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(54) **SYNTHETIC JET WITH NON-METALLIC BLADE STRUCTURE**

SYNTHETISCHER STRAHL MIT NICHTMETALLISCHER BLADESTRUKTUR

JET SYNTHÉTIQUE AVEC STRUCTURE DE LAME NON MÉTALLIQUE

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EP 2 969 229 B1

Description

BACKGROUND OF THE INVENTION

[0001] Synthetic jet actuators are a widely-used technology that generates a synthetic jet of fluid to influence the flow of that fluid over a surface to disperse heat away therefrom. A typical synthetic jet actuator comprises a housing defining an internal chamber. An orifice is present in a wall of the housing. The actuator further includes a mechanism in or about the housing for periodically changing the volume within the internal chamber so that a series of fluid vortices are generated and projected in an external environment out from the orifice of the housing. Examples of volume changing mechanisms may include, for example, a piston positioned in the jet housing to move fluid in and out of the orifice during reciprocation of the piston or a flexible diaphragm as a wall of the housing. The flexible diaphragm is typically actuated by a piezoelectric actuator or other appropriate means.

[0002] Typically, a control system is used to create time-harmonic motion of the volume changing mechanism. As the mechanism decreases the chamber volume, fluid is ejected from the chamber through the orifice. As the fluid passes through the orifice, sharp edges of the orifice separate the flow to create vortex sheets that roll up into vortices. These vortices move away from the edges of the orifice under their own self-induced velocity. As the mechanism increases the chamber volume, ambient fluid is drawn into the chamber from large distances from the orifice. Since the vortices have already moved away from the edges of the orifice, they are not affected by the ambient fluid entering into the chamber. As the vortices travel away from the orifice, they synthesize a jet of fluid, i.e., a "synthetic jet."

[0003] It is recognized that acoustic noise is one negative aspect of synthetic jet operation, including dual cooling jets (DCJs) that employ an actuator (i.e., piezoelectric actuator) on each of opposing surfaces of the device. DCJs are typically excited at or near their mechanical resonance mode(s) in order to optimize electrical to mechanical conversion and so as to achieve maximum deflection at minimal mechanical energy input. While DCJ operation is optimized when operated at or near their mechanical resonance mode(s), it is recognized that operating the DCJ at certain frequencies can generate a substantial amount of acoustic noise, as the acoustic signature of the device is in part determined by the drive frequency of the device.

[0004] Synthetic jets of many variants, including the DCJ, are typically constructed using a metalized piezoactuator bonded to a metallic plate or blade with an electrically conductive adhesive. Electrical connections to the piezo-actuator are achieved by connecting to the metalized exposed piezo side and connecting to the plate material. Solders or conductive adhesives are typically used. Two of these plates are then adhered together along the perimeter leaving an orifice opening to form the jet. Upon actuation of the piezo-actuators, air is inhaled and exhaled through the orifice causing a net positive air flow.

[0005] One drawback to metallic plates or blades is that they are expensive and their stiffness causes higher resonant frequencies that increase DCJ operating noise. In addition, the metal mass can cause increased vibration. Still further, the resonant frequency of the DCJ can be increased due to the metallic plates.

[0006] It would therefore be desirable to provide a synthetic jet, such as a DCJ, having plates that are fabricated to have much lower resonant frequency for less noise. It would also be desirable for the plates to have a reduced mass that can provide lower vibration.

[0007] US2011/220339 discloses reducing acoustic noise in a synthetic jet by separating the structural and Helmholtz resonant frequencies of the device.

BRIEF DESCRIPTION OF THE INVENTION

[0008] According to the present invention there is provided a synthetic jet device as claimed in claim 1 and a method of manufacture as claimed in claim 10.

[0009] According to one aspect of the invention, a synthetic jet device includes a first plate, a second plate spaced apart from the first plate, a spacing component coupled to and positioned between the first and second plates to form a chamber and including an orifice therein, and an actuator element coupled to at least one of the first or second plates to selectively cause deflection thereof, wherein the first and second plates are formed at least in part of a non-metallic material and comprise a single piece of non-metallic material folded along a bridge thereof to form the first and second plates.

[0010] In accordance with another aspect of the invention, a method of fabricating a synthetic jet device includes constructing a first plate and a second plate at least in part of a non-metallic material, attaching an actuator element to at least one of the first and second plates to selectively cause deflection thereof, and positioning the first plate relative to the second plate by way of a spacing component, the spacing component securing the first plate to the second plate in a spaced apart arrangement to form a chamber and including an orifice therein. The method also includes attaching electrical connections to the actuator element and the respective one of the first and second plates to which the actuator element is attached so as to enable a selective applying of voltage to the actuator element; wherein the step of constructing the first plate and the second plate comprises: providing a single piece of electrically non-conductive, non-metallic material comprising a first plate portion, a second plate portion, and a bridge portion; and folding the single piece of electrically non-conductive, non-metallic material at the bridge portion to orient the first plate portion in a substantially parallel arrangement with the second plate portion, so as to form the first plate and the second plate; and wherein the single piece of electrically non-conductive, non-metallic material includes one of a lead formed internally therein that extends through the bridge portion and to the actuator element on the at least one of the first and second plates.

[0011] These and other advantages and features will be more readily understood from the following detailed description of preferred embodiments of the invention that is provided in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] The drawings illustrate various aspects and embodiments presently contemplated for carrying out the invention.

[0013] In the drawings:

FIGS. 1 and 2 are views of a synthetic jet assembly useable with embodiments of the invention.

FIG. 3 is a cross-section of the synthetic jet of FIGS. 1 and 2 depicting the jet as the control system causes the diaphragms to travel inward, toward the orifice.

FIG. 4 is a cross-section of the synthetic jet of FIGS. 1 and 2 depicting the jet as the control system causes the diaphragms to travel outward, away from the orifice.

FIG. 5 illustrates a build-up process for fabricating a synthetic jet that includes non-metallic plates therein.

FIG. 6 illustrates a build-up process for fabricating a synthetic jet that includes non-metallic plates therein.

FIG. 7 illustrates a build-up process for fabricating non-metallic plates of a synthetic jet.

FIG. 8 illustrates a build-up process for fabricating non-metallic plates of a synthetic jet.

FIG. 9 illustrates a build-up process for fabricating a double-folded non-metallic plate structure of a synthetic jet, according to an embodiment of the invention.

FIG. 10 illustrates a build-up process for fabricating double-folded non-metallic plate structure of a synthetic jet, according to an embodiment of the invention.

DESCRIPTION OF THE INVENTION

[0014] Embodiments of the invention are directed to a synthetic jet device having non-metallic plates that provide for a lower resonant frequency for less noise, as well as lower vibration.

[0015] FIGS. 1-4 illustrate a general structure of a synthetic jet assembly 10 useable with embodiments of the present invention, along with the movement of various components during operation thereof, for purposes of better understanding the invention.

[0016] Referring first to FIG. 1, the synthetic jet assembly 10 is shown as including a synthetic jet 12, a cross-section of which is illustrated in FIG. 2, and a mounting bracket 14. Mounting bracket 14 is a u-shaped mounting bracket that is affixed to a body or housing 16 of synthetic jet 12 at one or more locations, although it is recognized that the mounting bracket may be constructed as a bracket having a different shape/profile, such as a semi-circular bracket configured to receive a circular synthetic jet 12 therein. A circuit driver 18 can be externally located or affixed to mounting bracket 14. Alternatively, circuit driver 18 may be remotely located from synthetic jet assembly 10.

[0017] Referring now to FIGS. 1 and 2 together, and as shown therein, housing 16 of synthetic jet 12 defines and partially encloses an internal chamber or cavity 20 having a gas or fluid 22 therein. While housing 16 and internal chamber 20 can take virtually any geometric configuration according to various embodiments of the invention, for purposes of discussion and understanding, housing 16 is shown in cross-section in FIG. 2 as including a first plate 24 and a second plate 26 (alternately referred to as blades or foils), which are maintained in a spaced apart relationship by a spacer element 28 positioned therebetween. Spacer element 28 maintains a separation of approximately 1 mm between first and second plates 24, 26. One or more orifices 30 are formed between first and second plates 24, 26 and the side walls of spacer element 28 in order to place the internal chamber 20 in fluid communication with a surrounding, exterior environment 32. Alternatively, spacer element 28 includes a front surface (not shown) in which one or more orifices 30 are formed.

[0018] First and second plates 24, 26 may be formed from a metal, plastic, glass, and/or ceramic. Likewise, spacer element 28 may be formed from a metal, plastic, glass, and/or ceramic. Suitable metals include materials such as nickel, aluminum, copper, and molybdenum, or alloys such as stainless steel, brass, bronze, and the like. Suitable polymers and plastics include thermoplastics such as polyolefins, polycarbonate, thermosets, epoxies, urethanes, acrylics, silicones, polyimides, and photoresist-capable materials, and other resilient plastics. Suitable ceramics include, for example, titanates (such as lanthanum titanate, bismuth titanate, and lead zirconate titanate) and molybdates. Furthermore, various other components of synthetic jet 12 may be formed from metal as well.

[0019] Actuators 34, 36 may be coupled to respective first and second plates, 24, 26 to form first and second composite structures or flexible diaphragms 38, 40, which are controlled by driver 18 via a controller assembly or control unit system 42. The synthetic jet 12 is thus constructed as a DCJ. For controlling the diaphragms 38, 40, each flexible diaphragm 38, 40 may be equipped with a metal layer and a metal electrode may be disposed adjacent to the metal layer so that diaphragms 38, 40 may be moved via an electrical bias imposed between the electrode and the metal layer. As shown in FIG. 1, controller assembly 42 may be electronically coupled to driver 18, which may be coupled directly to mounting bracket 14 of synthetic jet 12. Alternatively, control unit system 42 may be integrated into a driver 18 that is remotely located from synthetic jet 12. Moreover, control system 42 may be configured to generate the electrical bias by any suitable device, such as, for example, a computer, logic processor, or signal generator.

[0020] Actuators 34, 36 may be piezoelectric motive (piezomotive) devices that may be actuated by application of a harmonic alternating voltage that causes the piezomotive devices to rapidly expand and contract. During operation, control system 42 transmits an electric charge, via driver 18, to piezoelectric actuators 34, 36, which undergo mechanical stress and/or strain responsive to the charge. The stress/strain of piezomotive actuators 34, 36 causes deflection of respective first and second plates 24, 26 such that a time-harmonic or periodic motion is achieved that changes the volume of the internal chamber 20 between plates 24, 26. Spacer element 28 can also be made flexible and deform to change the volume of internal chamber 20. The resulting volume change in internal chamber 20 causes an interchange of gas or other fluid between internal chamber 20 and exterior volume 32, as described in detail with respect to FIGS. 3 and 4.

[0021] Piezomotive actuators 34, 36 may be monomorph or bimorph devices. In a monomorph device, piezomotive actuators 34, 36 may be coupled to plates 24, 26 formed from materials including metal, plastic, glass, or ceramic. In a bimorph device, one or both piezomotive actuators 34, 36 may be bimorph actuators coupled to plates 24, 26 formed from piezoelectric materials. Alternatively, the bimorph may include single actuators 34, 36, and plates 24, 26 are the second actuators.

[0022] The components of synthetic jet 12 may be adhered together or otherwise attached to one another using adhesives, solders, and the like. A thermoset adhesive or an electrically conductive adhesive may be employed to bond actuators 34, 36 to first and second plates, 24, 26 to form first and second composite structures 38, 40. In the case of an electrically conductive adhesive, an adhesive may be filled with an electrically conductive filler such as silver, gold, and the like, in order to attach lead wires (not shown) to synthetic jet 12. Suitable adhesives may have a hardness in the range of Shore A hardness of 100 or less and may include as examples silicones, polyurethanes, thermoplastic rubbers, and the like, such that an operating temperature of 120 degrees or greater may be achieved.

[0023] Actuators 34, 36 may include devices other than piezoelectric motive devices, such as hydraulic, pneumatic, magnetic, electrostatic, and ultrasonic materials. Thus, control system 42 may be configured to activate respective actuators 34, 36 in corresponding fashion. For example, if electrostatic materials are used, control system 42 may be configured to provide a rapidly alternating electrostatic voltage to actuators 34, 36 in order to activate and flex respective first and second plates 24, 26.

[0024] The operation of synthetic jet 12 is described with reference to FIGS. 3 and 4. Referring first to FIG. 3, synthetic jet 12 is illustrated as actuators 34, 36 are controlled to cause first and second plates 24, 26 to move outward with respect to internal chamber 20, as depicted by arrows 44. As first and second plates 24, 26 flex outward, the internal volume of internal chamber 20 increases, and ambient fluid or gas 46 rushes into internal chamber 20 as depicted by the set of arrows 48. Actuators 34, 36 are controlled by control system 42 so that when first and second plates 24, 26 move outward from internal chamber 20, vortices are already removed from edges of orifice 30 and thus are not affected by the ambient fluid 46 being drawn into internal chamber 20. Meanwhile, a jet of ambient fluid 46 is synthesized by vortices creating strong entrainment of ambient fluid 46 drawn from large distances away from orifice 30.

[0025] FIG. 4 depicts synthetic jet 12 as actuators 34, 36 are controlled to cause first and second plates 24, 26 to flex inward into internal chamber 20, as depicted by arrows 50. The internal volume of internal chamber 20 decreases, and fluid 22 is ejected as a cooling jet through orifice 30 in the direction indicated by the set of arrows 52 toward a device 54 to be cooled, such as, for example a light emitting diode. As the fluid 22 exits internal chamber 20 through orifice 30, the flow separates at the sharp edges of orifice 30 and creates vortex sheets which roll into vortices and begin to move away from edges of orifice 30.

[0026] While the synthetic jet of FIGS. 1-4 is shown and described as having a single orifice therein, it is also envisioned that embodiments of the invention may include multiple orifice synthetic jet actuators. Additionally, while the synthetic jet actuators of FIGS. 1-4 are shown and described as having an actuator element included on each of first and second plates, it is also envisioned that embodiments of the invention may include only a single actuator element positioned on one of the plates. Furthermore, it is also envisioned that the synthetic jet plates may be provided in a circular, rectangular, or alternatively shaped configuration, rather than in a square configuration as illustrated herein.

[0027] A synthetic jet device may be provided that includes plates or blades that are formed in-part or in-whole of a non-metallic material - and thus are generally referred to hereafter as "non-metallic plates." The plates can be formed from any of a number of suitable non-metallic materials that may be selected and tailored to set the stiffness and thus adjust the resonant frequency of the synthetic jet. By selecting a specific non-metallic material from which to form the plates in-part or in-whole, the plates can be fabricated to have much lower resonant frequency for less noise and a reduced mass that can provide lower vibration.

[0028] The non-metallic material from which the plate is formed in-part or in-whole can be a number of suitable non-metallic materials, such as (but not limited to): a thermoplastic or thermoset in the form of polyethylene, polypropylene, polystyrene, polyvinyl chloride, and polytetrafluoroethylene (PTFE), Polyethylene terephthalate (PET), Polyethylene (PE), High-density polyethylene (HDPE), Polyvinyl chloride (PVC), Polyvinylidene chloride (PVDC) Low-density polyethylene (LDPE), Polypropylene (PP) Polystyrene (PS), High impact polystyrene (HIPS) Polyamides (PA) Acrylonitrile butadiene styrene (ABS) Polycarbonate (PC) Polycarbonate/Acrylonitrile Butadiene Styrene (PC/ABS) Polyurethanes (PU), Epoxies and combinations thereof, including combinations of various thermoplastics, thermosets and fillers. The fillers loading the plastic can include electrically conductive and insulating fillers such as silver particles, ceramics, glasses, etc. In forming the plates, common practices such as casting or injection molding may be employed.

[0029] A metallic coating may be applied to a plate formed of non-metallic material. Alternatively, the plate can be made sufficiently electrically conductive (via use of a filler) so that a metallic coating is not necessary.

[0030] Referring to FIG. 5, a build-up process for fabricating a non-metallic plate 60 (and synthetic jet 12) may be shown. In a first step of the process, a non-metallic and electrically insulating material or substrate 60 may be provided, such as a substrate formed of any of the thermoplastic or thermoset materials set forth above. In a next step, the non-metallic substrate 62 may be dipped in a catalyst (e.g., palladium catalyst), as indicated at 64, to activate a surface/backside protect for the plate. A metallic material that is electrically conducting, such as copper or nickel, may be then applied via electroless plating in a next step, as indicated at 66, to form the final structure of the non-metallic plate 60. Upon plating, a conductive epoxy (e.g., Ag epoxy) may be utilized to secure a piezomotive actuator 34, 36 to the plate 60. Finally, electrical conduits 68, such as wires or flex circuit material, are attached to the piezomotive actuator 34, 36 and the plate 60. An adhesive, such as silicon, can then be used to join the two plates 60 of the synthetic jet together - with the silicon forming the spacer element 28 between the two plates of the synthetic jet 12 that is formed.

[0031] With respect to the process illustrated and described in FIG. 5, processing alternate to electroless plating, such as evaporation or sputtering techniques, can be used to deposit the metal. Electroplating can then follow if a thicker metal is desired. Typical metallization schemes may include palladium activated electroless copper or nickel, sputtered or evaporated Ti, Cr, TiW, Cu, Ni, Au, Al followed by thicker plating of Cu, or Ni capped with a thin Au layer (if needed to prevent oxidation). Sputtered or evaporated processes will typically start with deposition of Ti, Cr, or TiW to promote metal adhesion. The finished metal can be patterned if desired using shadow masking or common lithographic pattern and etch steps. Alternatively, the plate may be cast from a piezo-polymer material, metalized on both sides and polarized to form an integral actuator plate.

[0032] Referring now to FIG. 6, another example of a non-metallic plate(s) 70 (and a build-up process for fabrication of a synthetic jet 12) is shown. The non-metallic plates 70 in FIG. 6 are formed as a thin single-sided copper coated glass-reinforced epoxy laminate sheet (e.g., FR4 PCB blanks) - alternately referred to hereafter as copper coated PCB blanks. In fabrication of the synthetic jet 12, the copper coated PCB blanks 70 are provided and a conductive epoxy (e.g., Ag epoxy) and piezo-actuator 34, 36 are then subsequently applied thereto, with the epoxy securing the piezo-actuator 34, 36 to the copper coating of the non-metallic plates 70. Electrical conduits 68, such as urethane coated wires, are then attached to the piezo element and the copper coated PCB blanks 70 (e.g., soldered, conductive epoxied, or mechanically attached), with an adhesive such as silicon 28 applied along a perimeter of the plates 70 used to join the two plates of the synthetic jet 12 together - the silicon 28 sealing the plates 70 together while also leaving an aperture or orifice therein.

[0033] The non-metallic plates of the synthetic jet 12 may be formed of Kapton® or another suitable dielectric material. One example where Kapton plates are utilized for forming non-metallic plates is provided in FIG. 7, where a build-up process for fabrication of the plate(s) is illustrated. As shown in the build-up process of FIG. 7, for each non-metallic plate, a bare Kapton plate 72 is first provided, with a conductive lead 74 then being formed on the top surface 76 thereof - in the form of a sputtered lead, Kapton connector, wire, or line of conductive epoxy. In a next step of the build-up process, a piezo-actuator 34, 36 is placed on each Kapton plate 72 so as to be electrically coupled to the conductive lead 74. Finally, electrical connections 68 are provided for connection to the piezo-actuators 34, 36 and the conductive leads 68. An adhesive, such as silicon, can then be used to join the two plates of the synthetic jet together - with the silicon forming the spacer element between the two plates of the synthetic jet.

[0034] Where Kapton plates are utilized, and as shown in the build-up process of FIG. 8, non-metallic plates 78 may be provided that are each constructed as a Kapton circuit - with a thicker layer of Kapton being provided with internal wiring 80 therein that can connect to the piezo-actuator 34, 36. The internal wiring 80 can be completely covered by Kapton and exposed locally at the piezo-actuator 34, 36 and lead contacts (for connection of electrical conduits 68), or can be exposed entirely.

[0035] Referring now to FIGS. 9 and 10, in embodiments of the invention, the non-metallic plates of a synthetic jet are made out of a single piece of non-metallic material that is folded double at a bridge portion to form a pair of plates. Referring first to the build-up process of FIG. 9, a double-folded plate is fabricated by first providing a single piece of non-metallic material (e.g., Kapton) 82 that is folded double at a bridge portion 84 to define a pair of plate portions 86, 88. As shown in FIG. 9, the bridge portion 84 is formed as a thin strip of material that is centered along a width of the plates 86, 88. It is recognized, however, that the bridge portion 84 could instead be formed to extend a full width of the plates 86, 88 but be configured to provide for a folding thereof to generally in define separate first and second plates 86, 88. According to an exemplary embodiment, the double-folded plate 82 includes internal electrical connections or leads formed therein that are covered and exposed locally at the piezo-actuators and lead contacts.

[0036] In the embodiment of FIG. 9, the internal wiring includes a continuous lead 90 that extends between the two piezo-actuators 34, 36 that are positioned on the respective plates 86, 88 and connects to each of the piezo-actuators 34, 36 - such that the number of internal leads formed in the double-folded plate is reduced. The number of electrical connections 68 provided for connection to the synthetic jet is also reduced, as connections 68 are only needed for each of the two piezo-actuators 34, 36 and for the continuous conductive lead 90 that extends across the bridge portion 84 - for a total of three electrical connections 68 to the synthetic jet.

[0037] In an alternative embodiment of the double-folded plate of FIG. 9 (and the continuous lead shown therein extending across the bridge portion), FIG. 10 shows a double-folded plate 82 having a discontinuous lead through the bridge portion - such that two separate leads 92 are defined. The separate leads 92 are connected to the two piezo-actuators 34, 36 positioned on the respective plates 86, 88, with electrical connections 68 being provided for connection to the two piezo-actuators 34, 36 and for the conductive leads 92. Thus, in the embodiment of FIG. 10, a total of four electrical connections 68 are provided for to the synthetic jet.

[0038] Beneficially, embodiments of the invention thus provide a synthetic jet assembly that incorporates non-metallic plates to lower a level of acoustic noise during operation of the synthetic jet. The non-metallic plates are fabricated to have a lower stiffness than metallic plates so as to provide a lower resonant frequency that generates less noise, with the plates also having a reduced mass that provides lower vibration during operation. The non-metallic plates may be formed of inexpensive materials such that the cost thereof is reduced as compared to metallic plates.

[0039] While the invention has been described in detail in connection with only a limited number of embodiments, it should be readily understood that the invention is not limited to such disclosed embodiments. Additionally, while various embodiments of the invention have been described, it is to be understood that aspects of the invention may include only some of the described embodiments. Accordingly, the invention is not to be seen as limited by the foregoing description, but is only limited by the scope of the appended claims.

Claims

1. A synthetic jet device (12) comprising:

a first plate (24);
a second plate (26) spaced apart from the first plate;
a spacing component (28) coupled to and positioned between the first and second plates (24, 26) to form a chamber (20) and including an orifice (30) therein; and
an actuator element (34, 36) coupled to at least one of the first or second plates (24, 26) to selectively cause deflection thereof;
wherein the first and second plates (24, 26) are formed at least in part of a non-metallic material **characterised in that**
the first and second plates (24, 26) comprise a single piece of non-metallic material folded along a bridge thereof to form the first and second plates.

2. The synthetic jet device (12) of claim 1, wherein the non-metallic material comprises an electrically non-conductive material.

3. The synthetic jet device (12) of claim 2, wherein the non-metallic material comprises at least one of a thermoplastic, thermoset, and a filler material.

4. The synthetic jet device (12) of claim 2, wherein each of the first and second plates (24, 26) includes an electrically conductive metallic material, the electrically conductive metallic material comprising one of a filler material, a metalizing layer, and internally or externally formed leads.

5. The synthetic jet device (12) of claim 4, wherein each of the first and second plates (24, 26) comprises:
an electrically non-conductive, non-metallic substrate; and
an electrically conductive metalizing layer applied onto the electrically non-conductive, non-metallic substrate.

6. The synthetic jet device (12) of claim 4, wherein each of the first and second plates (24, 26) comprises:

a flexible dielectric layer; and
electrically conductive leads formed on an exterior surface of the flexible dielectric layer or internally within the flexible dielectric layer.

7. The synthetic jet device (12) of claim 1, wherein a continuous electrically conductive lead is formed internally in the single piece of non-metallic material and extends through the bridge and to the actuator element on the respective first and second plates (24, 26).

8. The synthetic jet device (12) of claim 1, wherein a discontinuous electrically conductive lead is formed internally in the single piece of non-metallic material and extends through the bridge and to the actuator element on the first and second plates (24, 26).

9. A method of fabricating a synthetic jet device (12) comprising:

constructing a first plate (24) and a second plate (26) at least in part of a non-metallic material;
attaching an actuator element (34, 36) to at least one of the first and second plates (24, 26) to selectively cause deflection thereof;
positioning the first plate (24) relative to the second plate (26) by way of a spacing component (28), the spacing component securing the first plate to the second plate in a spaced apart arrangement to form a chamber (20) and including an orifice (30) therein; and
attaching electrical connections to the actuator element and the respective one of the first and second plates to which the actuator element is attached so as to enable a selective applying of voltage to the actuator element, **characterised in that** the step of constructing the first plate and the second plate comprises:

providing a single piece of electrically non-conductive, non-metallic material comprising a first plate portion, a second plate portion, and a bridge portion; and
folding the single piece of electrically non-conductive, non-metallic material at the bridge portion to orient the first plate portion in a substantially parallel arrangement with the second plate portion, so as to form the first plate and the second plate;
wherein the single piece of electrically non-conductive, non-metallic material includes one of a lead formed internally therein that extends through the bridge portion and to the actuator element on the at least one of the first and second plates.

10. The method of claim 9, wherein constructing each of the first plate (24) and the second plate (26) further comprises selecting a material composition of the first and second plates to set a stiffness of the first and second plates (24, 26) to a desired amount, so as to adjust a resonant frequency of the synthetic jet device (12) to a desired level.

11. The method of claim 9, wherein constructing each of the first plate (24) and the second plate (26) further comprises:

providing an electrically non-conductive, non-metallic substrate; and
applying an electrically conductive metalizing layer onto the electrically non-conductive, non-metallic substrate.

12. The method of claim 9, wherein constructing each of the first plate (24) and the second plate (26) further comprises providing a copper-plated printed circuit board (PCB) blank.

13. The method of claim 9, wherein constructing each of the first plate (24) and the second plate (26) further comprises providing an electrically non-conductive, non-metallic material having an electrically conductive filler material mixed therein.

14. The method of claim 9, wherein the lead formed internally in the single piece of electrically non-conductive, non-metallic material comprises one of a continuous lead and a non-continuous lead.

Patentansprüche

1. Synthetische Strahlvorrichtung (12), umfassend:

eine erste Platte (24);
eine zweite Platte (26), die von der ersten Platte beabstandet ist;
eine Abstandskomponente (28), die mit der ersten und der zweiten Platte (24, 26) gekoppelt ist und zwischen diesen positioniert ist, um eine Kammer (20) zu bilden und eine Öffnung (30) darin aufzuweisen; und
ein Stellgliedelement (34, 36), das mit zumindest einer von der ersten oder der zweiten Platte (24, 26) gekoppelt ist, um selektiv deren Ablenkung zu bewirken;
wobei die erste und die zweite Platte (24, 26) zumindest teilweise aus einem nichtmetallischen Material gebildet sind, **dadurch gekennzeichnet, dass**
die erste und die zweite Platte (24, 26) ein einzelnes Stück nichtmetallischen Materials umfassen, das entlang einer Brücke davon gefaltet ist, um die erste und die zweite Platte zu bilden.

2. Synthetische Strahlvorrichtung (12) nach Anspruch 1, wobei das nichtmetallische Material ein elektrisch nicht leitendes Material umfasst.

3. Synthetische Strahlvorrichtung (12) nach Anspruch 2, wobei das elektrisch nicht leitende Material zumindest eines von einem thermoplastischen, einem duroplastischen und einem Füllmaterial umfasst.

4. Synthetische Strahlvorrichtung (12) nach Anspruch 2, wobei jede von der ersten und der zweiten Platte (24, 26) elektrisch leitendes metallisches Material aufweist, wobei das elektrisch leitende metallische Material eines von einem Füllmaterial, einer Metallisierungsschicht und innen oder außen gebildete Leitungen umfasst.

5. Synthetische Strahlvorrichtung (12) nach Anspruch 4, wobei jede von der ersten und der zweiten Platte (24, 26) umfasst:

ein elektrisch nicht leitendes, nichtmetallisches Substrat; und
eine elektrisch leitende Metallisierungsschicht, die auf das elektrisch nicht leitende, nichtmetallische Substrat aufgebracht ist.

6. Synthetische Strahlvorrichtung (12) nach Anspruch 4, wobei jede von der ersten und der zweiten Platte (24, 26) umfasst:

eine flexible dielektrische Schicht; und
elektrisch leitende Leitungen, die auf einer äußeren Oberfläche der flexiblen dielektrischen Schicht oder intern innerhalb der flexiblen dielektrischen Schicht gebildet sind.

7. Synthetische Strahlvorrichtung (12) nach Anspruch 1, wobei eine kontinuierliche elektrisch leitende Leitung intern in dem einzelnen Stück nichtmetallischen Materials gebildet ist und sich durch die Brücke und zu dem Stellgliedelement auf der jeweiligen ersten und zweiten Platte (24, 26) erstreckt.

8. Synthetische Strahlvorrichtung (12) nach Anspruch 1, wobei eine diskontinuierliche elektrisch leitende Leitung intern in dem einzelnen Stück nichtmetallischen Materials gebildet ist und sich durch die Brücke und zu dem Stellgliedelement auf der jeweiligen ersten und zweiten Platte (24, 26) erstreckt.

9. Verfahren zum Herstellen einer synthetischen Strahlvorrichtung (12), umfassend:

Konstruieren einer ersten Platte (24) und einer zweiten Platte (26) zumindest teilweise aus einem nichtmetallischen Material;
Befestigen eines Stellgliedelements (34, 36) an zumindest einer von der ersten und der zweiten Platte (24, 26), um selektiv deren Ablenkung zu bewirken;
Positionieren der ersten Platte (24) relativ zu der zweiten Platte (26) mittels einer Abstandskomponente (28), wobei die Abstandskomponente die erste Platte an der zweiten Platte in einer beabstandeten Anordnung sichert, um eine Kammer (20) zu bilden und eine Öffnung (30) darin aufzuweisen; und
Befestigen elektrischer Verbindungen an dem Stellgliedelement und der jeweiligen von der ersten und der zweiten Platte, an der das Stellgliedelement befestigt ist, um ein selektives Anlegen von Spannung an das Stellgliedelement zu ermöglichen, **dadurch gekennzeichnet, dass** der Schritt des Konstruierens der ersten Platte und der zweiten Platte umfasst:

Bereitstellen eines einzelnes Stücks elektrisch nicht leitenden, nichtmetallischen Materials, das einen ersten Plattenabschnitt, einen zweiten Plattenabschnitt und einen Brückenabschnitt umfasst; und
Falten des einzelnen Stücks elektrisch nicht leitenden, nichtmetallischen Materials an dem Brückenabschnitt, um den ersten Plattenabschnitt in einer im Wesentlichen parallelen Anordnung mit dem zweiten Plattenabschnitt auszurichten, um die erste Platte und die zweite Platte zu bilden;

wobei das einzelne Stück elektrisch nicht leitenden, nichtmetallischen Materials eine intern darin gebildete Leitung aufweist, die sich durch den Brückenabschnitt und zu dem Stellgliedelement auf der zumindest einen von der ersten und der zweiten Platte erstreckt.

10. Verfahren nach Anspruch 9, wobei das Konstruieren der ersten Platte (24) und der zweiten Platte (26) weiter ein Auswählen einer Materialzusammensetzung der ersten und der zweiten Platte umfasst, um eine Steifigkeit der ersten und der zweiten Platte (24, 26) auf einen gewünschten Betrag einzustellen, um eine Resonanzfrequenz der synthetischen Strahlvorrichtung (12) auf ein gewünschtes Niveau einzustellen.

11. Verfahren nach Anspruch 9, wobei das Konstruieren der ersten Platte (24) und der zweiten Platte (26) weiter umfasst:

Bereitstellen eines elektrisch nicht leitenden, nichtmetallischen Substrats; und
Aufbringen einer elektrisch leitenden Metallisierungsschicht auf das elektrisch nicht leitende, nichtmetallische Substrat.

12. Verfahren nach Anspruch 9, wobei das Konstruieren der ersten Platte (24) und der zweiten Platte (26) weiter ein Bereitstellen eines kupferplattierten Leiterplattenrohlings (PCB) umfasst.

13. Verfahren nach Anspruch 9, wobei das Konstruieren der ersten Platte (24) und der zweiten Platte (26) weiter ein Bereitstellen eines elektrisch nicht leitenden, nichtmetallischen Materials umfasst, das ein darin vermischtes elektrisch leitendes Füllmaterial aufweist.

14. Verfahren nach Anspruch 9, wobei die intern in dem einzelnen Stück elektrisch nicht leitenden, nichtmetallischen Materials gebildete Leitung eine von einer kontinuierlichen Leitung und einer diskontinuierlichen Leitung umfasst.

Revendications

1. Dispositif à jet synthétique (12) comprenant :

une première plaque (24) ;
une seconde plaque (26) espacée de la première plaque ;
un composant d'espacement (28) couplé aux et positionné entre les première et seconde plaques (24, 26) pour former une chambre (20) et incluant un orifice (30) dans celle-ci ; et
un élément actionneur (34, 36) couplé à au moins l'une des première ou seconde plaques (24, 26) pour entraîner sélectivement la déviation de celle-ci ;
dans lequel les première et seconde plaques (24, 26) sont formées au moins en partie en un matériau non métallique **caractérisé en ce que** les première et seconde plaques (24, 26) comprennent un unique morceau de matériau non métallique plié le long d'un pont de celui-ci pour former les première et seconde plaques.

2. Dispositif à jet synthétique (12) selon la revendication 1, dans lequel le matériau non métallique comprend un matériau électriquement non conducteur.

3. Dispositif à jet synthétique (12) selon la revendication 2, dans lequel le matériau non métallique comprend au moins l'un d'un matériau thermoplastique, d'un matériau thermodurci et d'un matériau de remplissage.

4. Dispositif à jet synthétique (12) selon la revendication 2, dans lequel chacune des première et seconde plaques (24, 26) inclut un matériau métallique électriquement conducteur, le matériau métallique électriquement conducteur comprenant l'un d'un matériau de remplissage, d'une couche de métallisation et de fils intérieurement ou extérieurement formés.

5. Dispositif à jet synthétique (12) selon la revendication 4, dans lequel chacune des première et seconde plaques (24, 26) comprend :

un substrat non métallique électriquement non conducteur ; et
une couche de métallisation électriquement conductrice appliquée sur le substrat non métallique électriquement non conducteur.

6. Dispositif à jet synthétique (12) selon la revendication 4, dans lequel chacune des première et seconde plaques (24, 26) comprend :

une couche diélectrique flexible ; et
des fils électriquement conducteurs formés sur une surface extérieure de la couche diélectrique flexible ou intérieurement au sein de la couche diélectrique flexible.

7. Dispositif à jet synthétique (12) selon la revendication 1, dans lequel un fil continu électriquement conducteur est formé intérieurement dans l'unique morceau de matériau non métallique et s'étend à travers le pont et jusqu'à l'élément actionneur sur les première et seconde plaques (24, 26) respectives.

8. Dispositif à jet synthétique (12) selon la revendication 1, dans lequel un fil discontinu électriquement conducteur est formé intérieurement dans l'unique morceau de matériau non métallique et s'étend à travers le pont et jusqu'à l'élément actionneur sur les première et seconde plaques (24, 26).

9. Procédé de fabrication d'un dispositif à jet synthétique (12) comprenant :

la construction d'une première plaque (24) et d'une seconde plaque (26) au moins en partie en un matériau non métallique ;
la fixation d'un élément actionneur (34, 36) à au moins l'une des première et seconde plaques (24, 26) pour entraîner sélectivement la déviation de celle-ci ;
le positionnement de la première plaque (24) par rapport à la seconde plaque (26) par le biais d'un composant d'espacement (28), le composant d'espacement arrimant la première plaque à la seconde plaque selon un agencement espacé pour former une chambre (20) et incluant un orifice (30) dans celle-ci ; et
la fixation de connexions électriques à l'élément actionneur et à l'une respective des première et seconde plaques à laquelle est fixé l'élément actionneur de manière à permettre une application sélective de tension à l'élément actionneur,
caractérisé en ce que l'étape de construction de la première plaque et de la seconde plaque comprend :

la fourniture d'un unique morceau de matériau non métallique électriquement non conducteur comprenant une première portion de plaque, une seconde portion de plaque et une portion de pont ; et

le pliage de l'unique morceau de matériau non métallique électriquement non conducteur au niveau de la portion de pont pour orienter la première portion de plaque selon un agencement sensiblement parallèle avec la seconde portion de plaque, de manière à former la première plaque et la seconde plaque ;

dans lequel l'unique morceau de matériau non métallique électriquement non conducteur inclut l'un d'un fil formé intérieurement dans celui-ci qui s'étend à travers la portion de pont et jusqu'à l'élément actionneur sur l'au moins une des première et seconde plaques.

10. Procédé selon la revendication 9, dans lequel la construction de chacune de la première plaque (24) et de la seconde plaque (26) comprend en outre la sélection d'une composition de matériau des première et seconde plaques pour régler une rigidité des première et seconde plaques (24, 26) à une quantité souhaitée, de manière à ajuster une fréquence de résonance du dispositif à jet synthétique (12) à un niveau souhaité.

11. Procédé selon la revendication 9, dans lequel la construction de chacune de la première plaque (24) et de la seconde plaque (26) comprend en outre :

la fourniture d'un substrat non métallique électriquement non conducteur ; et

l'application d'une couche de métallisation électriquement conductrice sur le substrat non métallique électriquement non conducteur.

12. Procédé selon la revendication 9, dans lequel la construction de chacune de la première plaque (24) et de la seconde plaque (26) comprend en outre la fourniture d'une découpe de carte de circuit imprimé (PCB) plaquée de cuivre.

13. Procédé selon la revendication 9, dans lequel la construction de chacune de la première plaque (24) et de la seconde plaque (26) comprend en outre la fourniture d'un matériau non métallique électriquement non conducteur ayant un matériau de remplissage électriquement conducteur mélangé dans celui-ci.

14. Procédé selon la revendication 9, dans lequel le fil formé intérieurement dans l'unique morceau de matériau non métallique électriquement non conducteur comprend l'un d'un fil continu et d'un fil non continu.

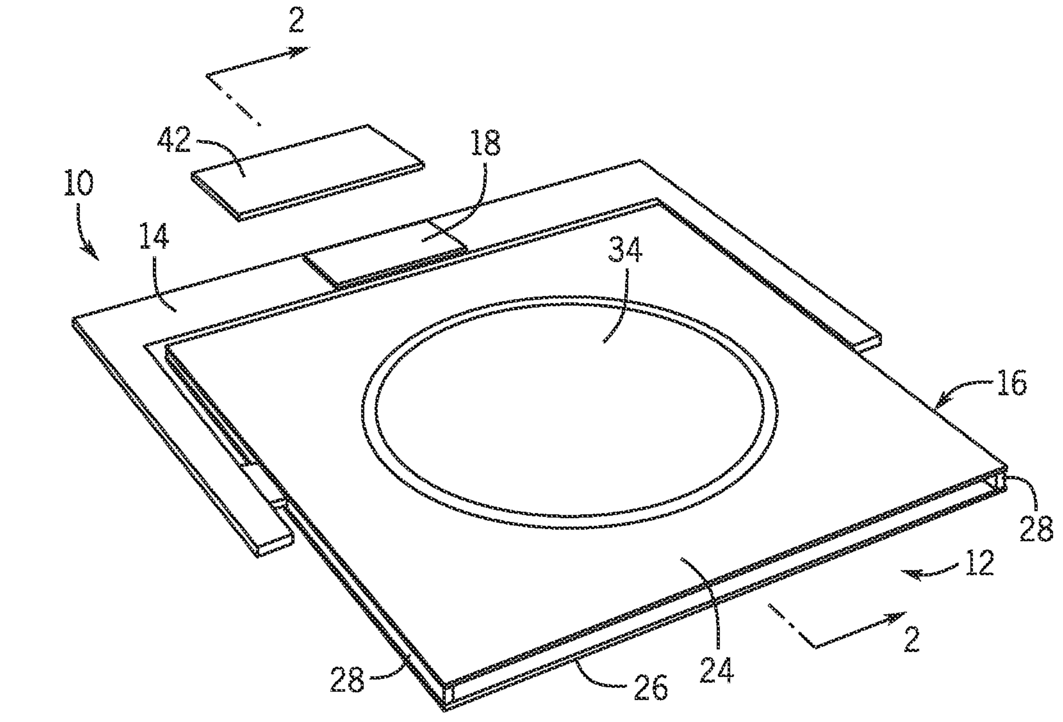


FIG. 1

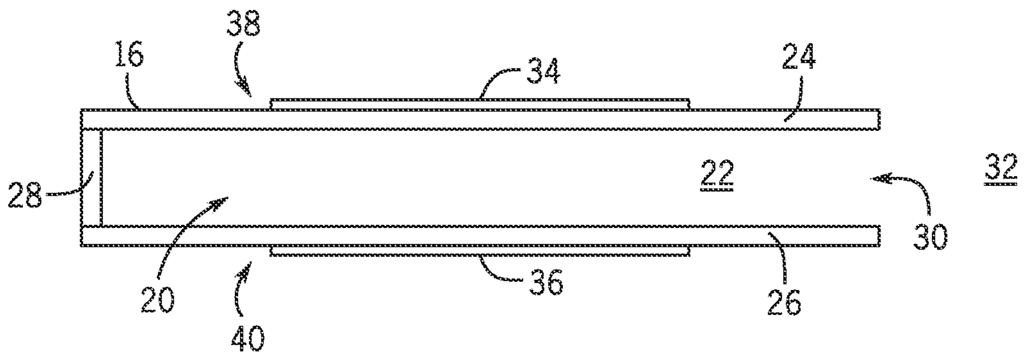
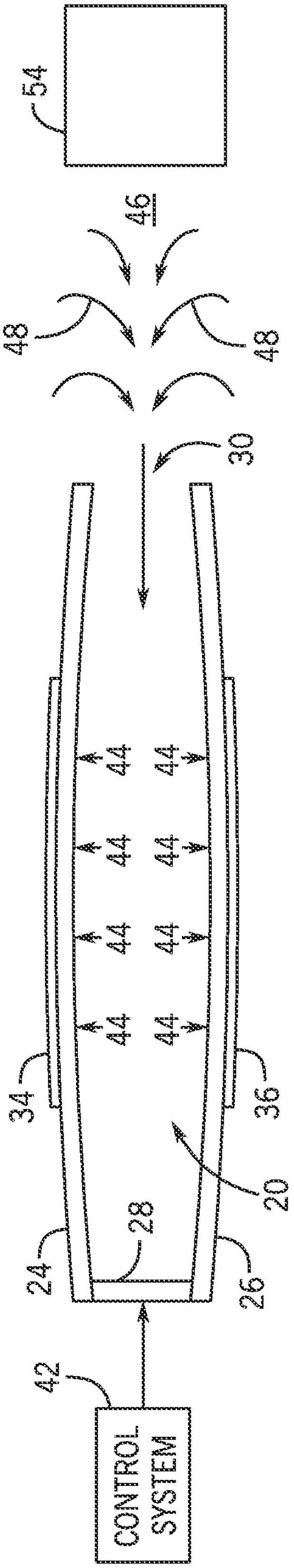


FIG. 2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CONTROL SYSTEM

FIG. 3

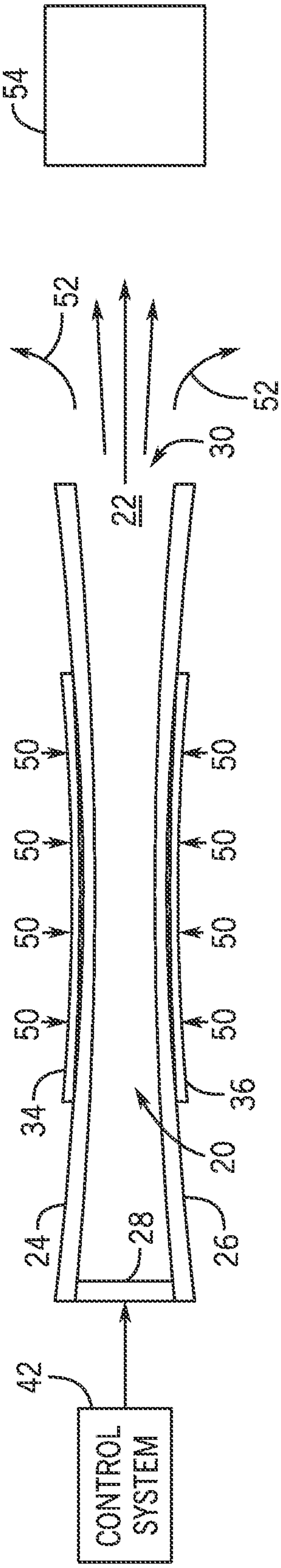
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FIG. 4

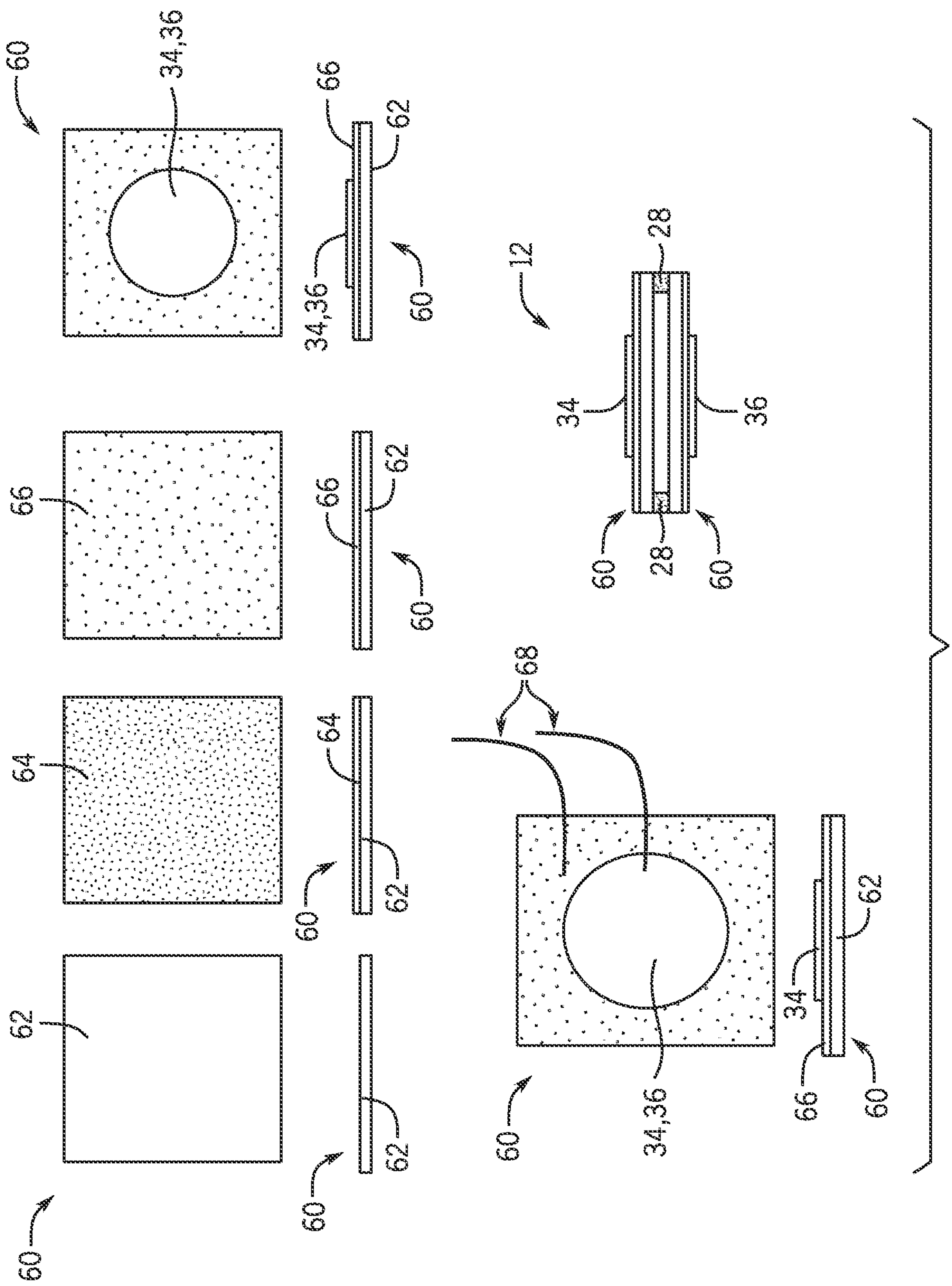

FIG. 5

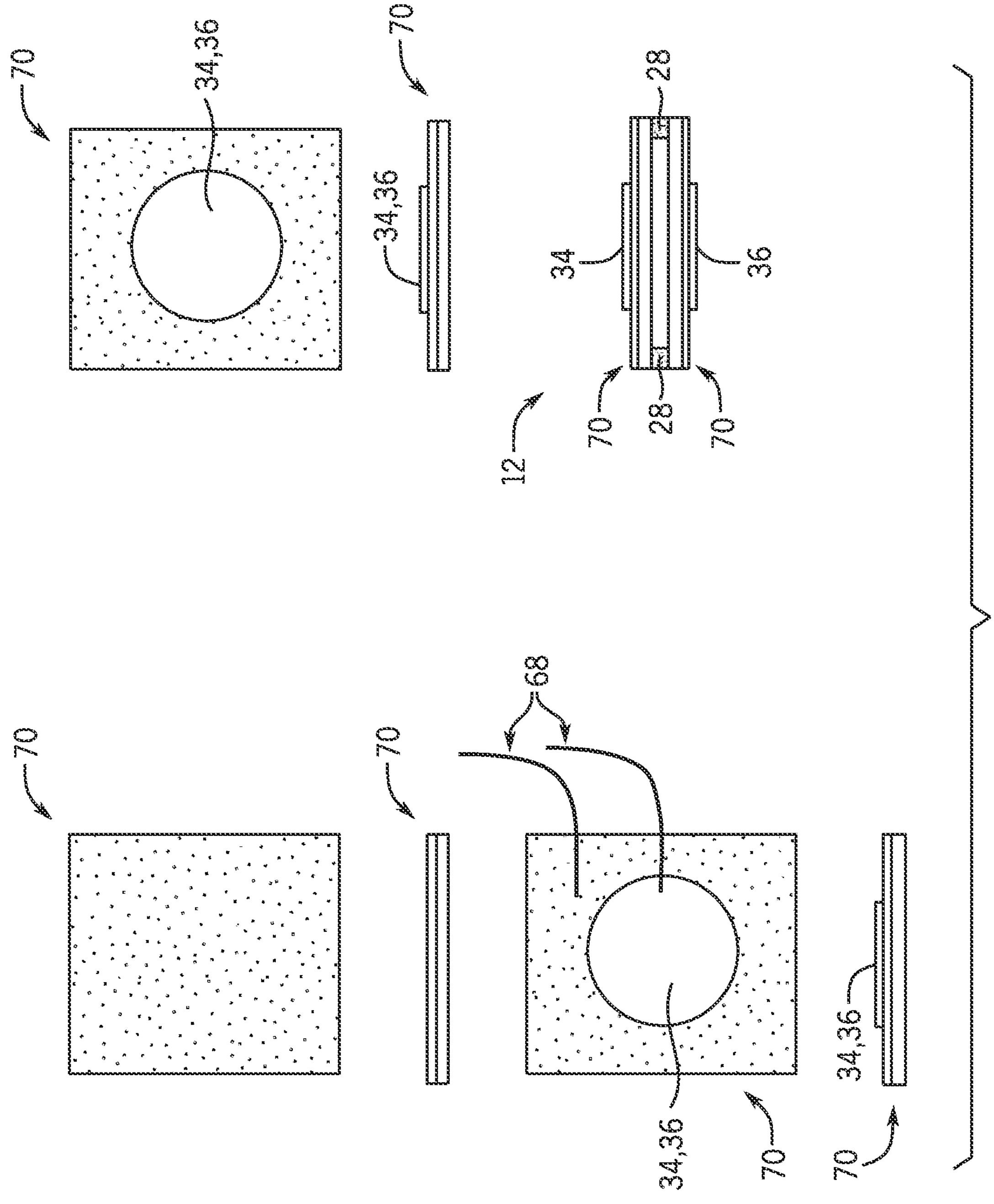

FIG. 6

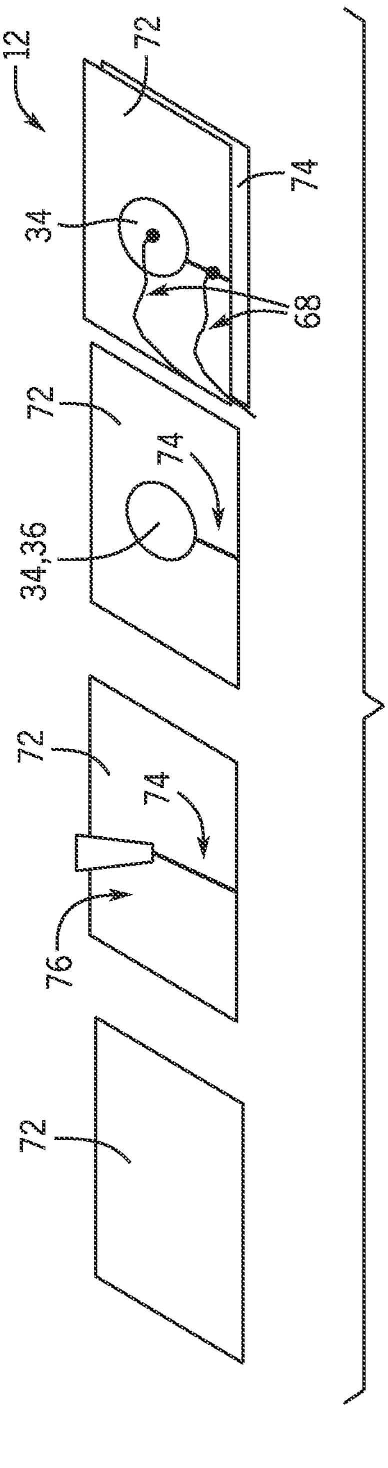
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FIG. 7

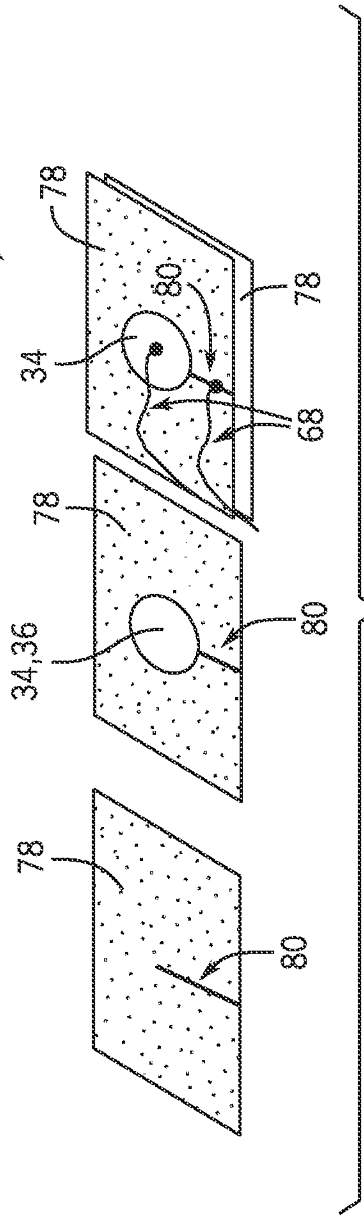
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FIG. 8

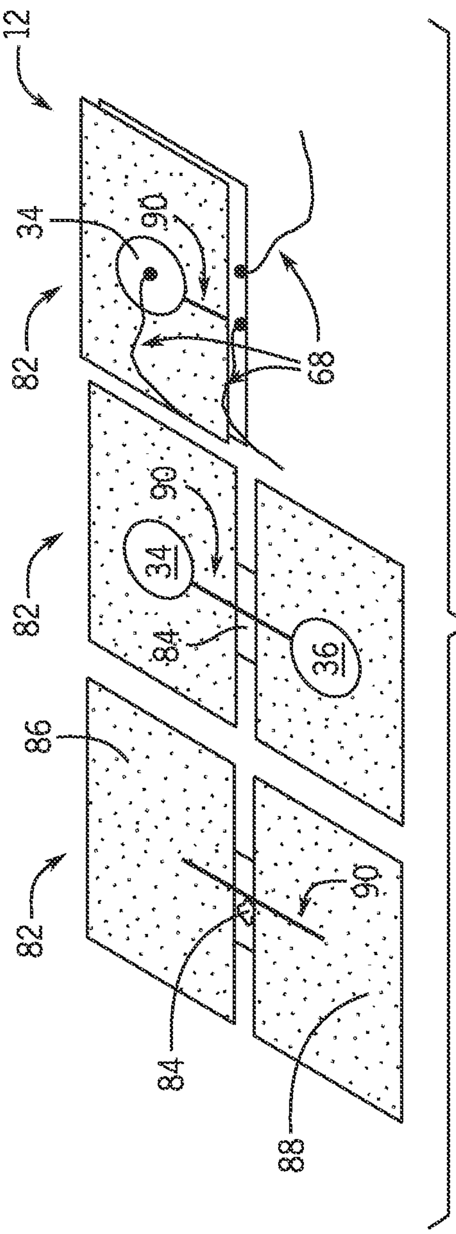
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FIG. 9

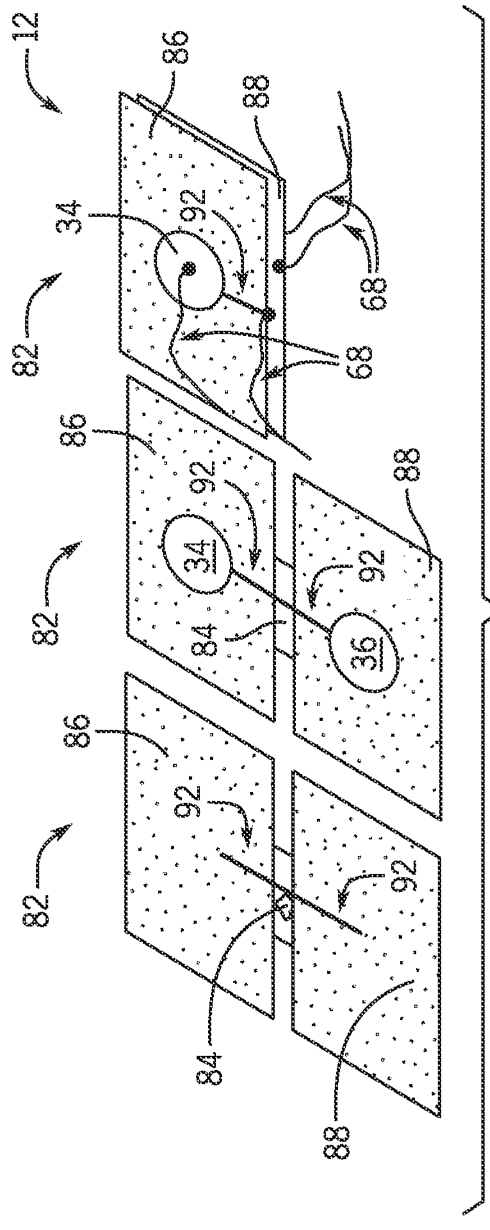
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FIG. 10

REFERENCES CITED IN THE DESCRIPTION

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