using a dicing saw without touching or otherwise affecting the ASIC **204**. If the electro-acoustic module **104** includes the wide stack elements **410** at the edges **412**, **414**, an extra margin may be provided for trimming the electro-acoustic module **104**, which in turn aids in dicing the electro-acoustic module **104** without affecting the ASIC **204**.

**[0044]** In one embodiment, as depicted in FIG. **16**, an electro-acoustic module **1600** includes first pads **1602** that are placed between acoustic elements **1604** and a flex interconnect element **1606**. Similarly, the electro-acoustic module **1600** includes second pads **1608** that are placed between an ASIC bump **1610** and the flex interconnect element **1606**. It may be noted that the first pads **1602** and the second pads **1608** are referred to as flex circuit pads. Further, the pads **1602**, **1608** and the ASIC bump **1610** are used for providing electrical connection between the acoustic elements **1604** and an ASIC **1611**.

**[0045]** Also, as depicted in FIG. **16**, a pitch of the second pads **1608** is matched with a pitch of the ASIC bump **1610**. However, a pitch of the first pads **1602** on a transducer side

**1614** is designed to be slightly larger than the pitch of the second pads **1608** on an ASIC side **1612**. In one example, if the pitch of the second pads **1608** is 'x' then the pitch of the first pads **1602** may be 'x+y'. It may be noted that though the pads **1602**, **1608** have different pitches, the pads **1602**, **1608** may still have overlapping region **1618** to provide electrical connection between them. Further, while dicing the acoustic elements **1604**, the center saw cut is aligned with the center **1616** of the electro-acoustic module **1600** and the pitch of the saw or dicing cut is matched with the pitch of the first pads **1602** on the transducer side **1614**. In one example, the pitch of the dicing cut may be 'x+y' which is same as the pitch of the first pads **1602** on the transducer side **1614**.

**[0046]** Furthermore, since the pitch of the dicing cut is larger than the pitch of the second pads on the ASIC side, an extra pitch 'y' may be accumulated for each dicing cut from the center **1616** to the edge of the electro-acoustic module **1600**. Thus, if the electro-acoustic module **1600** has 'n' dicing cuts between the center **1616** and the edge of the electro-acoustic module **1600**, the acoustic element at the edge of the electro-acoustic module **1600** may be offset from the ASIC bump **1610** by an amount 'n*y'. This in turn provides extra room to trim the acoustic array without affecting the ASIC or ASIC bump **1610**. Also, it may be noted that the acoustic elements **1604** typically will be of uniform size across the electro-acoustic module **1600** irrespective of the pitch of the dicing cut.

**[0047]** Additionally, it may be noted that if the dicing cut is not aligned with the center **1616** of the electro-acoustic module **1600**, the acoustic elements **1604** may still have a uniform size. However, an acoustic element **1604** at one edge of the electro-acoustic module **1600** may have an uneven amount of overhang as compared to the acoustic element **1604** at the other edge of the electro-acoustic module **1600**.

**[0048]** In another embodiment, as depicted in FIG. **17**, the pitch of the first pads **1602** and the second pads **1608** may be designed to be the same as the pitch of the ASIC bump **1610**. In one example, the pitch of the first pads **1602**, the second pads **1608**, and the ASIC bump **1610** are designed to be 'x'. However, the pitch of the dicing cut may be designed to be larger than the pitch of the pads **1602**, **1608** and the ASIC bump **1610**. For example, if the pitch of the pads **1602**, **1608** and the ASIC bump is 'x', then the pitch of the dicing cut is designed to be 'x+y'. Further, while dicing the acoustic elements **1604**, an extra pitch 'y' may be accumulated for each dicing cut from the center **1616** to the edge of the electro-acoustic module **1600**. Thus, if the electro-acoustic module **1600** has 'n' dicing cuts between the center **1616** and the edge of the electro-acoustic module **1600**, the acoustic element at the edge of the electro-acoustic module **1600** may be offset from the ASIC bump **1610** by an amount 'n*y'. This again provides extra room to trim the acoustic array without affecting the ASIC or ASIC bump **1610**. Further it may be noted that, in this embodiment, the acoustic elements **1604** may not be perfectly aligned with the first pads **1602** on the transducer side **1614**. However, the acoustic elements **1604** and the first pads **1602** may have an overlapping region to provide sufficient electrical connection between them. Here again, the acoustic elements **1604** will be of uniform size irrespective of the pitch of the dicing cut.

**[0049]** In yet another embodiment, as depicted in FIG. **18**, the pitch of the first pads **1602** and the second pads **1608** may be designed to be the same as the pitch of the acoustic elements **1604**. In one example, the pitch of the first pads **1602** and the second pads **1608** may be designed to be 'x+y'. However, the pitch of the ASIC bump **1610** may be designed to be lesser than the pitch of the pads **1602**, **1608**. For example, if the pitch of the pads **1602**, **1608** is 'x+y', then the pitch of the ASIC bump **1610** is designed to be 'x'. Further, while dicing the acoustic elements **1604**, an extra pitch 'y' may be accumulated for each dicing cut from the center **1616** to the edge of the electro-acoustic module **1600**. Thus, if the electro-acoustic module **1600** has 'n' dicing cuts between the center **1616** and the edge of the electro-acoustic module **1600**, the acoustic element at the edge of the electro-acoustic module **1600** may be offset from the ASIC bump **1610** by an amount 'n*y'. This in turn provides extra room to trim the acoustic array without affecting the ASIC or ASIC bump **1610**. Further, it may be noted that, in this embodiment, the second pads **1608** may not be perfectly aligned with the ASIC bump **1610** on the ASIC side **1612**. However, the second pads **1608** and the ASIC bump **1610** may have an overlapping region **1620** to provide sufficient electrical connection between them.

**[0050]** Referring to FIG. **5**, a perspective view of the electro-acoustic module, in accordance with an embodiment of the present disclosure, is depicted. For ease of understanding, the electro-acoustic module **500** is described with reference to the components of FIGS. **1-4**. If the electro-acoustic modules having flat sides, as depicted in FIG. **1**, are positioned on a convex surface, the bottom surfaces of these electro-acoustic modules may interfere with each other, while the top corners of these electro-acoustic modules may be separated by a large gap between the electro-acoustic modules. This large gap may in turn cause loss in the signal received from the object and thereby, an improper image of the object may be obtained.

**[0051]** To overcome the above problem, the sides of the electro-acoustic module **500** are beveled, as depicted in FIG. **5**. Particularly, the electro-acoustic module **500** includes a bottom surface **502** and a top surface **504**. The bottom surface **502** is adjacent to a support structure **102** when the electro-acoustic module is disposed on the support structure **102**. Further, the top surface **504** is opposite to the bottom surface **502** and positioned away from the support structure **102**. Also, acoustic energy is emitted from the top surface **504** in a direction that is away from the bottom surface **502**. In addition, the electro-acoustic module **500** includes at least two beveled sides **506**, **508**, as depicted in FIG. **5**. In one embodiment, the sides **506**, **508** may be beveled at an angle 'θ' that is in a range from about 5 degrees to about 20 degrees. Each of the beveled sides **506**, **508** may form a surface **510** extending between the bottom surface **502** and the top surface **504**. Also, this surface **510** may have a first width **512** at the bottom surface **506** and a second width **514** at the top surface **504** of the electro-acoustic module **500**. The first width **512** may be lesser than the second width **514**. In one example, the beveled sides **506**, **508** may be obtained by tapering the surface **510** from the top surface **504** to the bottom surface **502**, as depicted in FIG. **5**.

**[0052]** Furthermore, as depicted in FIG. **6**, electro-acoustic modules **602**, **604** that are similar to the electro-acoustic module **500** are positioned on the convex support structure. Particularly, when the electro-acoustic modules **602**, **604** having beveled sides are positioned on the convex support structure, the gap between the electro-acoustic modules **602**, **604** may be substantially reduced. Thus, the electro-acoustic modules **602**, **604** having beveled sides are used for assembling or forming a convex transducer array which may be further used for diagnostic applications, such as abdominal imaging.

**[0053]** Referring to FIG. **7**, a cross section of a transducer array, in accordance with one embodiment of the present disclosure, is depicted. The transducer array **700** includes a plurality of acoustic modules **702**, **704** that are interconnected by a flex interconnect **706**. Particularly, the acoustic modules **702**, **704** are serially coupled to each other via the flex interconnect **706**, as depicted in FIG. **7**. In one embodiment, a vertical gap **712** may be maintained between the acoustic modules **702**, **704** to allow movement of the acoustic modules **702**, **704**. Further, each of the acoustic modules **702**, **704** includes an acoustic array **708**, the flex interconnect **706**, and an ASIC **710**. The acoustic array **708** may be similar to the matrix acoustic array **200** of FIG. **2**. Similarly, the ASIC **710** may be similar to the ASIC **204** of FIG. **2**.

**[0054]** Moreover, the flex interconnect **706** may be diced in orthogonal azimuth and elevation directions at a region between the acoustic modules **702**, **704** to promote bending of the flex interconnect **706**. Particularly, the flex interconnect **706** may be partially diced, as depicted in FIG. **7**, so that the flex interconnect **706** may be bent to move the acoustic modules **702**, **704** in the azimuth direction. In one example, the flex interconnect **706** may be bent to position the acoustic modules **702**, **704** on a convex support structure **802**, as depicted in FIG. **8**. Since the acoustic modules **702**, **704** are connected to each other by the flex interconnect **706**, the acoustic modules **702**, **704** may instead be positioned on a flat structure to form a flat transducer array and the flat transducer array be bent along with the acoustic modules **702**, **704** to form a convex transducer array. Thus, single arrangement of acoustic modules **702**, **704** may be used to form the flat transducer array or the convex transducer array.

**[0055]** Referring to FIG. **9**, a cross section of a transducer array, in accordance with another embodiment of the present disclosure, is depicted. The transducer array **900** is similar to the transducer array **700** of FIG. **7** except that a thickness of a flexible interconnect **906** is varied to conform to a shape of an ultrasound probe. Particularly, the flexible interconnect **906** having variable thickness is coupled between an acoustic array **904** and an ASIC **902** so as to obtain a desired shape of the transducer array **900**, as depicted in FIG. **9**. In one embodiment, as depicted in FIG. **10**, the flex interconnect **902** may have lesser thickness at the edges **1002**, **1004** compared to the thickness of the flex interconnect **902** at the center of an acoustic module **1006**. This in turn aids in bringing the acoustic array and the ASIC proximate to each other at the edges **1002**, **1004** of the acoustic module **1006**. Further, by sequentially aligning or positioning such acoustic module **1006**, the transducer array **900** that more closely approximates a reference curve **908** may be obtained.

**[0056]** Referring to FIG. **11**, a cross section of a transducer array, in accordance with yet another embodiment of the present disclosure, is depicted. The transducer array **1100** is similar to the transducer array **700** of FIG. **7** except that a length of the ASIC is shortened compared to a length of the acoustic array in each acoustic module. Particularly, as depicted in FIG. **12**, the length **1202** of the ASIC **1200** is shortened compared to the length **1204** of the acoustic array **1208** in each acoustic module **1210**. Further, by positioning such acoustic modules sequentially, a convex transducer array **1100** that more closely approximates a reference curve **1102** may be obtained, as depicted in FIG. **11**. In one embodiment, the ASIC in each acoustic module **1200** may be allowed to curve slightly, but at a greater or equal radius of curvature (ROC) than the ultrasound probe is curved to reduce stress on the ASIC. In another embodiment, as depicted in FIG. **11**, the ASIC in each acoustic module **1200** may have lesser ROC than the ultrasound probe to obtain a predefined/desired shape of the ultrasound probe.

**[0057]** Referring to FIG. **13**, a perspective view of an ultrasound probe, in accordance with aspects of the present disclosure, is depicted. The ultrasound transducer probe **1300** includes a transducer array **1301** having three electro-acoustic modules **1302**, **1304**, **1306** that are coupled to a support structure **1308**. Each of the electro-acoustic modules **1302**, **1304**, **1306** is similar to the electro-acoustic module **500** except that the electro-acoustic modules **1302**, **1304**, **1306** include elongated flex interconnects **1310**, **1312**, **1314**, as depicted in FIG. **13**. Each of the elongated flex interconnects **1310**, **1312**, **1314** may be flexible and adaptable to provide electrical connection between an acoustic array and a circuit/interface board **1320**.

**[0058]** In one embodiment, each of the elongated flex interconnects **1310**, **1312**, **1314** may be a single strip/element that is connected between the acoustic array and the circuit/interface board **1320**. In another embodiment, each of the elongated flex interconnects **1310**, **1312**, **1314** may include a primary flex interconnect **1316** and a secondary flex interconnect **1318**, **1322**, as depicted in FIGS. **14** and **15**. Particularly, the primary flex interconnect **1316** is disposed between an acoustic array and an ASIC layer, while the secondary flex interconnect **1318**, **1322** is electrically coupled between the primary flex interconnect **1316** and a circuit/interface board **1320**.

**[0059]** In addition, the secondary flex interconnect **1318**, **1322** may have one or more shapes depending on the position of the electro-acoustic modules **1310**, **1312**, **1314** on a support structure. In one example, if the electro-acoustic module **1304** is on a flat portion **1303** of the transducer array **1301**, the secondary flex interconnect **1318** having a straight or unbent shape is coupled to the primary flex interconnect **1316**, as depicted in FIG. **14**. In another example, the electro-acoustic module **1302** is positioned on a left curved portion **1305** of the transducer array **1301**, and thus, a secondary flex interconnect **1322** having a slanted or angled edge is coupled to the primary flex interconnect **1316**, as depicted in FIG. **15**. Thus, one of different shapes of the secondary flex interconnect **1318**, **1322** may be selected to couple the primary flex interconnect **1316** to the circuit board **1320**.

**[0060]** Furthermore, as depicted in FIG. **13**, the electro-acoustic modules **1302**, **1304**, **1306** may be enclosed by a smooth curving material **1324**, such as RTV silicone, or other material with sound speed close to 1540 m/sec. In one example, the smooth curving material may act as a lens that is disposed on the electro-acoustic modules **1302**, **1304**, **1306**. The lens may act as a smooth surface on the electro-acoustic modules **1302**, **1304**, **1306**, which further aids in placing the ultrasound probe on objects such as chest or abdomen of a patient.

**[0061]** The various embodiments of the system and method aid in forming the transducer arrays that are interchangeable and adaptable to a shape of an ultrasound probe. Moreover, these transducer arrays can be assembled on a convex structure without bending electronics or ASIC, which in turn improves the functionality and/or reliability of the ASIC. In addition, these transducer arrays are formed with minimal scrap material, and thus reducing the cost of the ultrasound probe.

**[0062]** While only certain features of the invention have been illustrated and described herein, many modifications and changes will occur to those skilled in the art. It is, therefore, to be understood that the appended claims are intended to cover all such modifications and changes as fall within the true spirit of the invention.

**1**. An ultrasound transducer array for an ultrasound probe, comprising:
- a support structure; and
- a plurality of electro-acoustic modules coupled to the support structure, wherein each of the plurality of electro-acoustic modules comprises at least one matrix acoustic array and an interconnect element,
- wherein each of the plurality of electro-acoustic modules is interchangeable on the support structure so as to adapt to one or more shapes of the ultrasound probe, and
- wherein each of the plurality of electro-acoustic modules operates in a manner substantially identical to each other of the plurality of electro-acoustic modules.

**2**. The ultrasound transducer array of claim **1**, wherein at least a portion of the support structure is planar.

**3**. The ultrasound transducer array of claim **1**, wherein at least a portion of the support structure is non-planar.

**4**. The ultrasound transducer array of claim **3**, wherein the at least one matrix acoustic array and the interconnect element are configured to conform to a shape of the non-planar support structure.

**5**. The ultrasound transducer array of claim **3**, wherein the interconnect element having variable thickness is coupled to the at least one matrix acoustic array so as to conform each electro-acoustic module to the shape of the non-planar support structure.

**6**. The ultrasound transducer array of claim **1**, wherein each of the plurality of electro-acoustic modules is detachably coupled to the support structure.

**7**. The ultrasound transducer array of claim **1**, wherein each of the plurality of electro-acoustic modules is interchangeably coupled to the support structure.

**8**. The ultrasound transducer array of claim **1**, wherein each of the plurality of electro-acoustic modules is aligned on the support structure to conform to a predetermined shape of the ultrasound probe.

**9**. The ultrasound transducer array of claim **1**, wherein each of the electro-acoustic modules comprises a bottom surface adjacent to the support structure and a top surface opposite the bottom surface and positioned away from the support structure, and at least two beveled sides each forming a surface extending between the bottom surface and the top surface, wherein a first width of an electro-acoustic module measured near the bottom surface is less than a second width of the electro-acoustic module measured near the top surface.

**10**. The ultrasound transducer array of claim **1**, wherein each of the plurality of electro-acoustic modules further comprises an integrated acoustic backing coupled to a heat sink, wherein the heat sink and the integrated acoustic backing are configured to absorb heat generated in the electro-acoustic modules.

**11**. The ultrasound transducer array of claim **1**, wherein the matrix acoustic array comprises a plurality of stack elements at least partially separated by a vertical gap, wherein at least one narrow stack element is positioned between two wide stack elements, wherein the at least one narrow stack element has a width extending horizontally between the vertical gaps that is lesser than a width of the wide stack elements.

**12**. The ultrasound transducer array of claim **11**, wherein the two wide stack elements are disposed on two sides of the matrix acoustic array such that the two wide stack elements overhang an ASIC in a corresponding electro-acoustic module.

**13**. The ultrasound transducer array of claim **1**, wherein the matrix acoustic array comprises:
- a plurality of first pads coupled between a plurality of stack elements and the interconnect element; and
- a plurality of second pads coupled between an ASIC bump and the interconnect element, wherein a pitch of at least one of the first pads, the second pads, the ASIC bump, and a dicing cut is varied by a predefined amount so that the matrix acoustic array overhang the ASIC.

**14**. The ultrasound transducer array of claim **13**, wherein the stack elements have uniform size irrespective of the pitch of the at least one of the first pads, the second pads, the ASIC bump, and the dicing cut.

**15**. The ultrasound transducer array of claim **1**, wherein the plurality of electro-acoustic modules are enclosed by a smooth curving material.

**16**. The ultrasound transducer array of claim **1**, wherein at least one of the electro-acoustic modules remains coupled to at least one other of the electro-acoustic modules.

**17**. An electro-acoustic module for an ultrasound transducer array, comprising:
- a base unit comprising an acoustic backing and a heat sink, wherein the heat sink is configured to detachably couple to a support structure of the ultrasound transducer array;
- an ASIC layer individually coupled to the base unit;
- a flex interconnect disposed on the ASIC layer and electrically coupled to a circuit board; and
- a matrix acoustic array disposed on the flex interconnect and comprising a plurality of stack elements at least partially separated by a vertical gap, wherein at least one narrow stack element is positioned between two wide stack elements, wherein the at least one narrow stack element has a width extending horizontally between the vertical gaps that is lesser than a width of the wide stack elements.

**18**. The electro-acoustic module of claim **17**, wherein the matrix acoustic array comprises:
- a plurality of first pads coupled between the stack elements and the flex interconnect; and
- a plurality of second pads coupled between an ASIC and the flex interconnect, wherein a pitch of the first pads is larger than a pitch of the second pads so as to obtain the wide stack elements when the acoustic array is diced.

**19**. The electro-acoustic module of claim **17**, wherein the heat sink comprises at least one threaded aperture for receiving at least one protruding member from the support structure.

**20**. The electro-acoustic module of claim **17**, wherein the heat sink comprises at least one aperture for receiving at least one pin from the support structure.

**21**. The electro-acoustic module of claim **20**, wherein the at least one pin allows the electro-acoustic module to align to the support structure.

**22**. The electro-acoustic module of claim **17**, wherein the flex interconnect comprises:

a primary flex interconnect disposed on the ASIC layer; and

a secondary flex interconnect electrically coupled to the primary flex and the circuit board.

**23**. The electro-acoustic module of claim **22**, wherein the secondary flex interconnect is configured to couple the primary flex interconnect to the circuit board independent of a position of the electro-acoustic module on the ultrasound transducer array.

**24**. The electro-acoustic module of claim **17**, wherein the two wide stack elements are disposed on two sides of the matrix acoustic array such that the two wide stack elements overhang the ASIC layer.

**25**. The electro-acoustic module of claim **17** further comprising a lens disposed on the matrix acoustic array.

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摘要(译)

提出了一种用于超声探头的超声换能器阵列。超声换能器阵列包括支撑结构。此外，超声换能器阵列包括耦合到支撑结构的多个电声模块，其中多个电声模块中的每一个包括至少一个矩阵声阵列和互连元件，其中多个电声模块中的每一个声学模块在支撑结构上是可互换的，以便适应超声波探头的一个或多个形状，并且其中多个电声模块中的每一个以与多个电声模块中的彼此基本相同的方式操作。 。