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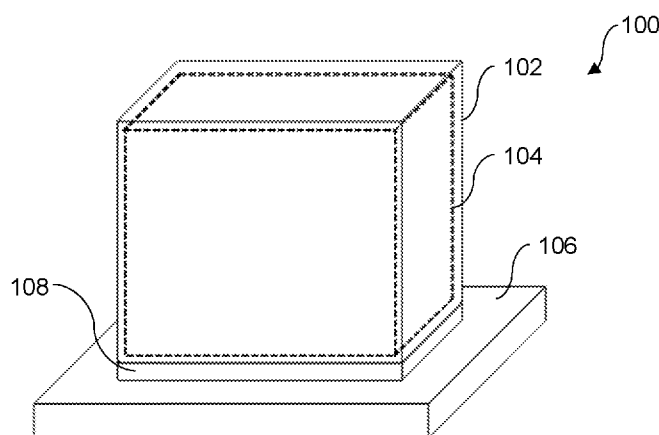


Fig. 1A

(57) Abstract: In an example, a contour analyzer may include a compliant cell and an electromagnetic fluid disposed within the compliant cell. Further, an example contour analyzer may also include a sensor plate having a sensor to detect a deformation of the electromagnetic fluid. An example contour analyzer may further include a sealing layer disposed in between the compliant cell and the sensor plate to seal the electromagnetic fluid within the compliant cell.



CONTOUR ANALYZERS WITH ELECTROMAGNETIC FLUID

BACKGROUND

[0001] Scanning devices such as two-dimensional (2D) or document scanners may be able to scan a physical object such as a sheet of paper or other media and create a digital representation of such an object, or text or images thereon. Further, three-dimensional (3D) scanning devices may be able to scan a 3D object and create a digital representation of such an object, or surfaces or features thereon. In some implementations, 3D scanning devices may be able to scan and digitally recreate not only the physical surfaces of an object, but also colors, designs, or aesthetics thereof.

BRIEF DESCRIPTION OF THE DRAWINGS

- [0002] Fig. 1A is a perspective view of an example contour analyzer.
- [0003] Fig. 1B is another perspective view of the example contour analyzer of Fig. 1A.
- [0004] Fig. 2 is a schematic view of another example contour analyzer.
- [0005] Fig. 3 are top and side views of another example contour analyzer.
- [0006] Fig. 4A is a perspective exploded view of another example contour analyzer.
- [0007] Fig. 4B is a top view of a sensor plate of the example contour analyzer of Fig. 4A.
- [0008] Fig. 5 is a perspective view of an example 3D scanner having an example contour analyzer.
- [0009] Fig. 6 is a perspective view of another example 3D scanner having an example contour analyzer.

DETAILED DESCRIPTION

[0010] Scanning devices such as two-dimensional (2D) or document scanners may be able to scan a physical object such as a sheet of paper or other media and create a digital representation of such an object, or text or images thereon. Further, three-dimensional (3D) scanning devices may be able to scan a 3D object and create a digital representation of such an object, or surfaces or features thereon. In some implementations, 3D scanning devices may be able to scan and digitally recreate not only the physical surfaces of an object, but also colors, designs, or aesthetics thereof, so as to create a visually accurate digital depiction. Such digital depictions or digital 3D models of an object may then subsequently be used by an additive manufacturing device, or 3D printer, to accurately recreate a physical 3D depiction of the object, or, further, to create other 3D objects that may closely conform or correspond to the originally-scanned object. In some implementations, a 3D scanner may be used to scan and create a digital 3D model of a body part, e.g., a foot, of a user. Such 3D data may then be used to print or create customized footwear or insoles for the user, for example.

[0011] In some situations, optical scanning technology may be utilized to 3D scan an object. While useful for capturing top-facing or visible surfaces of the object, it may be difficult to obtain 3D models of the bottom-facing surfaces of such an object and may require that the object be physically rotated about multiple axes in order to completely capture an accurate 3D model. In some situations, it may be especially difficult or complex to capture complete 3D images of a person or body part, e.g., a foot. Such optical scanning technology may entail that the subject step on a transparent surface such as glass, while optical 3D scanners located beneath the glass may then scan the bottom of the subject's foot in order to capture a complete digital representation. Such systems may be quite expensive, and also the results of which may be negatively affected by a subject's physical characteristics such as skin tone, hair, and/or skin texture.

[0012] Therefore, in some situations, it may be desirable to provide a 3D scanning technology or system that may effectively scan and provide an accurate digital representation of an object. Additionally, it may be desirable for such a 3D scanner to be able to accurately scan a bottom surface, i.e., a bottom-facing or not visible surface, of an object without the need to physically rotate, handle, or manipulate the object. Further, it may also be desirable that such a

3D scanning system be able to provide accurate scans of a surface despite differing physical characteristics, such as object color, texture, or other aspects.

[0013] Implementations of the present disclosure provide contour analyzers which may be able to read, scan, or otherwise detect a surface of an object, or contours, textures, shapes, etc., thereof, and provide a digital recreation of such a surface. Further, example contour analyzers disclosed herein may be utilized as part of a larger 3D scanner or scanning system to be able to capture 3D scans of additional, non-bottom-facing surfaces to provide a more complete 3D representation of the object being scanned.

[0014] Referring now to Fig. 1A, a perspective view of an example contour analyzer 100 is illustrated. Example contour analyzer 100 may include a compliant cell 102 and an electromagnetic fluid 104 disposed within the compliant cell 102. As such, electromagnetic fluid 104 is illustrated using dotted lines. Further, example contour analyzer 100 may also include a sensor plate 106 comprising a sensor (not shown) to detect a deformation of the electromagnetic fluid 104. Example contour analyzer 100 may further include a sealing layer 108 disposed in between the compliant cell 102 and the sensor plate 106 to hermetically seal the electromagnetic fluid 104 within the compliant cell 102.

[0015] The compliant cell 102 may be a resilient and pliable component, such that it may be able to return to its original shape after undergoing a deformation. In other words, the compliant cell 102 may be elastically deformable. Further, the compliant cell 102 may be substantially hollow, or have an inner cavity within which the electromagnetic fluid 104 may be disposed. While illustrated in Fig. 1A as being substantially rectangular or cuboidal, the compliant cell 102 may have any suitable shape or structure so as to be able to receive an external force and be elastically deformed from such a force. Further, the compliant cell 102 may have a suitably sized shape and structure, e.g., wall thickness, so as to be able to transfer such a deforming external force to the electromagnetic fluid 104 within the compliant cell 102. In other words, a deformation of the compliant cell 102, may cause a corresponding deformation of the electromagnetic fluid 104 within the compliant cell 102. In some implementations, the compliant cell 102 may be formed of a polymer material, e.g., silicone or rubber. In further implementations, the compliant cell 102 may have a Shore A durometer hardness of about between 25-70. In yet further implementations, the compliant cell 102 may be constructed of silicone with a Shore A durometer hardness of about 30. In other implementations, the

compliant cell 102 may include any material and/or physical structure suitable to provide a linear force versus displacement relationship. In this context, linear force versus displacement relationship may refer to the ability of the compliant cell 102, as well as the electromagnetic fluid 104 within the compliant cell 102, to deform in a linear fashion, as compared to an external force applied to the compliant cell 102. In other words, the ratio between how much force is applied, and the corresponding deformation of the compliant cell 102 and electromagnetic fluid 104 caused by such a force, i.e., the slope of a force versus displacement graph, may be substantially constant, regardless of the amount of force applied throughout an operable range of deformation of the compliant cell 102. In some implementations, the compliant cell 102 and the electromagnetic fluid 104 may have a force per displacement value of about 0.20 kilograms (Kg) per 1 millimeter (mm) of displacement.

[0016] The electromagnetic fluid 104 may be disposed within the compliant cell 102. In some implementations, the electromagnetic fluid 104 may be disposed within the compliant cell 102 without the presence or addition of other fluids, e.g., air, in order to maintain a linear force versus displacement relationship of a deformation of the compliant cell 102. As such, the contour analyzer 100 may further include a sealing layer 108 disposed in between the compliant cell 102, or the electromagnetic fluid 104 therein, and the sensor plate 106. The sealing layer 108 may hermetically seal the electromagnetic fluid 104 within the compliant cell 102 in order to prevent the electromagnetic fluid 104 from escaping or leaking from the compliant cell 102, and also to prevent air or other fluids from entering the compliant cell 102 and altering the deformation characteristics of the compliant cell 102 and/or electromagnetic fluid 104. In some implementations, the sealing layer 108 may be a silicone layer, film, or sealant.

[0017] The electromagnetic fluid 104 may be a liquid that may become magnetized in the presence of a magnetic field. Further, the electromagnetic fluid 104 may include ferromagnetic or ferrimagnetic particles suspended in a carrier fluid. The carrier fluid may be a hydrocarbon or synthetic hydrocarbon carrier fluid, in some implementations. The particles may contain iron, and thus may contribute to the magnetic response of the fluid. Further, the particles may be suspended in the carrier fluid using a surfactant so as to minimize clumping of the particles within the carrier fluid. In some implementations, the electromagnetic fluid 104 may be a ferromagnetic fluid, or ferrofluid. In further implementations, the electromagnetic fluid 104 may have a viscosity of about 300 centipoise (cP). In some implementations, the electromagnetic

fluid 104 may have a saturation magnetization of about 275 Gauss. In yet further implementations, the electromagnetic fluid 104 may be a commercially-available ferrofluid, e.g., Ferrotec APG E Series ferrofluid, or, specifically, APG-E26 ferrofluid.

[0018] The contour analyzer 100 may further include a sensor plate 106 having a sensor (not shown). In some implementations, the sensor may be able to detect or sense a characteristic or attribute of the electromagnetic fluid 104 within the compliant cell 102. The sensor plate 106, and/or the sensor thereof, may have or be attached to or integrated with a printed circuit board, printed circuit assembly (PCB, PCA), or other electronic components. In some implementations, the electromagnetic fluid 104 and the sensor of the sensor plate 106 may together form or be a part of an inductor-capacitor (LC) circuit, resonant circuit, and/or tank circuit. The sensor may thus be able to detect a frequency of the LC circuit. When the compliant cell 102, and thus the electromagnetic fluid 104 within the compliant cell 102, is in an undeformed state, as illustrated in Fig. 1A, the sensor may detect a first frequency of the LC circuit. The LC circuit is described in more detail below with regard to Fig. 2.

[0019] Referring additionally to Fig. 1B, another perspective view of the example contour analyzer 100 is illustrated. The compliant cell 102 is illustrated as having undergone a deformation, e.g., from pressing force 103. As such, the electromagnetic fluid 104 within the compliant cell 102 has also undergone a deformation. As a result of the deformation, the electromagnetic fluid 104 may have a change in characteristic or property, which may affect the performance or function of the LC circuit. In some implementations, the deformation of the electromagnetic fluid 104 may affect the frequency of the LC circuit, and, in other implementations, may cause the sensor to detect or read a second frequency, which may be lower than the first frequency. In other words, the sensor may detect a change in frequency of the LC circuit to determine an amount of deformation of the electromagnetic fluid 104.

[0020] Referring now to Fig. 2, a schematic view of an LC circuit of an example contour analyzer is illustrated. The example LC circuit of an example contour analyzer, e.g., the LC circuit as described above with regard to contour analyzer 100, is represented in diagrams 205a and 205b, wherein the LC circuit makes use of a deformable conductive medium, i.e., the electromagnetic fluid 104, represented by the ferrofluid (for example) in the diagrams. The deformable conductive medium, i.e., the electromagnetic fluid 104, is disposed within a flexible film, i.e., the compliant cell 102 as described above, in order to allow the electromagnetic fluid

104 to deform under an external force. Diagram 205a is a schematic representation of the LC circuit wherein the electromagnetic fluid 104 is undeformed, e.g., as illustrated in Fig. 1A, and diagram 205b is a schematic representation of the LC circuit wherein the electromagnetic fluid 104 has undergone a deformation, e.g., as illustrated in Fig. 1B. As such, cross-sectional distance D1 of the undeformed electromagnetic fluid 104 is larger than cross-sectional distance D2 of the deformed electromagnetic fluid 104, as illustrated in diagrams 205a and 205b, respectively. In the view of Fig. 2, the flexible film on the left represents a top surface of the compliant cell 102, whereupon the pressing force 103 is applied as illustrated in Fig. 1B.

[0021] Further, L1 is the inductor of the LC circuit in diagram 205a, representing a first inductive state, and L2 is the inductor of the LC circuit in diagram 205b, representing a second inductive state. The deformable medium, i.e., the electromagnetic fluid 104, may act as or be a part of the inductor L1 and L2. Thus, the size and or volume of the electromagnetic fluid 104 within the flexible film, i.e., compliant cell 102, affects the magnetic field of the inductor L1 and L2. In some implementations, the magnetic field of the inductor L1 and L2 is dependent on the cross-sectional area of the electromagnetic fluid 104, i.e., dependent on any change in volume of the electromagnetic fluid 104. In the undeformed state of diagram 205a, the electromagnetic fluid 104 may have a distance D1 across the cross-section of its volume, whereas, in the deformed state of diagram 205b, the electromagnetic fluid 104 may have a distance D2, less than D1, across the cross-section of its volume. Therefore, the electromagnetic fluid 104 may have a smaller cross-sectional area once it is deformed, which thus may affect the magnetic field of the inductor. Specifically, the smaller the cross-sectional area of the electromagnetic fluid 104, the lower the reluctance or magnetic resistance of the inductor will be. Therefore, the inductor in the first inductive state as represented by L1 may be greater or have greater reluctance than the inductor in the second inductive state as represented by L2.

[0022] In some implementations, the LC circuit may oscillate at a resonant frequency, with the electric field of the capacitor driving the magnetic field of the inductor until the capacitor voltage reaches zero, wherein the magnetic field of the inductor may then charge the electric field of the capacitor with a voltage of opposite polarity until the current running through the inductor reaches zero. The cycle may then repeat, resulting in an energy oscillation from one terminal of the capacitor to the other, through the inductor. The LC circuit may oscillate at a particular frequency, which may be detected by the sensor of the sensor plate 106, as described

above. The frequency of the LC circuit may change with the reluctance of the inductor. E.g., if the reluctance of the inductor decreases, the frequency, or one divided by the period of oscillation, will also decrease. Thus, as the electromagnetic fluid 104 is deformed, and D2 decreases relative to D1, the frequency of the LC circuit as measured by the sensor of the sensor plate 106 will also decrease. In some implementations, the frequency of the LC circuit in the undeformed state as shown in diagram 205a may be about 3 megahertz (Mhz). In further implementations, the frequency of the LC circuit may be reduced and read or sensed by the sensor at below 2 Mhz as the electromagnetic fluid 104 is deformed. The sensor may therefore be able to detect a decrease in frequency of the LC circuit. Upon detecting the lower frequency and determining the difference between the detected frequency and the starting frequency, the sensor, or electronic or computing components connected thereto, may determine the amount of deformation of the electromagnetic fluid 104, and due to the linear force versus displacement nature of the compliant cell 102 and the electromagnetic fluid 104, may further determine the magnitude of force being exerted upon the compliant cell 102.

[0023] Referring now to Fig. 3, top and side views of another example contour analyzer comprising an array 310 of compliant cells 302a, 302b, 302c . . . 302n (referred to collectively as compliant cells 302) is illustrated. Example contour analyzer 300 may be similar to other example contour analyzers, described above. Further, the similarly-named elements of example contour analyzer 300 may be similar in function and/or structure to the respective elements of other example contour analyzers, as they are described above. Each compliant cell 302 may have a ferrofluid disposed and sealed within the compliant cell 302. Further, contour analyzer 300 may have a sensor plate having a plurality or array of sensors 312 corresponding to the array of compliant cells 302 to detect deformations of the ferrofluid within each compliant cell 302. Each sensor 312 of the array of sensors may be disposed adjacent to or below a corresponding compliant cell 302.

[0024] Similar to described above, the ferrofluid within each compliant cell 302 and the corresponding sensor 312 of the array of sensors may form or be a part of a LC circuit. The ferrofluid may be or act as the inductor of each LC circuit, and the sensor 312 may sense a change in frequency of the LC circuit, driven by a deformation of the ferrofluid, to determine an amount or magnitude of the deformation of the ferrofluid.

[0025] The compliant cells 302 may each have a width 311, a length 315 and a height 317. In some implementations, the compliant cells 302 may have a substantially trapezoidal and/or pyramidal structure, wherein a top width 313 is different from the width 311. In such a situation, the width may be referred to as a root width 311. In other implementations, the compliant cells 302 may have a rounded structure, wherein the root width 311 may be referred to as a root diameter. Each of the compliant cells 302 may be deformable and may result in a corresponding deformation of the ferrofluid within the compliant cell 302. For example, referring to compliant cell 302c, a pressing force 303 may be exerted on a top surface of the compliant cell 302c, which may cause the compliant cell 302c to deform in a downward direction, as illustrated. Such a deformation may result in the ferrofluid within the compliant cell 302c also being deformed in a similar manner. Further, as the compliant cell 302c is deformed downwards, an upper portion of the compliant cell 302c may expand outwards as represented by example arrow 309. The top width 313, in some implementations, may be sufficiently smaller than the root width 311, and the width or root width of adjacent compliant cells 302, such that, upon the compliant cell 302c being deformed, the compliant cell 302c does not contact, impact, or otherwise physically interfere with the adjacent compliant cells 302. Such a contact or interference may have adverse effects on the sensors 312 corresponding to the adjacent compliant cells 302 being able to accurately sense a change in frequency in the corresponding LC circuits.

[0026] Referring now to Fig. 4A, a perspective and exploded view of another example contour analyzer 400 is illustrated. Example contour analyzer 400 may be similar to other example contour analyzers, described above. Further, the similarly-named elements of example contour analyzer 400 may be similar in function and/or structure to the respective elements of other example contour analyzers, as they are described above. In some implementations, the contour analyzer 400 may include an array 410 of compliant cells 402, a ferrofluid 404 disposed within each compliant cell 402, a sensor plate 406 having an array of sensors 412 corresponding to the array of compliant cells 402 to detect deformations of the ferrofluid 404 within each compliant cell 402, and a sealing layer 408 disposed between the array of compliant cells 402 and the sensor plate 406 to hermetically seal the ferrofluid 404 within each compliant cell 402.

[0027] The contour analyzer 400 may further include a top layer 414. The top layer 414 may be disposed on top of the array of compliant cells 402 and may protect the structure of the

array of compliant cells 402. In some implementations, the top layer 414 may be able to receive a pressing force and may then transfer such pressing force to the array of compliant cells 402 to cause some or all of the compliant cells 402 to undergo a deformation. As such, top layer 414 may be constructed of a pliable and/or resilient material, such as a polymer or rubber. In further implementations, the top layer 414 may be constructed, at least in part, of silicone rubber and, in yet further implementations, the top layer 414 may comprise a layer of silicone having a thickness of about 2 mm. In some implementations, the top layer 414 may include silicone having a Shore A durometer hardness of about 30.

[0028] Each sensor 412 of the array of sensors may be disposed adjacent to or below a corresponding compliant cell 402. Each sensor 412 and the corresponding ferrofluid 404 may form a LC circuit, wherein the ferrofluid may act as the inductor. Upon the ferrofluid undergoing a deformation, for example, from the pressing force causing a deformation of some or all of the compliant cells 402, the sensor may detect a change in the frequency of the LC circuit, in order to determine an amount or magnitude of the deformation.

[0029] In some implementations, the array 410 of compliant cells 402 may be a two-dimensional (2D) array of compliant cells 402. In further implementations, the array 410 may be a 2D array of 33 by 33 compliant cells 402. Each compliant cell 402 may be spaced away from adjacent compliant cells 402 and have a pitch of about 12 mm from adjacent compliant cells 402. In further implementations, each compliant cell 402 of the array 410 may have a height of about 14 mm, and may have a measurable vertical displacement of about 10 mm. In other words, each compliant cell 402 may be able to be deformed up to about 10 mm from its undeformed height of about 14 mm, and such deformation may be transmitted to the ferrofluid 404 within the compliant cell 402. The corresponding sensor 412 may be able to detect and determine such a deformation, by way of a change in frequency of the LC circuit, of up to about 10 mm. Thus, such a deformation, and deformations of lesser amounts and/or magnitudes, are considered measurable by the sensor. In some implementations, each compliant cell 402 may have a substantially conical or pyramidal shape, wherein the compliant cell 402 may be wider or have a larger diameter at its base than at the top of the compliant cell 402. Such a base size may be referred to as a root diameter, in some implementations, and each compliant cell 402 may have a root diameter of about 10 mm, in further implementations.

[0030] Referring now to Fig. 4B, an example sensor plate 406 of the example contour analyzer 400 is illustrated. Sensor plate 406 may be illustrated in Fig. 4B as being just a portion of the example sensor plate 406 as illustrated in Fig. 4A, as taken from detail view 4B of Fig. 4A. Thus, such a portion of sensor plate 406 may include just four sensors 412. Further, sensor plate 406 is illustrated as being broken out into multiple layers, e.g., multiple layers of a printed circuit board (PCB). Each sensor, e.g., sensor 412a, may have multiple layers of traces, conductive pathways, or other sensor components distributed among the multiple layers of the sensor plate 406. For example, sensor 412a may have multiple components 416a, 416b, 416c, 416d, disposed throughout the multiple layers of the sensor plate 406. Such components may work together to form each individual sensor 412, and/or the LC circuit with which each sensor 412 may be associated or be a part. Note, this is one example of a sensor plate 406 and sensor 412 implementation, and other structures and/or layouts are contemplated.

[0031] Referring now to Fig. 5, a perspective view of an example three-dimensional (3D) scanner 501 is illustrated. 3D scanner 501 may include a top scanner 518 having a plurality of optical scanning units 520. Further, 3D scanner 501 may include a pressure plate having an example contour analyzer 500 attached to the top scanner 518 below the optical scanning units 520. Example contour analyzer 500 may be similar to other example contour analyzers, described above. Further, the similarly-named elements of example contour analyzer 500 may be similar in function and/or structure to the respective elements of other example contour analyzers, as they are described above. Contour analyzer 500 may include an array of compliant cells, a ferrofluid disposed within each compliant cell, and a sensor plate having an array of sensors. The ferrofluid may deform upon a corresponding deformation of the respective compliant cell. Further, the sensor plate may be able to detect the deformation of each compliant cell and/or ferrofluid, and also determine, by way of a change in frequency, the amount of deformation of each compliant cell.

[0032] In some implementations, the 3D scanner 501 may include four optical scanning units 520, one disposed at each corner of the 3D scanner 501 and facing inward toward the pressure plate. Each of the optical scanning units may be able to optically scan top surfaces of an object placed on the pressure plate, while the contour analyzer 500 of the pressure plate may be able to detect a contour of bottom-facing surfaces of the object. For example, if a person and/or user 522 of the 3D scanner 501 were to step into the 3D scanner 501 and on to the

pressure plate, the optical scanning units 520 may be able to optically scan the upper surfaces and or contours of the foot or feet of the user 522. Also, the contour analyzer 500 may be able to detect and or measure the contour and surfaces of the bottom of the feet or foot of the user 522 by the sensor plate measuring the amount of deformation applied to each compliant cell by the weight of the user 522. In this example, the weight of the user 522 stepping on the contour analyzer 500 may act as a pressing force on some or all of the compliant cells of the array of compliant cells. In addition to measuring the amount of deformation of each compliant cell being deformed, and thus determining the contour of the bottom of the user's foot, the sensors of the sensor plate may be able to use the linear force versus displacement characteristics of the compliant cells and ferrofluid to determine how much force is causing such deformation. Thus, the contour analyzer 500 may be able to determine the weight and/or weight distribution and balance characteristics of the user's feet.

[0033] Referring now to Fig. 6, a perspective view of another example 3D scanner 601 is illustrated. 3D scanner 601 may include a top scanner 618 having a plurality of optical scanning units 620. Further, 3D scanner 601 may include a pressure plate having an example contour analyzer 600 attached to the top scanner 618 below the optical scanning units 620. Example contour analyzer 600 may be similar to other example contour analyzers, described above. Further, the similarly-named elements of example contour analyzer 600 may be similar in function and/or structure to the respective elements of other example contour analyzers, as they are described above. In some implementations, the 3D scanner 601 may include two optical scanning units 620, each disposed along a side of the 3D scanner 601 and facing inwards. Thus, the optical scanning unit 620 may be able to scan the top surfaces of an object placed upon the pressure plate, while the contour analyzer 600 may be able to detect and determine, essentially scan, the bottom contours and/or surfaces of the object.

CLAIMS

What is claimed is:

1. A contour analyzer, comprising:
 - a compliant cell;
 - an electromagnetic fluid disposed within the compliant cell;
 - a sensor plate comprising a sensor to detect a deformation of the electromagnetic fluid; and
 - a sealing layer disposed between the compliant cell and the sensor plate to hermetically seal the electromagnetic fluid within the compliant cell.
2. The contour analyzer of claim 1, wherein a deformation of the compliant cell causes a corresponding deformation of the electromagnetic fluid within the compliant cell.
3. The contour analyzer of claim 2, wherein the electromagnetic fluid and the sensor of the sensor plate form an inductor-capacitor (LC) circuit wherein the sensor is to sense a change in frequency of the LC circuit to determine an amount of deformation of the electromagnetic fluid.
4. The contour analyzer of claim 3, wherein the electromagnetic fluid acts as the inductor of the LC circuit.
5. The contour analyzer of claim 3, wherein the electromagnetic fluid is a ferromagnetic fluid (ferrofluid).
6. A contour analyzer, comprising:
 - an array of compliant cells;
 - a ferromagnetic fluid (ferrofluid) disposed within each cell of the array of compliant cells;
 - a sensor plate comprising an array of sensors corresponding to the array of compliant cells to detect deformations of the ferrofluid; and

a sealing layer disposed between the array of compliant cells and the sensor plate to hermetically seal the ferrofluid within each compliant cell.

7. The contour analyzer of claim 6, wherein the ferrofluid within each compliant cell and the corresponding sensor of the array of sensors form an inductor-capacitor (LC) circuit, wherein the ferrofluid is to act as the inductor of the LC circuit, and wherein the sensor is to sense a change in frequency of the LC circuit to determine an amount of deformation of the ferrofluid.
8. The contour analyzer of claim 7, wherein the array is a two-dimensional (2D) array of 33 by 33 compliant cells.
9. The contour analyzer of claim 7, wherein each compliant cell has a pitch of about 12 millimeters (mm) from adjacent compliant cells.
10. The contour analyzer of claim 7, wherein each compliant cell has a root diameter of about 10 millimeters (mm).
11. The contour analyzer of claim 7, wherein each compliant cell has a height of about 14 millimeters (mm), and has a measurable vertical displacement of about 10 mm.
12. A three-dimensional (3D) scanner, comprising:
 - a top scanner having a plurality of optical scanning units; and
 - a pressure plate attached to the top scanner below the optical scanning units and having a contour analyzer, comprising:
 - an array of compliant cells;
 - a ferromagnetic fluid (ferrofluid) disposed within each compliant cell, the ferrofluid to deform upon a corresponding deformation of the respective compliant cell;

a sensor plate having an array of sensors corresponding to the array of compliant cells; and

a sealing layer disposed between the array of compliant cells and the sensor plate to hermetically seal the ferrofluid within each compliant cell.

13. The 3D scanner of claim 12, wherein each compliant cell of the array has a substantially trapezoidal shape so as to not interfere with adjacent compliant cells upon being deformed.

14. The 3D scanner of claim 12, wherein each sensor of the array of sensors is to form an inductor-capacitor (LC) circuit with the ferrofluid disposed within the respective compliant cell, the ferrofluid to act as the inductor of the LC circuit.

15. The 3D scanner of claim 14, wherein each sensor of the array of sensors is to detect a decrease in frequency of the LC circuit in the respective compliant cell upon the ferrofluid being deformed, the decrease in frequency having a linear relationship to an amount of the deformation.

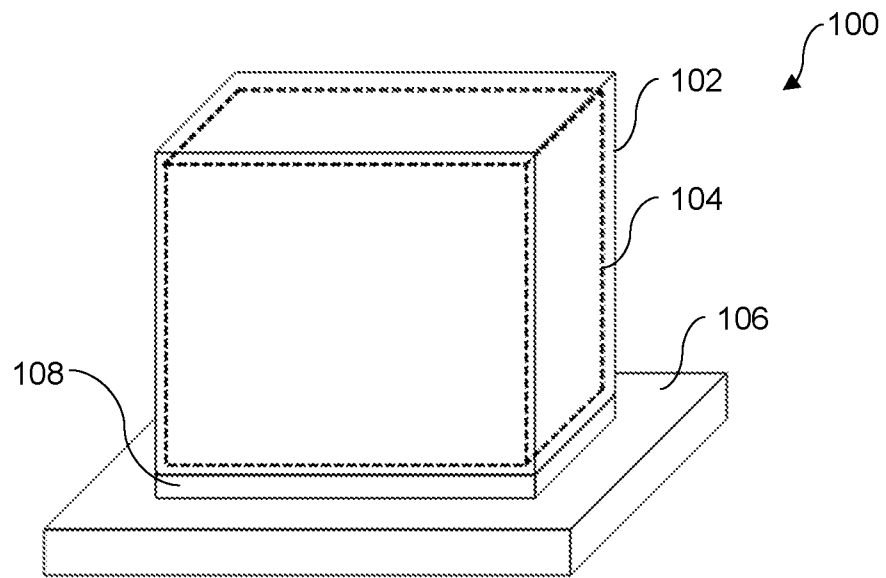


Fig. 1A

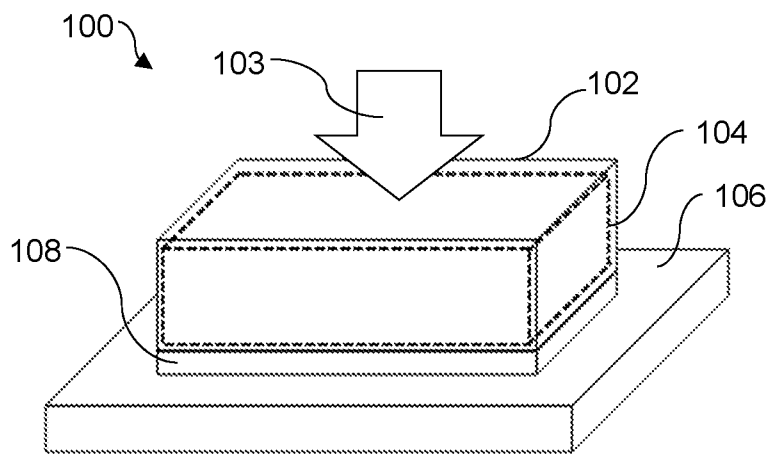


Fig. 1B

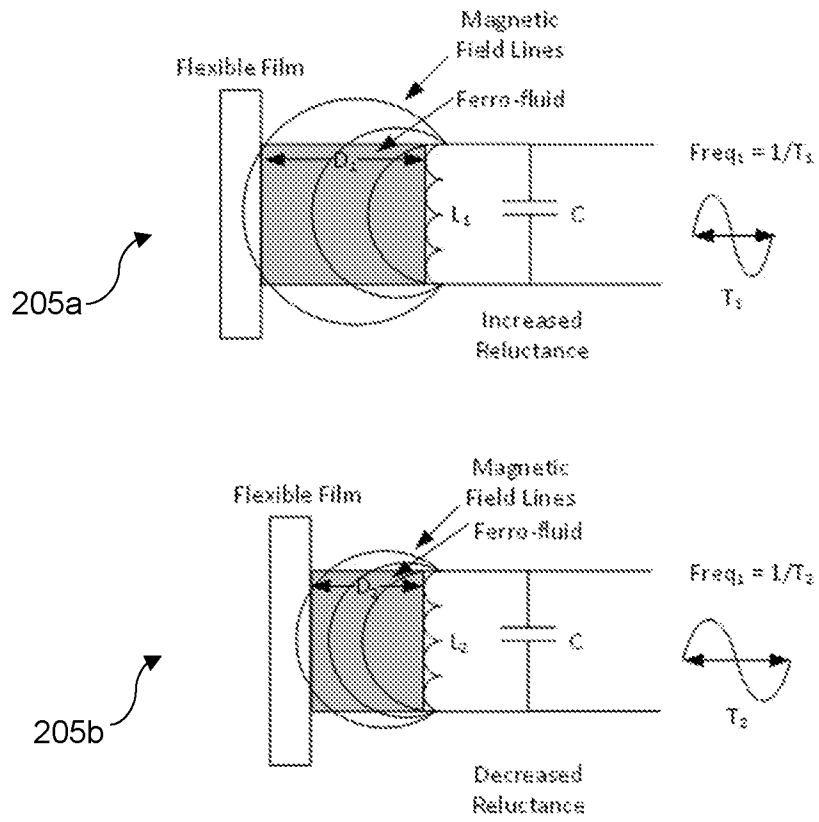


Fig. 2

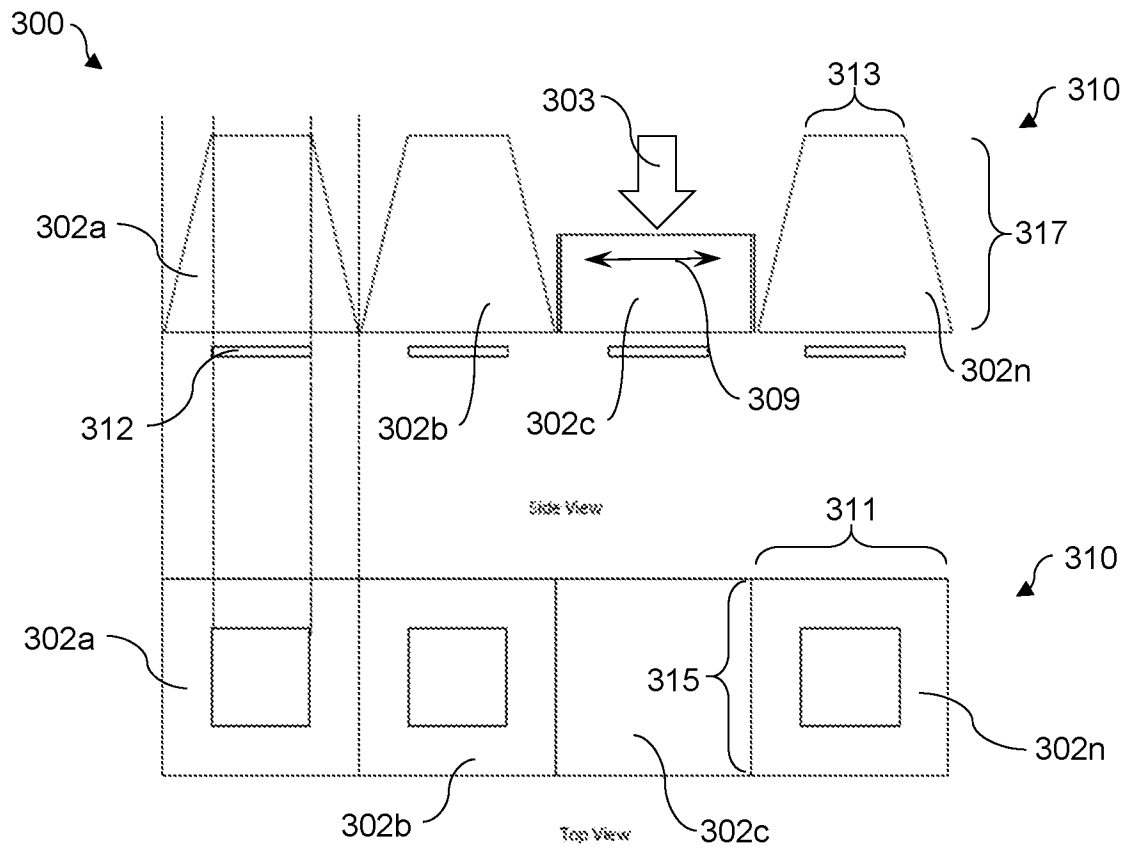


Fig. 3

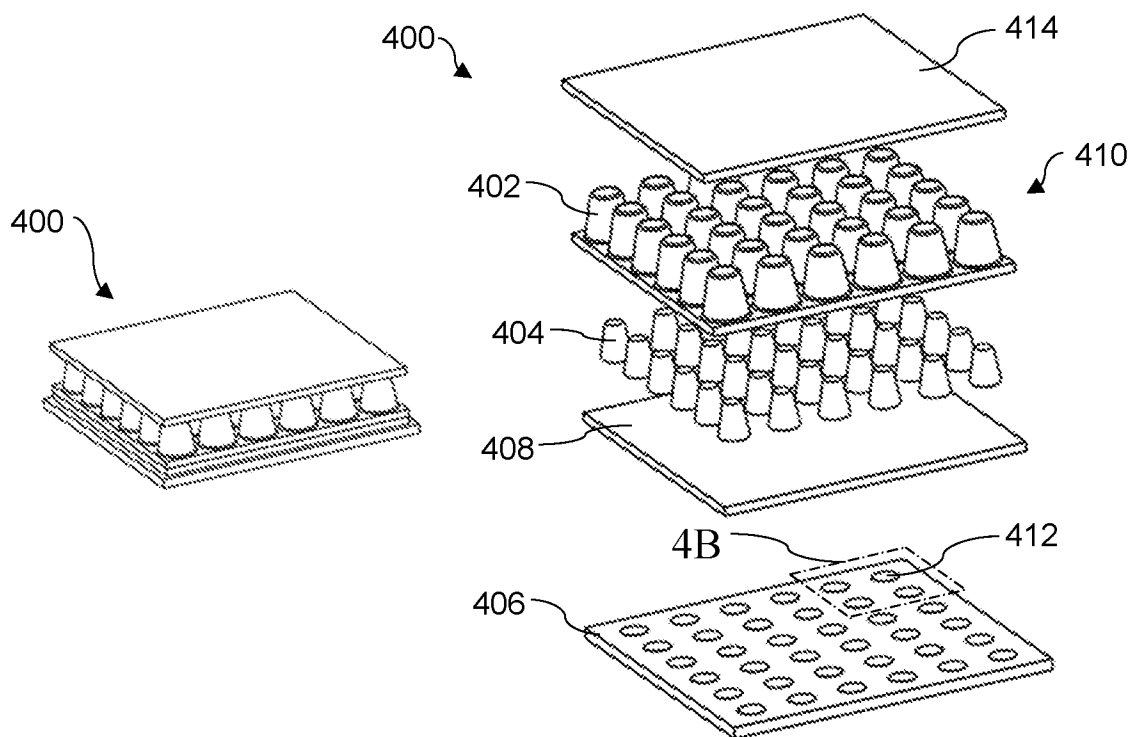


Fig. 4A

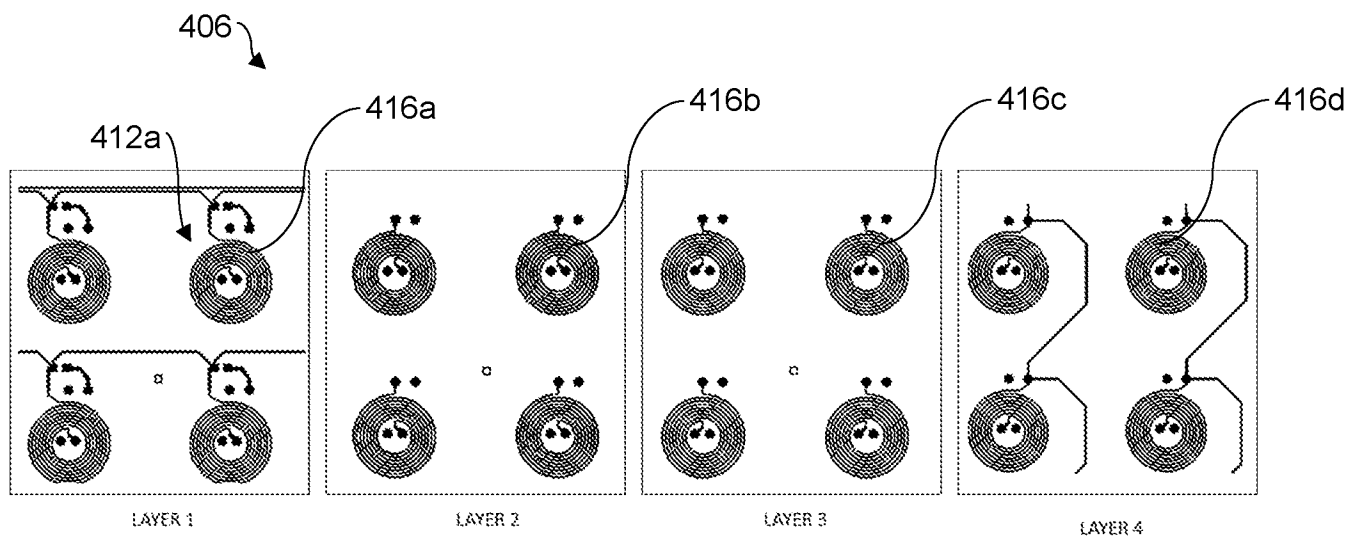


Fig. 4B

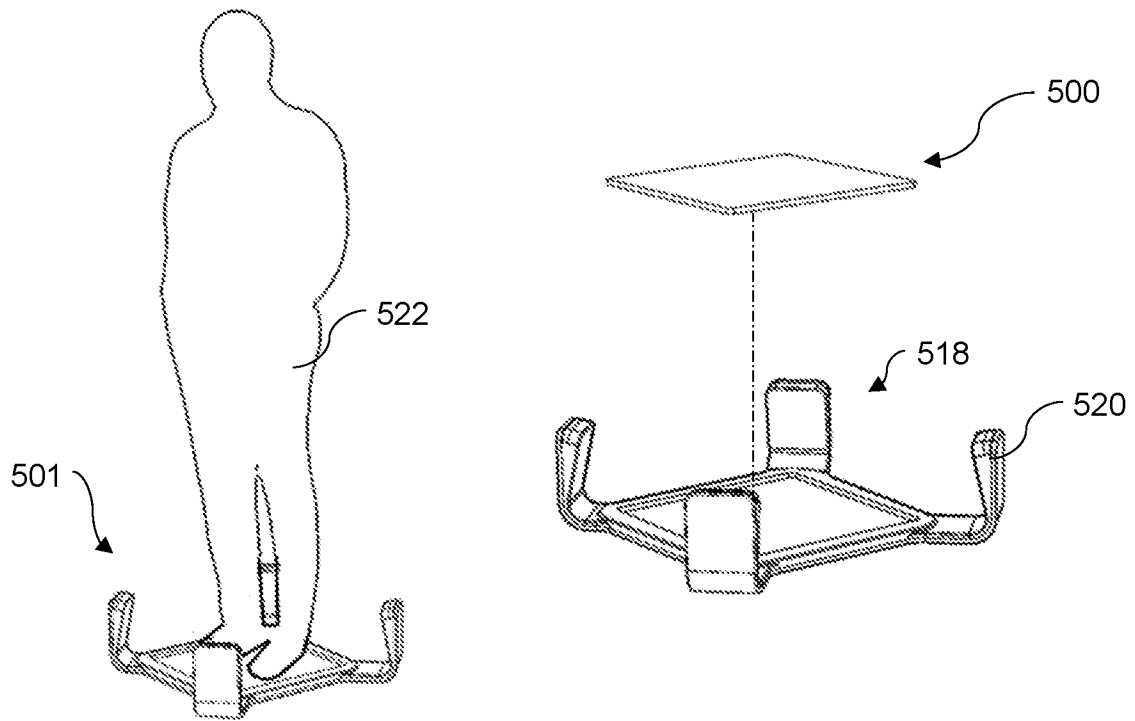


Fig. 5

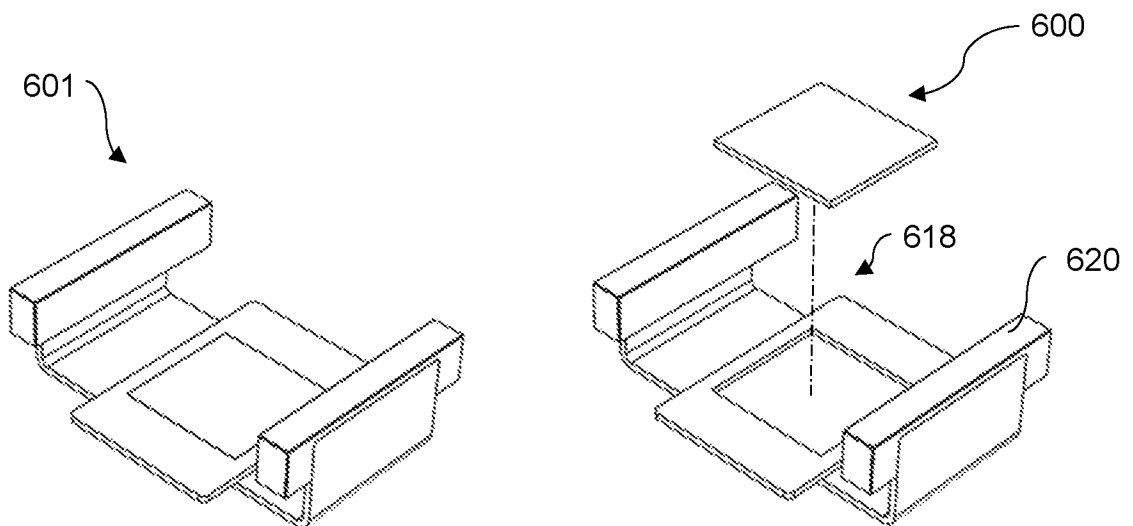


Fig. 6

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 2018/053581

A. CLASSIFICATION OF SUBJECT MATTER		
<i>H04N 1/409 (2006.01)</i> <i>G01B 5/20 (2006.01)</i> <i>G06T 15/00 (2011.01)</i>		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED		
Minimum documentation searched (classification system followed by classification symbols)		
H04N 1/00-1/409, G01B 5/00-5/20, G06T 15/00, B33Y 30/00, G01R 19/00		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)		
PatSearch (RUPTO internal), USPTO, PAJ, Esp@cenet, DWPI, EAPATIS, PATENTSCOPE, Information Retrieval System of FIPS		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CN 102901859 A (CHONGQING ELECTRIC POWER CORP NANAN POWER SUPPLY BUREAU; STATE GRID CORP CHINA) 30.01.2013	1-15
A	CN 201188116 Y (CHONGQING INSTITUTE OF TECHNOLOGY) 28.01.2009	1-15
A	CN 101354409 A (CHONGQING UNIVERSITY) 28.01.2009	1-15
☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.		
*	Special categories of cited documents:	
“A”	document defining the general state of the art which is not considered to be of particular relevance	
“E”	earlier document but published on or after the international filing date	
“L”	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	
“O”	document referring to an oral disclosure, use, exhibition or other means	
“P”	document published prior to the international filing date but later than the priority date claimed	
“T”	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention	
“X”	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone	
“Y”	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art	
“&”	document member of the same patent family	
Date of the actual completion of the international search 17 June 2019 (17.06.2019)		Date of mailing of the international search report 27 June 2019 (27.06.2019)
Name and mailing address of the ISA/RU: Federal Institute of Industrial Property, Berezhkovskaya nab., 30-1, Moscow, G-59, GSP-3, Russia, 125993 Facsimile No: (8-495) 531-63-18, (8-499) 243-33-37		Authorized officer M. Kondratiev Telephone No. (499) 240-25-91