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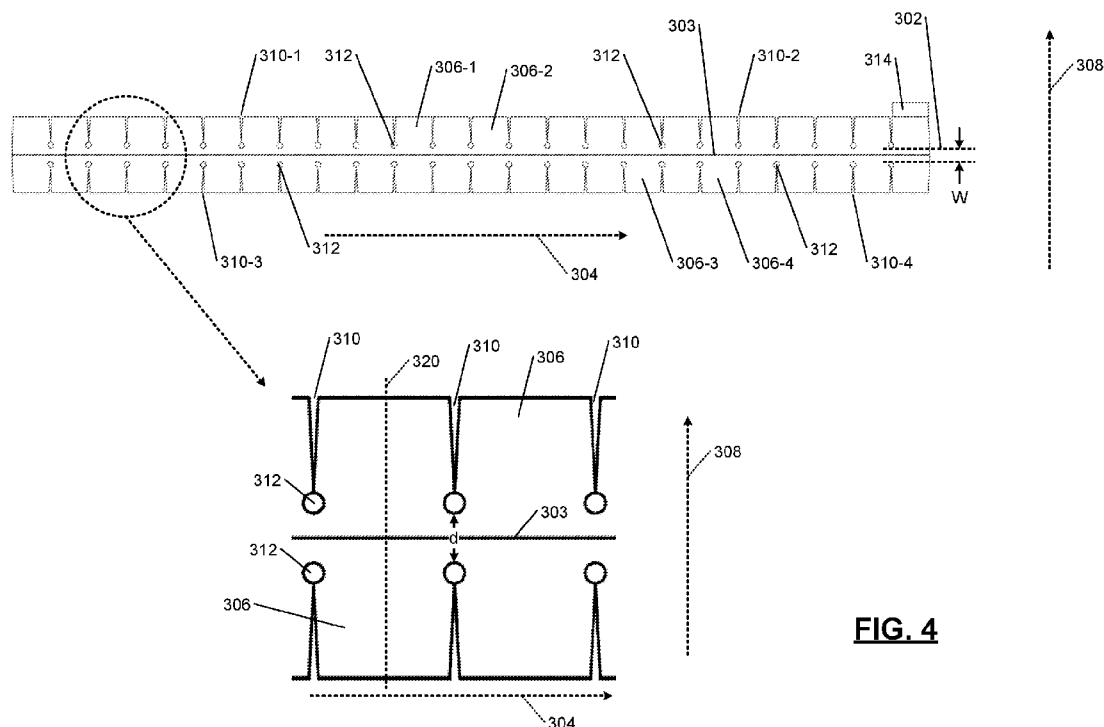


FIG. 4

(57) Abstract: A flexible circuit comprises a flexible substrate made of an electrically non-conducting material and electrically conductive traces disposed on the flexible substrate. The flexible substrate comprises a center portion (302) and a plurality of side portions (306-1, 306-2, 306-3, 306-4) extending perpendicularly from the center portion on opposite sides of the center portion. Centers of the side portions on one side of the center portion are collinear with centers of corresponding side portions on an opposite side of the center portion.

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FLEXIBLE SUBSTRATE BASED STEERING WHEEL HEATER AND SENSOR

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of United States Provisional Application No. 63/397,001, filed on August 11, 2022. The entire disclosure of the application referenced
5 above is incorporated herein by reference.

FIELD

[0002] The present disclosure relates generally to automotive heating and hands on detection sensing systems and more particularly to flexible substrate based steering wheel heater and sensor assembly.

BACKGROUND

[0003] The background description provided here is for the purpose of generally presenting the context of the disclosure. Work of the presently named inventors, to the extent it is described in this background section, as well as aspects of the description that may not otherwise qualify as prior art at the time of filing, are neither expressly nor
15 impliedly admitted as prior art against the present disclosure.

[0004] In some vehicles, steering wheels comprise heaters to heat the steering wheels. In addition, the steering wheels can comprise hands-on detection sensors (e.g., capacitive sensors) to sense whether or not an occupant's hand or hands are on the steering wheel of the vehicle. For example, in partially autonomous vehicles, while an
20 autonomous control system automatically controls driving of the vehicle under some conditions, some situations may require a driver to intervene and/or take control of the vehicle. For example, while driving on a highway may be handled by the autonomous control system, driver intervention may be requested in the event of an accident or construction on the roadway or when the autonomous system cannot function. Using the
25 hands-on detection sensors in the steering wheels, the vehicles can sense whether or not an occupant's hand or hands are on the steering wheel prior to disengaging the autonomous control system.

SUMMARY

[0005] A flexible circuit comprises a flexible substrate made of an electrically non-
30 conducting material and electrically conductive traces embedded in the flexible substrate

. The flexible substrate comprises a center portion and a plurality of side portions extending perpendicularly from the center portion on opposite sides of the center portion. Centers of the side portions on one side of the center portion are collinear with centers of corresponding side portions on an opposite side of the center portion.

5 **[0006]** In other features, the flexible substrate is a planar two-dimensional structure, and the center portion is rectangular.

10 **[0007]** In other features, adjacent side portions are separated by angular cutouts. Vertices of angles of the angular cutouts lie on opposite sides of a rectangle formed by the center portion. The vertices of the angles of the angular cutouts on one side of the rectangle are collinear with the vertices of the angles of the corresponding angular cutouts on the opposite side of the rectangle.

15 **[0008]** In other features, the flexible circuit further comprises holes that coincide with the vertices of the angles of the angular cutouts. The holes lie on opposite sides of the rectangle. The holes on one side of the rectangle are collinear with the corresponding holes on the opposite side of the rectangle.

20 **[0009]** In another feature, the electrically conductive traces are routed through at least one of the center portion and the side portions.

25 **[0010]** In another feature, the electrically conductive traces are configured to operate as at least one of a heater and a capacitive sensor.

30 **[0011]** In another feature, the electrically conductive traces are using a dry-milling process, a printed conductive ink, electrodeposition, vapor-deposition, photo-resist, laminated circuit sheets, or stencil.

35 **[0012]** In another feature, the electrically conductive traces are disposed on a first surface of the flexible substrate, a second surface of the flexible substrate that is opposite to the first surface, or both.

40 **[0013]** In another feature, the electrically conductive traces are embedded in the flexible substrate.

45 **[0014]** In other features, a steering wheel comprises the flexible circuit and further comprises a rigid core and a first layer disposed around the rigid core. The first layer comprises flat facets along an outer perimeter of the first layer and sidewall facets along sidewalls and an inner perimeter of the first layer. The center portion of the flexible circuit

is attached to the flat facets of the first layer. The side portions of the flexible circuit are attached to the sidewall facets of the first layer.

[0015] In other features, the center portion and the side portions of the flexible circuit are respectively attached to the flat facets and the sidewall facets of the first layer without causing plastic deformation of the center portion and the side portions of the flexible circuit.

[0016] In other features, the center portion of the flexible circuit and the flat facets of the first layer are rectangular and have substantially the same width.

[0017] In another feature, the flat facets of the first layer have substantially the same circumferential length.

[0018] In another feature, the flat facets of the first layer have unequal circumferential lengths.

[0019] In another feature, a width of the flat facets of the first layer is selected based on a density of the electrically conductive traces in the center portion of the flexible circuit.

[0020] In other features, adjacent side portions of the flexible circuit are separated by angular cutouts, and an angle of the angular cutouts is a function of a number of the flat facets and a diameter of the steering wheel.

[0021] In other features, the steering wheel further comprises a second layer disposed on the flexible circuit and the first layer. The second layer is toroidal in shape.

[0022] In another feature, the steering wheel further comprises a cover disposed on the second layer.

[0023] In other features, the first and second layers comprise a foam.

[0024] In other features, the first and second layers comprise a dielectric material.

[0025] In other features, the first and second layers comprise an electrically non-conducting material.

[0026] In other features, a system comprises the steering wheel. The electrically conductive traces in the flexible circuit are configured to operate as at least one of a heater and a capacitive sensor. The system further comprises a first circuit and a second circuit. The first circuit is coupled to the heater and configured to control the heater to heat the steering wheel. The second circuit is coupled to the capacitive sensor and configured to sense presence or absence of a hand on the steering wheel.

[0027] Further areas of applicability of the present disclosure will become apparent from the detailed description, the claims and the drawings. The detailed description and specific examples are intended for purposes of illustration only and are not intended to limit the scope of the disclosure.

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BRIEF DESCRIPTION OF THE DRAWINGS

[0028] The present disclosure will become more fully understood from the detailed description and the accompanying drawings, wherein:

[0029] FIG. 1 shows an example of a steering wheel of a vehicle;

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[0030] FIG. 2A shows examples of shapes having more than one degrees of surface curvature;

[0031] FIG. 2B shows examples of shapes having a single degree of surface curvature;

[0032] FIGS. 3A and 3B show a steering wheel with a faceted geometry according to the present disclosure;

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[0033] FIG. 4 shows a flexible circuit comprising a heater and a sensor according to the present disclosure;

[0034] FIGS. 5A and 5B show the flexible circuit of FIG. 4 mounted to the faceted geometry of the steering wheel of FIGS. 3A and 3B according to the present disclosure;

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[0035] FIG. 6 shows a finished steering wheel comprising the flexible circuit of FIG. 4 mounted to the faceted geometry as shown in FIGS. 5A and 5B and having a Class A shape according to the present disclosure;

[0036] FIGS. 7A and 7B show cross-sectional and internal views of the steering wheel of FIG. 6; and

[0037] FIG. 8 shows an example of a circuit to control the heater and/or the sensor in the flexible circuit of FIG. 4 according to the present disclosure.

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[0038] In the drawings, reference numbers may be reused to identify similar and/or identical elements.

DETAILED DESCRIPTION

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[0039] The present disclosure provides a flexible substrate -based flexible circuit that can be installed around steering wheels without introducing plastic deformation strain (e.g., wrinkling) caused by forming a two-dimensional flexible substrate onto a 3-

dimensional two-degree-of-curvature object and a double-foaming method for manufacturing the steering wheels, which enables reliable installation and operation of the flexible circuit around the steering wheels. As described below in detail, the double-foaming method provides a faceted geometry for simple bending installation of the flexible circuit around the steering wheels and also provides the final Class A shape to the steering wheels. Specifically, the faceted geometry enables simple single degree of curvature bending of the flexible circuit during installation around the steering wheels, which eliminates plastic deformation of the flexible circuit. The flexible circuit installed using the faceted geometry is compatible with the double curvature shape of class A steering wheel's toroidal geometry.

[0040] Specifically, the double-foaming method comprises applying a first foam shot (i.e., a first or inner foam layer) on a structural core of a steering wheel to generate the faceted geometry. For example, the core of the steering wheel may be made of a rigid material such as a metal, an alloy, or any other structurally rigid material. The flexible circuit is assembled on the faceted geometry without inelastic plastic buckling strain (e.g., wrinkling). The assembly (i.e., the steering wheel with the first foam shot and the flexible circuit installed on the faceted geometry provided by the first foam shot) is then inserted into a molding tool to apply a second foam shot (i.e., a second or outer foam layer) on the flexible circuit installed on the faceted geometry to generate the final Class A round surface for the steering wheel. The flexible circuit can provide heating and/or capacitive sensing functions.

[0041] Existing methods of installing flexible circuits on toroidal steering introduce plastic deformation of the flexible circuits that incorporate the heating and sensing features. The plastic deformation is required to force a flat object (i.e., the flexible circuit) to conform to the two-degree-of-curvature shape of the steering wheel. A flat object has to take up a greater area (or strain) when wrapped around a 2-degree of curvature 3D object, which causes the plastic deformation, which is prevented by the design of the present disclosure as explained below in detail. Examples of stretchable solutions include wire-based heating and sensing systems that are attached to a stretchable substrate (e.g., fleece, foam). Other examples of the flexible circuits include stretchable conductors provided in the form of inks deposited onto stretchable substrates such as polyurethane substrates. In systems that use non-stretchable substrates, the non-stretchable substrates can be damaged when the flat non-stretchable substrate conforms to the toroidal shape of the steering wheel. The non-stretchable substrate can be damaged

since in-plane strains are generated that cause the non-stretchable substrate to buckle and crease, which can cause damage to the conductive traces.

[0042] Other problems with wire-based solutions include difficulties in creating enough conductor area for effective heating and sensing. Sufficient conductor area is needed particularly when steering wheels are manufactured using a double foamed construction, where foam is introduced between the sensor and leather wrap, which reduces sensor sensitivity. Further, there are limits on how much wire can be sewn to attach the sensor to the steering wheel. High wire density requires small bending radius, which can damage wire insulation. Wire insulation can also be damaged during sewing (e.g., by needle strikes). Damage to wire insulation manifests during steering wheel assembly, which typically uses liquid glue during stretching process. Damaged insulation in combination with liquid glue creates leakage current defects until the glue dries, which complicates end of line testing of the sensor. Further, high wire density is expensive due to added material and cycle time for manufacture.

[0043] In contrast, in double-foamed steering wheels manufactured according to the present disclosure, a series of flat facets (also called spine facets) and sidewall facets are generated around the steering wheel's outer diameter by applying the first foam shot. The flexible circuit can now be assembled on the flat facets and the sidewall facets via single axis bending without introducing unwanted plastic deformation strain on the flexible circuit that could cause failure of metallic conductor traces. The second foam shot covers the flexible circuit to generate the intended Class A surface to which leather cover is attached. Using this method, stretching of the conductors in the flexible substrate is avoided, which prevents stress that could otherwise damage the integrity of conductors over the lifespan of the steering wheel.

[0044] In the flexible circuit of the present disclosure, metallic traces (also generally called electrically conductive traces) can be designed to create heating and capacitive sensing circuits. The layout and dimensions (e.g., width) of the metallic traces can be varied to compensate for varying foam thickness for heating and capacitive sensing applications. The metallic traces can be formed on the flexible substrate using a dry-milling process, a printed conductive ink, electrodeposition, vapor-deposition, photo-resist, laminated circuit sheets, stencil, or any other suitable process. The flexible circuit can be single sided or double sided (i.e., metallic traces can be installed on one side, an opposite side, or both sides of the flexible circuit) to achieve intended design functionality.

Alternatively, the metallic traces can be embedded in the flexible substrate as well. This design of the flexible circuit includes using an extra layer as a shield or in cases where packaging density does not allow using a single layer for combined heater and sensor designs.

5 **[0045]** Further, the flexible circuit of the present disclosure can be assembled in the steering wheel using dry adhesives quickly and without mess, which eliminates capacitive sensing issues posed by wet glue and improves end of line test time and performance. The assembly process does not require stretching of the flexible circuit due to the faceted geometry provided by the first foam shot. The size of the facets determine area available
10 for routing traces along the length of the flexible circuit. The design can be varied based on a tradeoff between the minimum width needed for routing traces, minimizing the number of facets that needed, and minimizing the variation in the second shot foam thickness caused by chord height (sagitta) as explained below in detail.

[0046] Accordingly, as outlined above, the present disclosure provides a foaming
15 method and a flexible circuit to manufacture a steering wheel with a heater/sensor without the problems described above. The foaming method provides a steering wheel with flat spine facets and single-degree-of-curvature sidewall facets or portions with a single degree of curvature. The faceted surfaces comprise a plurality of portions free of compound curvatures. The heater/sensor with a flexible substrate (collectively called a
20 flexible circuit) include cutouts that define areas that overlay the flat faceted surfaces and the plurality of tubular sidewall portions. A material such as foam is applied over the sensor/heater to make curved (toroidal) Class A outer surface of the steering wheel. These and other features of the present disclosure are described below in detail.

[0047] FIG. 1A shows a typical steering wheel 100. The steering wheel 100 is a toroid
25 with two degrees of surface curvature, which is similar to a sphere where the spherical surface also has two degrees of curvature. A flexible circuit comprising a heater/sensor is typically flat and rectangular in shape (see FIG. 4). The flexible circuit, when assembled around the toroidal steering wheel 100, cannot conform to the toroid-shaped steering wheel 100 without causing plastic inelastic stress, which causes creases (wrinkles) in the
30 flexible circuit that can damage metallic traces (conductors used as heater/sensor) in the flexible circuit. The undesired wrinkling can cause several failures ranging from open circuits in the heater/sensor and thermal events causing hot spots in the steering wheel 100 over the lifespan of the heater/sensor.

[0048] FIG. 1B shows examples of surfaces of typical steering wheels with two degrees of surface curvature. For example, the surface of a typical steering wheel can be freeform spline type as shown at 102 or spherical as shown at 104. The flexible circuit, when assembled around these surfaces, cannot conform to these surfaces without causing plastic inelastic stress, which causes creases in the flexible circuit that can damage the metallic traces in the flexible circuit.

[0049] Instead, if the flexible circuit is mounted to a surface with a single degree of curvature, a simple bending of the flexible circuit along the single degree of curvature avoids in-plane buckling strain that otherwise causes the creases in the flexible circuit and prevents damage to the metallic traces in the flexible circuit. The faceted geometry described below overcomes these problems resulting from wrapping flat flexible circuit around toroid-shaped steering wheels by simple bending of the flexible circuit along the single degree of curvature, which can be easily calculated and modeled. FIG. 1C shows examples of functional shapes with a single degree of surface curvature. For example, a conical shape is shown at 106, a cylindrical shape is shown at 108, and a flat surface is shown at 110.

[0050] FIGS. 3A and 3B show a steering wheel 200 with a faceted geometry according to the present disclosure. Specifically, the steering wheel 200 comprises two foam layers. While only one foam layer is shown in FIGS. 3A and 3B, a second foam layer shown in FIGS. 6-7B. Since the steering wheel 200 comprises two foam layers, the steering wheel 200 is called a double-foamed steering wheel 200. The two foam layers are applied as follows.

[0051] In FIG. 3A, a first foam shot (i.e., a first foam layer) 202 is initially applied to a structural core 201 (shown in FIG. 5B) of the steering wheel 200. For example, the core 201 may comprise a die-cast structure. Specifically, the first foam layer 202 is applied to and all around the core 201 of the steering wheel 200 to create a faceted geometry all around the steering wheel 200. The first foam layer 202 (also generally called a first layer) is made of a dielectric material or an electrically non-conducting material.

[0052] FIG. 3B shows the faceted geometry in further detail. The faceted geometry comprises a plurality of flat facets (also called spine facets) 204 formed at an outer periphery (or around an outer perimeter) of the first foam layer 202 on the steering wheel 200. Additionally, the faceted geometry comprises a plurality of sidewall facets 206 formed on sidewalls and an inner periphery (or around an inner perimeter) of the first

foam layer 202 on the steering wheel 200. The flat facets 204 and the sidewall facets 206 have a simple single degree of curvature. The flat facets 204 and the sidewall facets 206 are formed all around the core 201 of the steering wheel 200.

[0053] The flat facets 204 have a width facet width FW and circumferential facet length L. The circumferential length L of the flat facets 204 need not be uniform (i.e., the same) for all of the flat facets 204. Rather, the circumferential length L of the flat facets 204 can be varied to accommodate the final Class A shape of the steering wheel 200. In general, while most of the flat facets 204 can be of substantially similar dimensions relative to each other, more complex steering wheel geometries can require the flat facets 204 to have different size and shape. The number of facets 204, 206 and the width FW of the flat facets 204 are determined as described below in detail.

[0054] FIG. 4 shows a flexible circuit 300 comprising a heater and a sensor (shown in FIG. 8) according to the present disclosure. The heater and the sensor are embedded in a flexible substrate (i.e., sandwiched between two layers of a flexible substrate) made of an electrically non-conducting material to form the flexible circuit 300. The flexible circuit 300 is a planar structure that is generally rectangular in shape and is therefore two-dimensional.

[0055] The flexible circuit 300 comprises a center portion 302 that extends along a first axis 304. The center portion 302 is rectangular. The center portion 302 has a width W, which is also the width FW of the flat facet 204 on the first foam layer 202. A line 303 drawn through the center of the center portion 302, which is also the center of the flexible circuit 300, along the length of the flexible circuit 300 (i.e., along the first axis 304), is called a spine 303 of the flexible circuit 300. The spine 303 and the center portion 302 of the flexible circuit 300 are parallel to the first axis 304. The length of the flexible circuit 300 is less than or equal to the perimeter of the first foam layer 202 (i.e., the circumference of the steering wheel 200).

[0056] Additionally, the flexible circuit 300 comprises a plurality of side portions 306-1, 306-2, 306-3, 306-4, ... (collectively the side portions 306) that extend perpendicularly from the center portion 302 on either side of the center portion 302 along a second axis 308. The second axis 308 is perpendicular to the first axis 304. Thus, the side portions 306 extend perpendicularly to the spine 303 and the length of the flexible circuit 300.

[0057] The side portions 306 are formed by removing portions (also called cutouts) 310-1, 310-2, 310-3, 310-4, ... (collectively the cutouts 310) of the flexible circuit 300. The

cutouts 310 are formed by removing material from the flexible circuit 300 at an acute angle relative to the vertical axis 308. The angle at which the cutouts 310 are formed depends on the diameter of the steering wheel 200 and the number of facets 204, 206, and therefore also on a number of the side portions 306.

- 5 **[0058]** The vertices of the angles of the cutouts 310 on opposite of the center portion 302 lie on the opposite sides of the rectangle formed by the center portion 302. The vertices of the angles of the cutouts 310 on one side of the center portion 302 are collinear with the vertices of the angles of the corresponding cutouts 310 on the opposite side of the center portion 302.
- 10 **[0059]** The side portions 306 and the cutouts 310 on opposite sides of the spine 303 are mirror images of each other. That is, if the flexible circuit 300 is folded along the spine 303, the side portions 306 on opposite sides of the spine 303 will lie on top of each other exactly, and the cutouts 310 on opposite sides of the spine 303 will lie on top of each other exactly. In other words, the side portions 306 and the cutouts 310 are symmetrically
- 15 arranged on opposite sides of the spine 303.

- [0060]** The side portions 306 and the cutouts 310 on opposite sides of the spine 303 are not axially offset relative to each other along the length of the flexible circuit 300 (i.e., along the first axis 304). Rather, each side portion 306 on one side of the spine 303 lies on the same axis perpendicular to the spine 303 (i.e., parallel to the second axis 308)
- 20 with a corresponding side portion 306 on the opposite side of the spine 303, and each cutout 310 on one side of the spine 303 lies on the same axis perpendicular to the spine 303 (i.e., parallel to the second axis 308) with a corresponding cutout 310 on the opposite side of the spine 303.

- [0061]** The centers of the side portions 306 on opposite sides of the spine 303 are
- 25 collinear as shown at 320, and the vertices of the angles of the cutouts 310 on opposite sides of the spine 303 are also collinear. Lines drawn through the collinear centers of the side portions 306 on opposite sides of the spine 303 are perpendicular to the spine 303, the length of the flexible circuit 300, the center portion 302 of the flexible circuit 300, and the first axis 304. Lines drawn through the collinear vertices of the angles of the cutouts
- 30 310 on opposite sides of the spine 303 are also perpendicular to the spine 303, the length of the flexible circuit 300, the center portion 302 of the flexible circuit 300, and the first axis 304. Thus, due to the arrangement of the center portion 302, the side portions 306,

and the cutouts 310 as described above, the flexible circuit 300 is symmetric around the spine 303.

[0062] The flexible circuit 300 further comprises a plurality of holes 312 at the vertices of the angles of the cutouts 310. The centers of the holes 312 on opposite sides of the spine 303 are collinear. The centers of the holes 312 coincide with the vertices of the angles of the cutouts 310. The centers of the holes 312 on one side of the spine 303 lie on one side of the rectangle formed by the center portion 302, and the centers of the holes 312 on the opposite side of the spine 303 lie on the opposite side of the rectangle formed by the center portion 302. Thus, the vertices of the angles of the cutouts 310 and the corresponding holes 312 on opposite sides of the spine 303 are also collinear. Further, the vertices and the corresponding holes 312 that are collinear lie on an axis that is different than and parallel to an axis on which the collinear centers of the side portions 306 lie, where these axes are perpendicular to the spine 303 of the flexible circuit 300 (i.e., parallel to the second axis 308).

[0063] The holes 312 reduce the strain on the flexible circuit 300 and avoid wrinkling of the flexible circuit 300 when the flexible circuit 300 is wrapped around the first foam layer 202. Additionally, the holes 312 facilitate bonding of a second foam layer 312 (shown in FIG. 6) to the first foam layer 202. The cutouts 310 and the holes 312 facilitate attachment of the center portion 302 and the side portions 306 of the flexible circuit 300 respectively to the facets 204, 206 of the first foam layer 202 without causing strain and wrinkling of the center portion 302 and the side portions 306 of the flexible circuit 300.

[0064] The distance d between the holes 312 across the spine 303 (i.e., the distance between a hole 312 on one side of the spine 303 and a corresponding hole 312 on the opposite side of the spine 303) is the width W of the center portion 302 of the flexible circuit 300, which is also the width FW of the flat facet 204 on the first foam layer 202. The distance between the holes 312 is determined by the number of the facets 204, 206 on the first foam layer 202.

[0065] The number of the facets 204, 206 depends on a number of factors such as assembly feasibility of the flexible circuit 300 on the first foam layer 202, molding feasibility of applying the second foam layer 212, and routing of the conductive trace that form the heater and the sensor in the flexible circuit 300 through the center portion 302 and optionally through the side portions 306 of the flexible circuit 300. For example, the number of the facets 204, 206 determine the assembly time required to wrap the flexible

circuit 300 around the first foam layer 202. Further, the width FW of the flat facet 204 (and therefore the width W of the center portion 302 of the flexible circuit 300 and the distance d between the holes 312) is determined by a density of the conductive traces for the application (i.e., depending on whether the flexible circuit 300 includes a heater, a sensor, or a heater and a sensor).

[0066] The holes 312 are not located close to the spine 303. Rather, the holes 312 are located at the corners of the flat facets 204 (see FIGS. 5A and 5B). The holes 312 are not located close to the spine 303 because the faceted design already eliminates the plastic buckling strain on the flexible circuit 300 when the flexible circuit 300 is wrapped around the first foam layer 202 by bending the center portion 302 of the flexible circuit 300 only in one degree of curvature due to the flatness of the flat facets 204. Therefore, the holes 312 need not be located close to the spine 303 to reduce the strain.

[0067] The flexible circuit 300 further comprises a port 314 at one end of the flexible circuit 300. The conductive traces of the heater and/or the sensor in the flexible circuit 300 are collected at the port 314. The port 314 connects the conductive traces in the flexible circuit 300 to circuitry (shown in FIG. 8) used to control the heater and/or the sensor in the flexible circuit 300. The port 314 of the flexible circuit 300 can be accessed through an exit location 214 (shown in FIG. 6) provided in a second foam layer 212 (shown in FIG. 6) to connect to the circuitry.

[0068] When the flexible circuit 300 is wrapped around the first foam layer 202, the distal ends of the side portions 306 of the flexible circuit 300 may not contact each other. Instead, the distal ends of the side portions 306 of the flexible circuit 300 may be separated by a distance. If the second foam layer 212 that covers the flexible circuit 300 is thin, the separation between the distal ends of the side portions 306 of the flexible circuit 300 can prevent accidental damage to the flexible circuit 300 when the leather cover (not shown) is sewed to the second foam layer 212. However, depending on the thickness of the second foam layer 212, the distal ends of the side portions 306 of the flexible circuit 300 may contact each other and yet the leather cover can be sewn to the second foam layer 212 without damaging the flexible circuit 300.

[0069] FIGS. 5A and 5B show the flexible circuit 300 mounted to the first foam layer 202 on the steering wheel 200. As shown, the center portion 302 of the flexible circuit 300 is attached (e.g., glued) to the flat facets 204 of the first foam layer 202 (see FIG. 5B) without causing any deformation (e.g., stress, creasing, wrinkling) to the center portion

302 of the flexible circuit 300. The deformation of the center portion 302 of the flexible circuit 300 is avoided due to the single degree of curvature (flatness) of the flat facets 204 of the first foam layer 202. Additionally, the side portions 306 of the flexible circuit 300 are attached (e.g., using an adhesive) to the sidewall facets 206 of the first foam layer 202 (see FIG. 5B) without causing any plastic deformation to the side portions 306 of the flexible circuit 300 providing the bending stress is determined to be below the elastic limit of the flexible circuit 300. The deformation the side portions 306 of the flexible circuit 300 is avoided due to the single degree of curvature (flatness) of the sidewall facets 206 of the first foam layer 202.

[0070] The conductive traces for the heater and/or the sensor can be routed along the spine 303 in the center portion 302 of the flexible circuit 300 and optionally also through the side portions 306 of the flexible circuit 300. Further, the conductive traces can be arranged on an inner (first) side of the flexible circuit 300 that is attached to the first foam layer 202 and/or on an outer (second) side of the flexible circuit 300 that is opposite to the inner (first) side of the flexible circuit 300. The conductive traces for the heater and/or the sensor can be arranged in any combination through the center portion 302 and optionally through the side portions 306 on the inner and outer sides of the flexible circuit 300.

[0071] FIG. 6 shows the steering wheel 200 finished with a second foam shot (i.e., the second foam layer) 212. The second foam layer 212 is applied to the flexible circuit 300 after the flexible circuit 300 is mounted to the faceted geometry of the first foam layer 202. The exit location 214 is provided in the second foam layer 212 for the port 314 of the flexible circuit 300 to connect to the circuitry (shown in FIG. 8) that controls the heater and/or the sensor in the flexible circuit 300. When finished by applying the second foam layer 212, the steering wheel 200 conforms to the Class A surface to which leather cover (not shown) is attached. Like the first foam layer 202, the second foam layer 212 (also generally called a second layer) is also made of a dielectric material or an electrically non-conducting material.

[0072] Steering wheels can have a complexity of variant shapes and may have varying cross-sectional shapes, which may be non-circular. Regardless, the faceted geometry of the first foam layer 202 can accommodate any shape of the steering wheel by simply varying the size of the flat facets 204 to conform to any shape of the steering wheel and

by varying the length of the sidewall facets 206 to conform to varying cross-sectional shapes of the steering wheel.

[0073] FIGS. 7A and 7B show cross-sectional and internal views of the finished steering wheel 200. FIG. 7A shows the core 201, the first foam layer 202 with the faceted geometry applied to the core 201, the flexible circuit 300 mounted to the faceted geometry of the first foam layer 202, and the second foam layer 212 applied to the flexible circuit 300. The width FW of the flat facets 204 is determined based on requirements for routing the conductive traces (i.e., the heater and/or the sensor) in the flexible circuit 300.

[0074] A chord height h of the flat facets 204 is a distance between the flat facets 204 and the outer diameter of the second foam layer 212. Minimizing the chord height h is desired so that less variation occurs with the dielectric and insulation properties of the second foam layer 212 for the sensor's sensitivity and the heater's uniformity. Minimizing the chord height h also improves thermal warmup time and thermal uniformity in the region near the flat facets 204.

[0075] Increasing the number of the flat facets 204 decreases the chord height h of the flat facets 204. Increased chord height can increase the amount of foam in the second foam layer 212 above the flat facets 204, which decreases the thermal and dielectric insulation above the flat facets 204. Increased thermal insulation above the flat facets 204 can reduce the performance of the heater above the flat facets 204. Increased dielectric insulation above the flat facets 204 can reduce the sensitivity of the sensor above the flat facets 204. The number and dimensions of the flat facets 204 can be optimized to improve the sensitivity of the sensor and thermal uniformity of the heater throughout the steering wheel 200.

[0076] FIG. 7B shows the cross-sectional view and additionally shows an internal view of the steering wheel 200 showing the flexible circuit 300 mounted to the faceted geometry of the first foam layer 202. All of the elements shown are already described above and their description is therefore not repeated for brevity.

[0077] FIG. 8 shows an example of a circuit 401 to control the heater/sensor formed in the flexible circuit 300 by embedding conductive traces in the flexible circuit 300. For example, the flexible circuit 300 comprises a heater 400 and a sensor 402. Each of the heater 400 and the sensor 402 may comprise one or more conductive traces routed through the flexible circuit 300 as described above. The circuit 401 comprises a heater controller 404 and a capacitance sensing circuit 406. The heater controller 404 controls

the heater 400 as described below in detail. The capacitance sensing circuit 406 senses a capacitance formed by the sensor 402 in the flexible circuit 300 as described below in detail. An autonomous driving control system may use the sensed capacitance measurement to determine whether the driver's hand or hands are on or off the steering wheel 200.

[0078] The heater controller 404 comprises a heater driver circuit 410 and a voltage source 412. The heater driver circuit 410 selectively supplies power from the voltage source 412 to the heater 400 to heat the steering wheel 200. The heater controller 404 controls supply of the power to the heater 400 based on one or more switches (not shown) used by an occupant of the vehicle to actuate the heating of the steering wheel 200. For example, the switches may include physical switches or pushbuttons (e.g., on the dashboard of the vehicle or on the steering wheel 200). In some examples, the switches may include soft switches provided on a touchscreen associated with an infotainment system of the vehicle or another input device. In other examples, the switches can be actuated automatically in conjunction with a heating, ventilation, and air conditioning (HVAC) system (not shown) of the vehicle.

[0079] The capacitance sensing circuit 406 senses a change in the capacitance of the sensor 402 that is induced when an occupant of the vehicle places a hand or hands on the steering wheel 200 or when the occupant removes the hand or hands from the steering wheel 200. The capacitance sensing circuit 406 comprises an excitation circuit 420, a resonant circuit (e.g., an LC tank circuit) 422, and a frequency measurement circuit 424. The excitation circuit 420 selectively outputs an excitation signal (such as a square wave or a waveform of another shape) to the resonant circuit 422 that is connected to the sensor 402. The frequency measurement circuit 424 measures a resonant frequency of the resonant circuit 422.

[0080] When an occupant's hand is proximate to the sensor 402 (e.g., on the steering wheel 200), the capacitance of the combined circuit varies. The variation in capacitance due to the presence or absence of the occupant's hands on the steering wheel 200 affects the resonant frequency of the resonant circuit 422. The capacitance sensing circuit 406 measures the variation in capacitance based on the changes in the resonant frequency of the resonant circuit 422. Based on the variation in the capacitance, the capacitance sensing circuit 406 detects the presence or absence of the occupant's hands on the steering wheel 200. The heater 400 and the heater controller 404 can operate

independently of the sensor 402 and the capacitance sensing circuit 406 or synchronously with each other depending on the application and design of the heater/sensor.

[0081] In some examples, the flexible circuit 300 may comprise one or more shield wires 430 to provide an electrical shield and reduce the effect of stray capacitances between the sensor 402 and the heater 400. At least one of the shield wires 430 can be connected to ground. Alternatively, at least one of the shield wires 430 can be driven by an active signal while the other one of the shield wires 430, if not driven by an active signal, may be connected to ground. For example, at least one of the shield wires 430 can be driven by the signal output to the sensor 402 by the capacitance sensing circuit 406. Alternatively, or additionally, at least one of the shield wires 430 can be driven by respective signals output to the sensor 402 and heater 400 by the capacitance sensing circuit 406 and the heater controller 404. When at least one of the shield wires 430 is actively driven by a signal, the shield wires 430 are electrically insulated using a layer of an electrically non-conducting material disposed between the shield wires 430 to electrically isolate the shield wires 430.

[0082] The foregoing description is merely illustrative in nature and is not intended to limit the disclosure, its application, or uses. The broad teachings of the disclosure can be implemented in a variety of forms. Therefore, while this disclosure includes particular examples, the true scope of the disclosure should not be so limited since other modifications will become apparent upon a study of the drawings, the specification, and the following claims.

[0083] It should be understood that one or more steps within a method may be executed in different order (or concurrently) without altering the principles of the present disclosure. Further, although each of the embodiments is described above as having certain features, any one or more of those features described with respect to any embodiment of the disclosure can be implemented in and/or combined with features of any of the other embodiments, even if that combination is not explicitly described. In other words, the described embodiments are not mutually exclusive, and permutations of one or more embodiments with one another remain within the scope of this disclosure.

[0084] Spatial and functional relationships between elements (for example, between controllers, circuit elements, semiconductor layers, etc.) are described using various terms, including “connected,” “engaged,” “coupled,” “adjacent,” “next to,” “on top of,”

“above,” “below,” and “disposed.” Unless explicitly described as being “direct,” when a relationship between first and second elements is described in the above disclosure, that relationship can be a direct relationship where no other intervening elements are present between the first and second elements, but can also be an indirect relationship where one or more intervening elements are present (either spatially or functionally) between the first and second elements. As used herein, the phrase at least one of A, B, and C should be construed to mean a logical (A OR B OR C), using a non-exclusive logical OR, and should not be construed to mean “at least one of A, at least one of B, and at least one of C.”

[0085] In the figures, the direction of an arrow, as indicated by the arrowhead, generally demonstrates the flow of information (such as data or instructions) that is of interest to the illustration. For example, when element A and element B exchange a variety of information but information transmitted from element A to element B is relevant to the illustration, the arrow may point from element A to element B. This unidirectional arrow does not imply that no other information is transmitted from element B to element A. Further, for information sent from element A to element B, element B may send requests for, or receipt acknowledgements of, the information to element A.

[0086] In this application, including the definitions below, the term “controller” may be replaced with the term “circuit.” The term “controller” may refer to, be part of, or include: an Application Specific Integrated Circuit (ASIC); a digital, analog, or mixed analog/digital discrete circuit; a digital, analog, or mixed analog/digital integrated circuit; a combinational logic circuit; a field programmable gate array (FPGA); a processor circuit (shared, dedicated, or group) that executes code; a memory circuit (shared, dedicated, or group) that stores code executed by the processor circuit; other suitable hardware components that provide the described functionality; or a combination of some or all of the above, such as in a system-on-chip.

[0087] The controller may include one or more interface circuits. In some examples, the interface circuits may include wired or wireless interfaces that are connected to a local area network (LAN), the Internet, a wide area network (WAN), or combinations thereof. The functionality of any given controller of the present disclosure may be distributed among multiple controllers that are connected via interface circuits. For example, multiple controllers may allow load balancing.

[0088] The term code, as used above, may include software, firmware, and/or microcode, and may refer to programs, routines, functions, classes, data structures, and/or objects. The term shared processor circuit encompasses a single processor circuit that executes some or all code from multiple controllers. The term group processor circuit
5 encompasses a processor circuit that, in combination with additional processor circuits, executes some or all code from one or more controllers.

[0089] References to multiple processor circuits encompass multiple processor circuits on discrete dies, multiple processor circuits on a single die, multiple cores of a single processor circuit, multiple threads of a single processor circuit, or a combination of the
10 above. The term shared memory circuit encompasses a single memory circuit that stores some or all code from multiple controllers. The term group memory circuit encompasses a memory circuit that, in combination with additional memories, stores some or all code from one or more controllers.

[0090] The term memory circuit is a subset of the term computer-readable medium. The
15 term computer-readable medium, as used herein, does not encompass transitory electrical or electromagnetic signals propagating through a medium (such as on a carrier wave); the term computer-readable medium may therefore be considered tangible and non-transitory. Non-limiting examples of a non-transitory, tangible computer-readable medium are nonvolatile memory circuits (such as a flash memory circuit, an erasable
20 programmable read-only memory circuit, or a mask read-only memory circuit), volatile memory circuits (such as a static random access memory circuit or a dynamic random access memory circuit), magnetic storage media (such as an analog or digital magnetic tape or a hard disk drive), and optical storage media (such as a CD, a DVD, or a Blu-ray Disc).

[0091] The apparatuses and methods described in this application may be partially or fully implemented by a special purpose computer created by configuring a general-purpose computer to execute one or more particular functions embodied in computer programs. The functional blocks, flowchart components, and other elements described
25 above serve as software specifications, which can be translated into the computer programs by the routine work of a skilled technician or programmer.

[0092] The computer programs include processor-executable instructions that are stored on at least one non-transitory, tangible computer-readable medium. The computer programs may also include or rely on stored data. The computer programs may

encompass a basic input/output system (BIOS) that interacts with hardware of the special purpose computer, device drivers that interact with particular devices of the special purpose computer, one or more operating systems, user applications, background services, background applications, etc.

- 5 **[0093]** The computer programs may include: (i) descriptive text to be parsed, such as HTML (hypertext markup language), XML (extensible markup language), or JSON (JavaScript Object Notation) (ii) assembly code, (iii) object code generated from source code by a compiler, (iv) source code for execution by an interpreter, (v) source code for compilation and execution by a just-in-time compiler, etc. As examples only, source code
- 10 may be written using syntax from languages including C, C++, C#, Objective-C, Swift, Haskell, Go, SQL, R, Lisp, Java®, Fortran, Perl, Pascal, Curl, OCaml, Javascript®, HTML5 (Hypertext Markup Language 5th revision), Ada, ASP (Active Server Pages), PHP (PHP: Hypertext Preprocessor), Scala, Eiffel, Smalltalk, Erlang, Ruby, Flash®, Visual Basic®, Lua, MATLAB, SIMULINK, and Python®.

CLAIMS

What is claimed is:

1. A flexible circuit comprising:
a flexible substrate made of an electrically non-conducting material; and
5 electrically conductive traces disposed on the flexible substrate;
wherein the flexible substrate comprises a center portion and a plurality of side portions extending perpendicularly from the center portion on opposite sides of the center portion; and
wherein centers of the side portions on one side of the center portion are collinear
10 with centers of corresponding side portions on an opposite side of the center portion.
2. The flexible circuit of claim 1 wherein the flexible substrate is a planar two-dimensional structure and wherein the center portion is rectangular.
3. The flexible circuit of claim 2 wherein adjacent side portions are separated by angular cutouts, wherein vertices of angles of the angular cutouts lie on opposite sides
15 of a rectangle formed by the center portion, and wherein the vertices of the angles of the angular cutouts on one side of the rectangle are collinear with the vertices of the angles of the corresponding angular cutouts on the opposite side of the rectangle.
4. The flexible circuit of claim 3 further comprising holes that coincide with the vertices of the angles of the angular cutouts, wherein the holes lie on opposite sides of
20 the rectangle, and wherein the holes on one side of the rectangle are collinear with the corresponding holes on the opposite side of the rectangle.
5. The flexible circuit of claim 1 wherein the electrically conductive traces are routed through at least one of the center portion and the side portions.
6. The flexible circuit of claim 1 wherein the electrically conductive traces are
25 configured to operate as at least one of a heater and a capacitive sensor.
7. The flexible circuit of claim 1 wherein the electrically conductive traces are using a dry-milling process, a printed conductive ink, electrodeposition, vapor-deposition, photo-resist, laminated circuit sheets, or stencil.

8. The flexible circuit of claim 1 wherein the electrically conductive traces are disposed on a first surface of the flexible substrate, a second surface of the flexible substrate that is opposite to the first surface, or both.
9. The flexible circuit of claim 1 wherein the electrically conductive traces are embedded in the flexible substrate.
10. A steering wheel comprising the flexible circuit of claim 1 and further comprising:
a rigid core; and
a first layer disposed around the rigid core, the first layer comprising flat facets along an outer perimeter of the first layer and sidewall facets along sidewalls and an inner perimeter of the first layer;
wherein the center portion of the flexible circuit is attached to the flat facets of the first layer; and
wherein the side portions of the flexible circuit are attached to the sidewall facets of the first layer.
11. The steering wheel of claim 10 wherein the center portion and the side portions of the flexible circuit are respectively attached to the flat facets and the sidewall facets of the first layer without causing plastic deformation of the center portion and the side portions of the flexible circuit.
12. The steering wheel of claim 10 wherein the center portion of the flexible circuit and the flat facets of the first layer are rectangular and have substantially the same width.
13. The steering wheel of claim 10 wherein the flat facets of the first layer have substantially the same circumferential length.
14. The steering wheel of claim 10 wherein the flat facets of the first layer have unequal circumferential lengths.
15. The steering wheel of claim 10 wherein a width of the flat facets of the first layer is selected based on a density of the electrically conductive traces in the center portion of the flexible circuit.

16. The steering wheel of claim 10 wherein adjacent side portions of the flexible circuit are separated by angular cutouts, and wherein an angle of the angular cutouts is a function of a number of the flat facets and a diameter of the steering wheel.
17. The steering wheel of claim 10 further comprising a second layer disposed on the flexible circuit and the first layer wherein the second layer is toroidal in shape.
18. The steering wheel of claim 17 further comprising a cover disposed on the second layer.
19. The steering wheel of claim 17 wherein the first and second layers comprise a foam.
20. The steering wheel of claim 17 wherein the first and second layers comprise a dielectric material.
21. The steering wheel of claim 17 wherein the first and second layers comprise an electrically non-conducting material.
22. A system comprising the steering wheel of claim 10 wherein the electrically conductive traces in the flexible circuit are configured to operate as at least one of a heater and a capacitive sensor, the system further comprising:
a first circuit coupled to the heater and configured to control the heater to heat the steering wheel; and
a second circuit coupled to the capacitive sensor and configured to sense presence or absence of a hand on the steering wheel.

AMENDED CLAIMS
received by the International Bureau on
29 November 2023 (29.11.2023)

1. A flexible circuit comprising:
a flexible substrate made of an electrically non-conducting material; and
electrically conductive traces disposed on the flexible substrate, wherein the
electrically conductive traces are configured to operate as a heater and a capacitive
5 sensor;
wherein the flexible substrate comprises a center portion and a plurality of side
portions extending perpendicularly from the center portion on opposite sides of the
center portion; and
wherein centers of the side portions on one side of the center portion are
10 collinear with centers of corresponding side portions on an opposite side of the center
portion.
2. The flexible circuit of claim 1 wherein the flexible substrate is a planar two-
dimensional structure and wherein the center portion is rectangular.
3. The flexible circuit of claim 2 wherein adjacent side portions are separated by
15 angular cutouts, wherein vertices of angles of the angular cutouts lie on opposite sides
of a rectangle formed by the center portion, and wherein the vertices of the angles of
the angular cutouts on one side of the rectangle are collinear with the vertices of the
angles of the corresponding angular cutouts on the opposite side of the rectangle.
4. The flexible circuit of claim 3 further comprising holes that coincide with the
20 vertices of the angles of the angular cutouts, wherein the holes lie on opposite sides of
the rectangle, and wherein the holes on one side of the rectangle are collinear with the
corresponding holes on the opposite side of the rectangle.
5. The flexible circuit of claim 1 wherein the electrically conductive traces are
routed through at least one of the center portion and the side portions.
- 25 6. (Canceled)
7. The flexible circuit of claim 1 wherein the electrically conductive traces are using
a dry-milling process, a printed conductive ink, electrodeposition, vapor-deposition,
photo-resist, laminated circuit sheets, or stencil.

8. The flexible circuit of claim 1 wherein the electrically conductive traces are disposed on a first surface of the flexible substrate, a second surface of the flexible substrate that is opposite to the first surface, or both.

5 9. The flexible circuit of claim 1 wherein the electrically conductive traces are embedded in the flexible substrate.

10. A steering wheel comprising the flexible circuit of claim 1 and further comprising:
a rigid core; and
a first layer disposed around the rigid core, the first layer comprising flat facets along an outer perimeter of the first layer and sidewall facets along sidewalls and an
10 inner perimeter of the first layer;
wherein the center portion of the flexible circuit is attached to the flat facets of the first layer; and
wherein the side portions of the flexible circuit are attached to the sidewall facets of the first layer.

15 11. The steering wheel of claim 10 wherein the center portion and the side portions of the flexible circuit are respectively attached to the flat facets and the sidewall facets of the first layer without causing plastic deformation of the center portion and the side portions of the flexible circuit.

20 12. The steering wheel of claim 10 wherein the center portion of the flexible circuit and the flat facets of the first layer are rectangular and have substantially the same width.

13. The steering wheel of claim 10 wherein the flat facets of the first layer have substantially the same circumferential length.

25 14. The steering wheel of claim 10 wherein the flat facets of the first layer have unequal circumferential lengths.

15. The steering wheel of claim 10 wherein a width of the flat facets of the first layer is selected based on a density of the electrically conductive traces in the center portion of the flexible circuit.

16. The steering wheel of claim 10 wherein adjacent side portions of the flexible circuit are separated by angular cutouts, and wherein an angle of the angular cutouts is a function of a number of the flat facets and a diameter of the steering wheel.
17. The steering wheel of claim 10 further comprising a second layer disposed on the flexible circuit and the first layer wherein the second layer is toroidal in shape.
18. The steering wheel of claim 17 further comprising a cover disposed on the second layer.
19. The steering wheel of claim 17 wherein the first and second layers comprise a foam.
20. The steering wheel of claim 17 wherein the first and second layers comprise a dielectric material.
21. The steering wheel of claim 17 wherein the first and second layers comprise an electrically non-conducting material.
22. A system comprising the steering wheel of claim 10 wherein the electrically conductive traces in the flexible circuit are configured to operate as at least one of a heater and a capacitive sensor, the system further comprising:
- a first circuit coupled to the heater and configured to control the heater to heat the steering wheel; and
 - a second circuit coupled to the capacitive sensor and configured to sense presence or absence of a hand on the steering wheel.

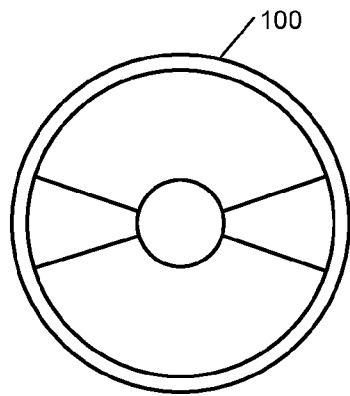


FIG. 1

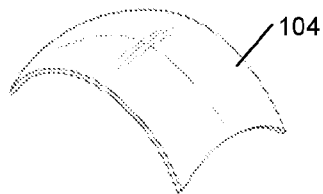
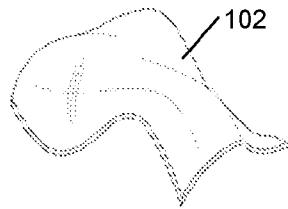
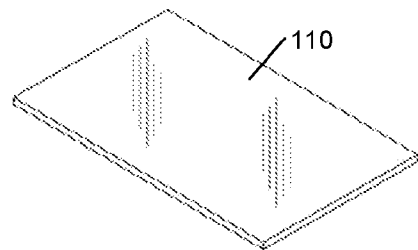
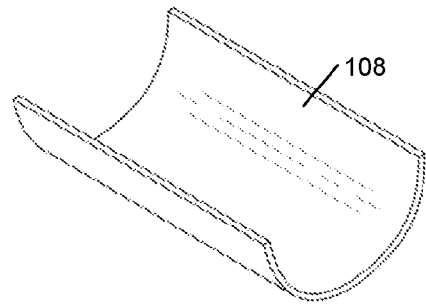
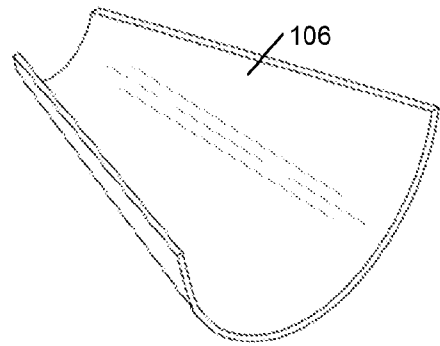


FIG. 2A

FIG. 2B

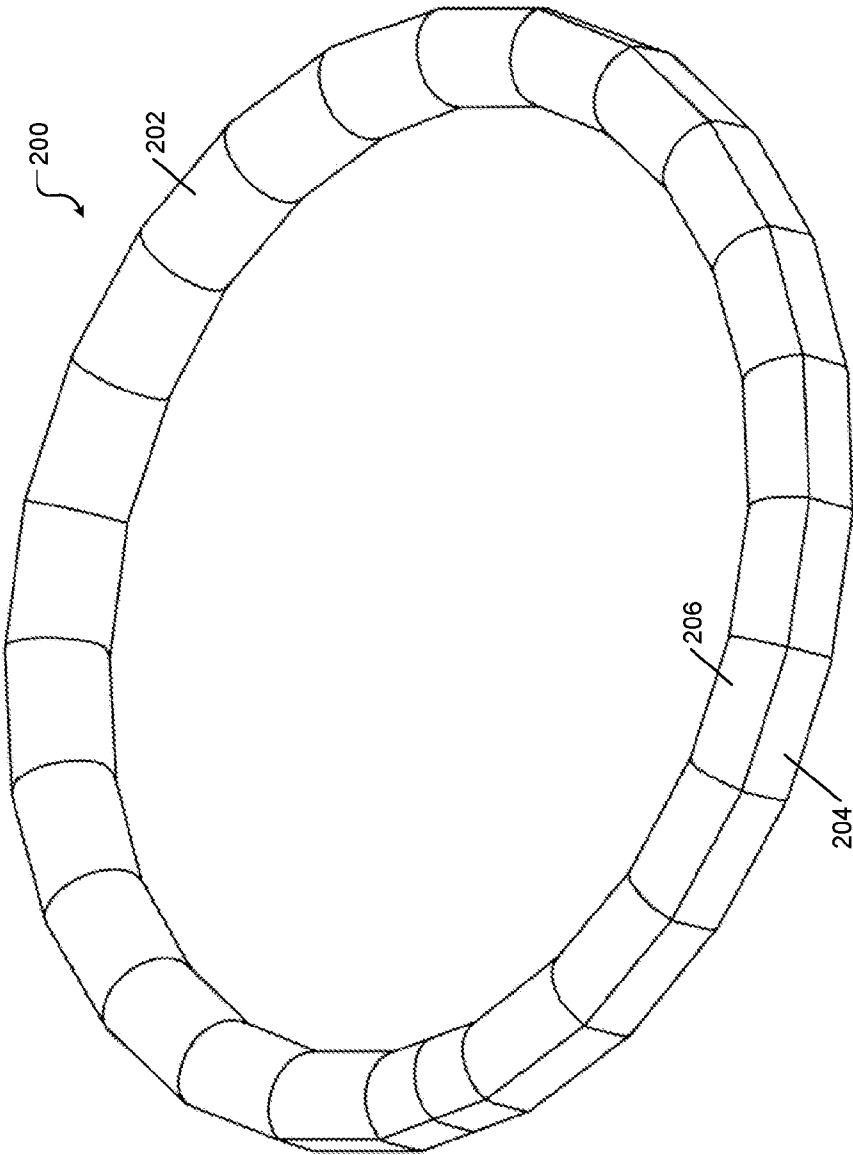


FIG. 3A

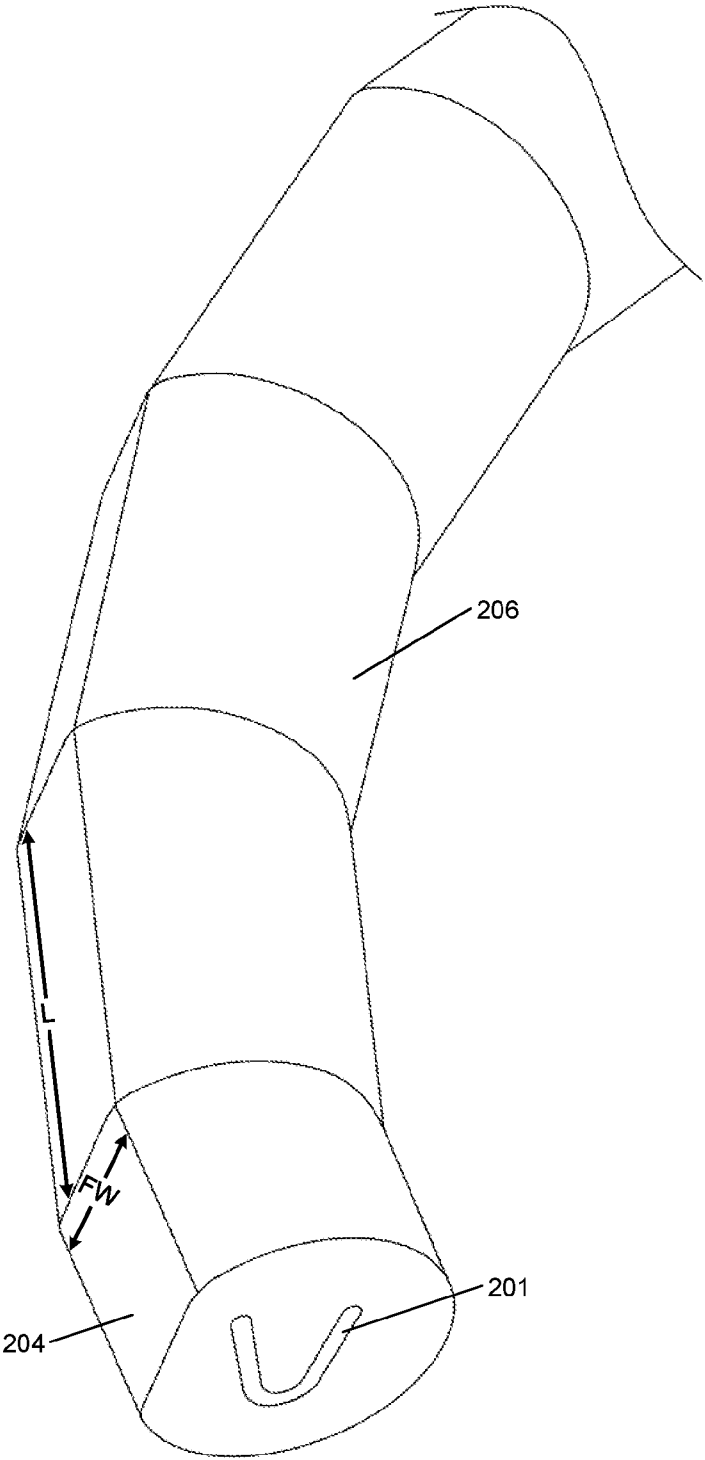
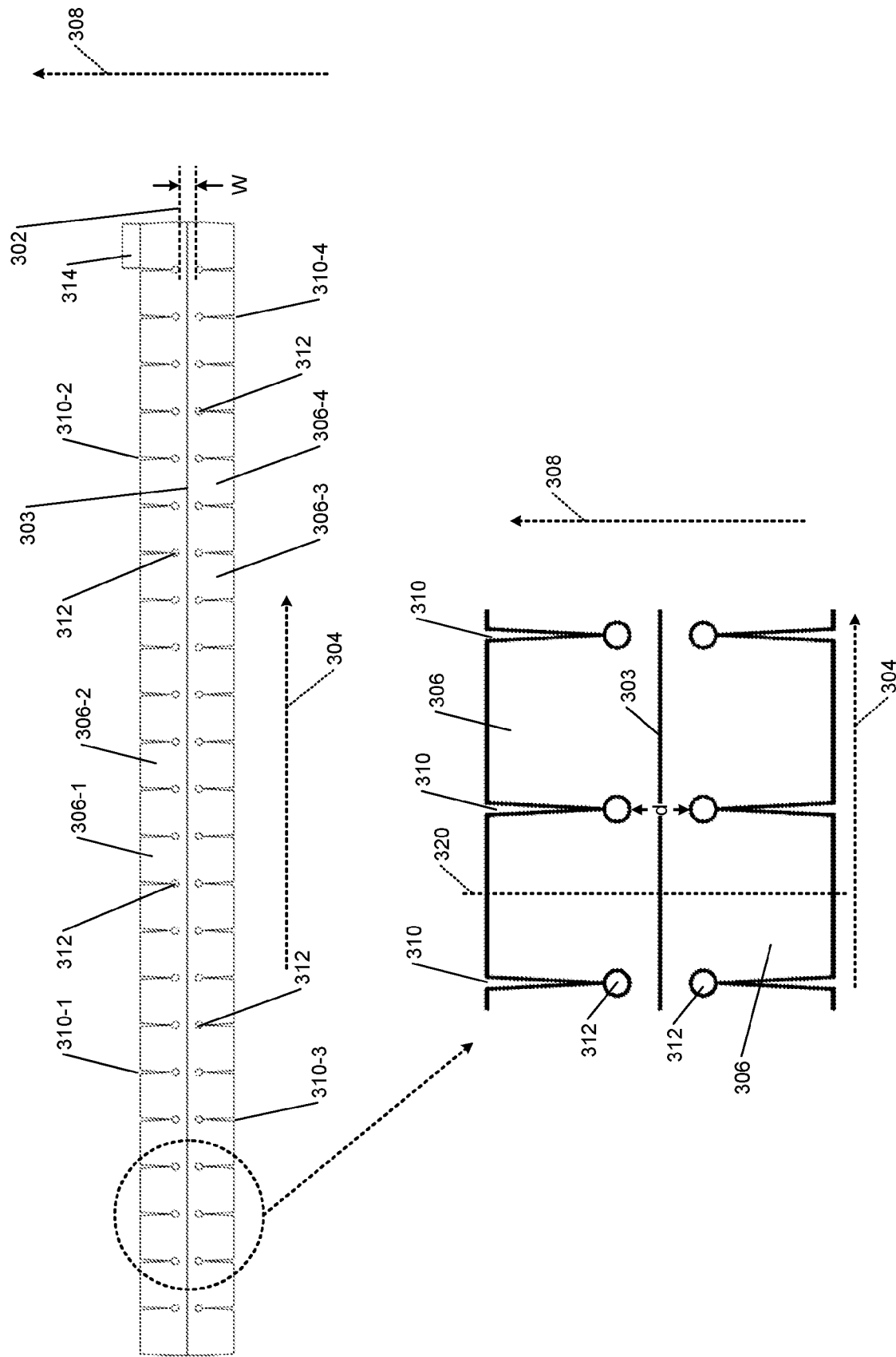


FIG. 3B

FIG. 4



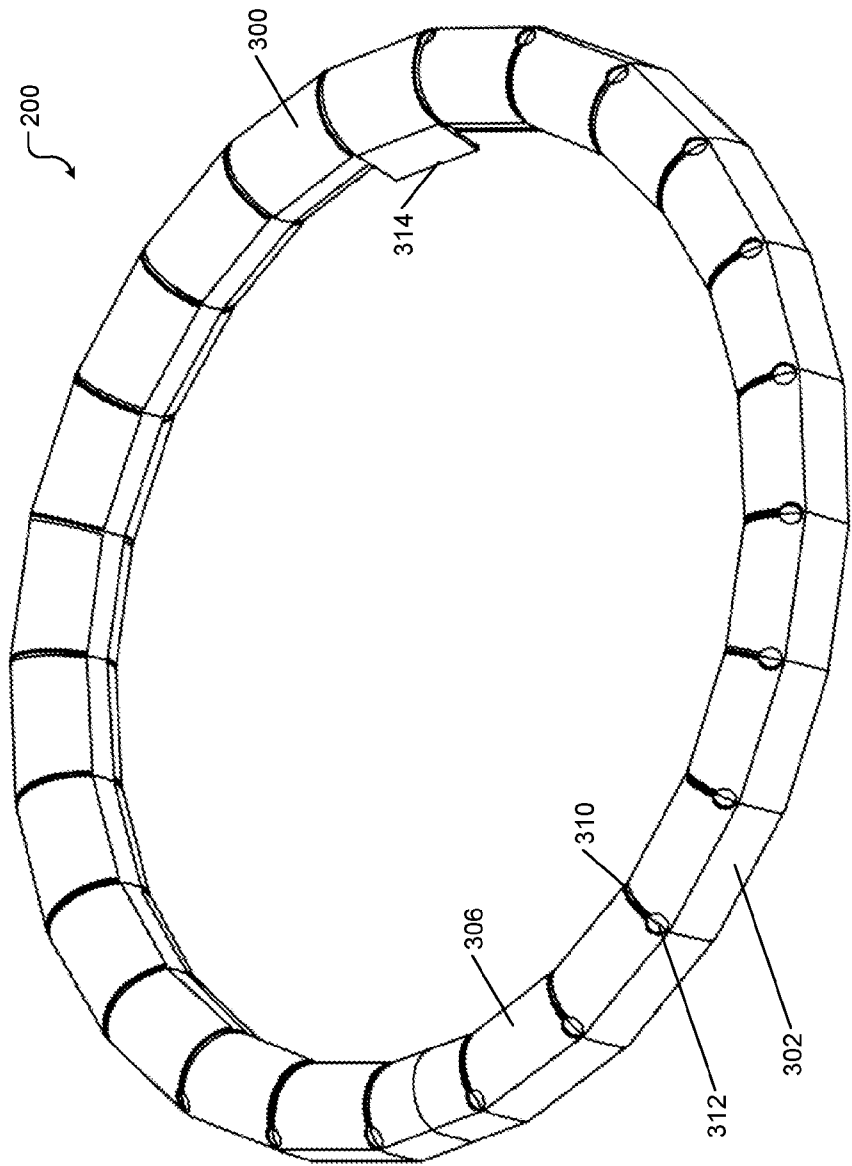


FIG. 5A

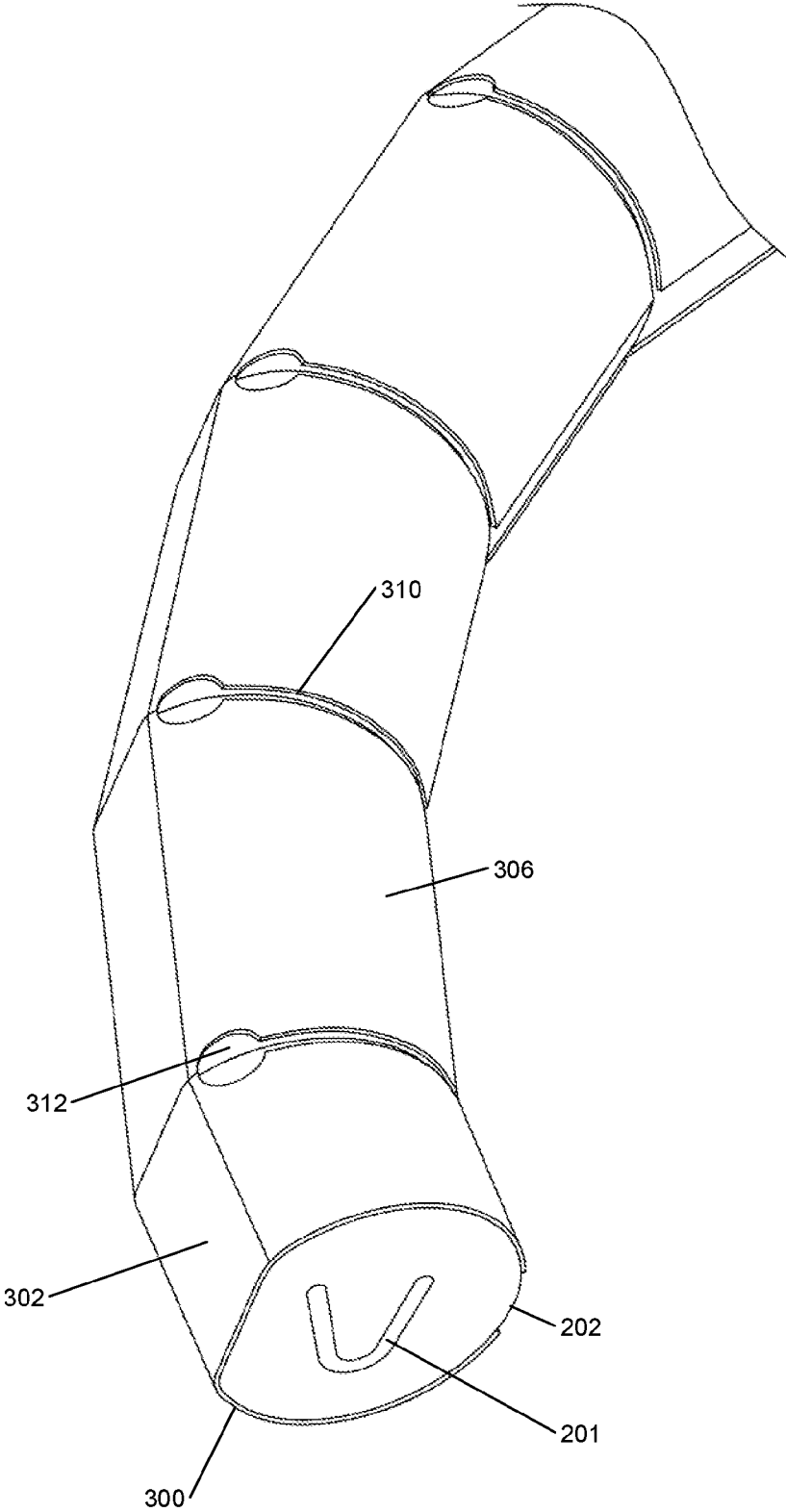


FIG. 5B

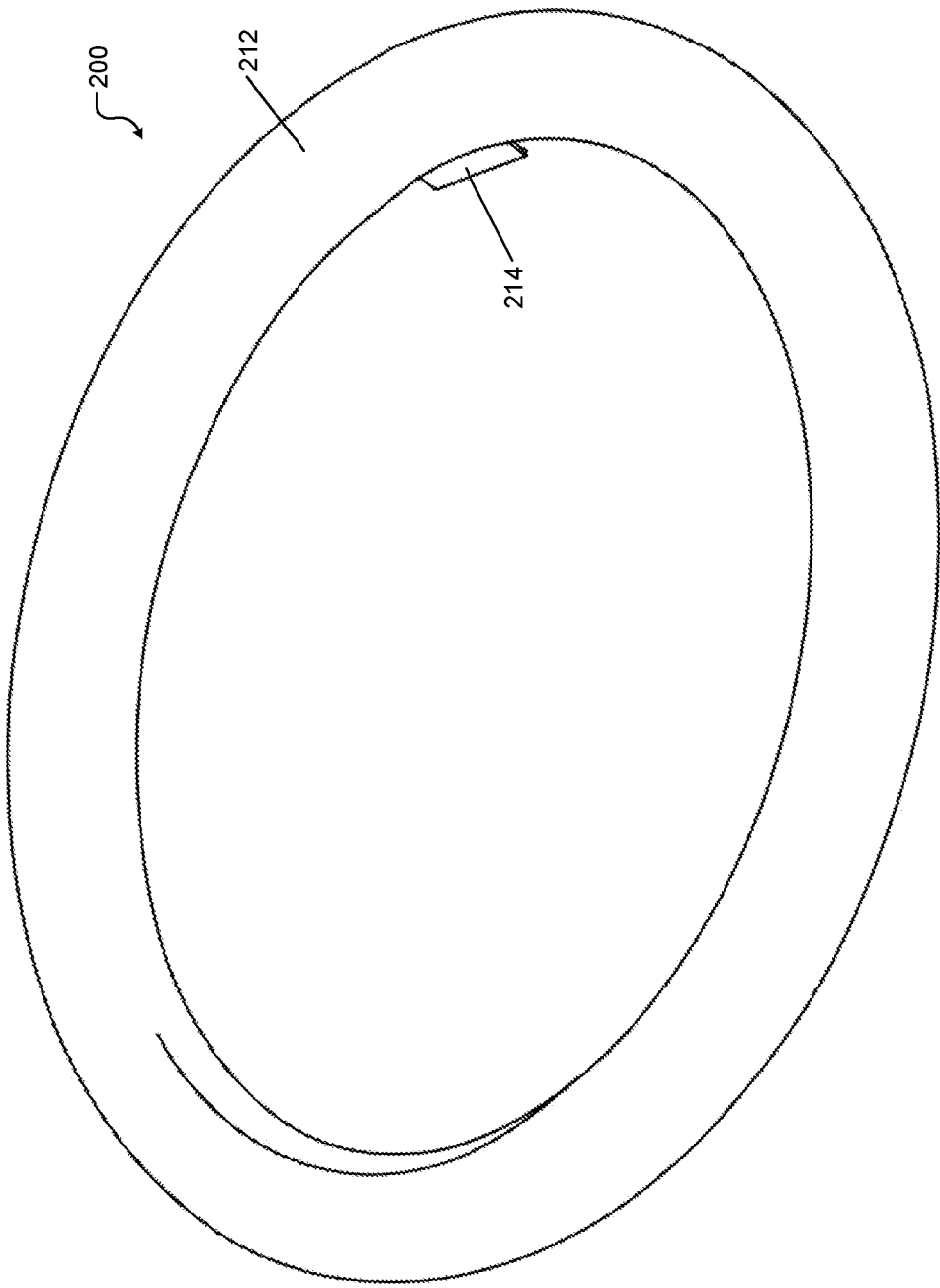


FIG. 6

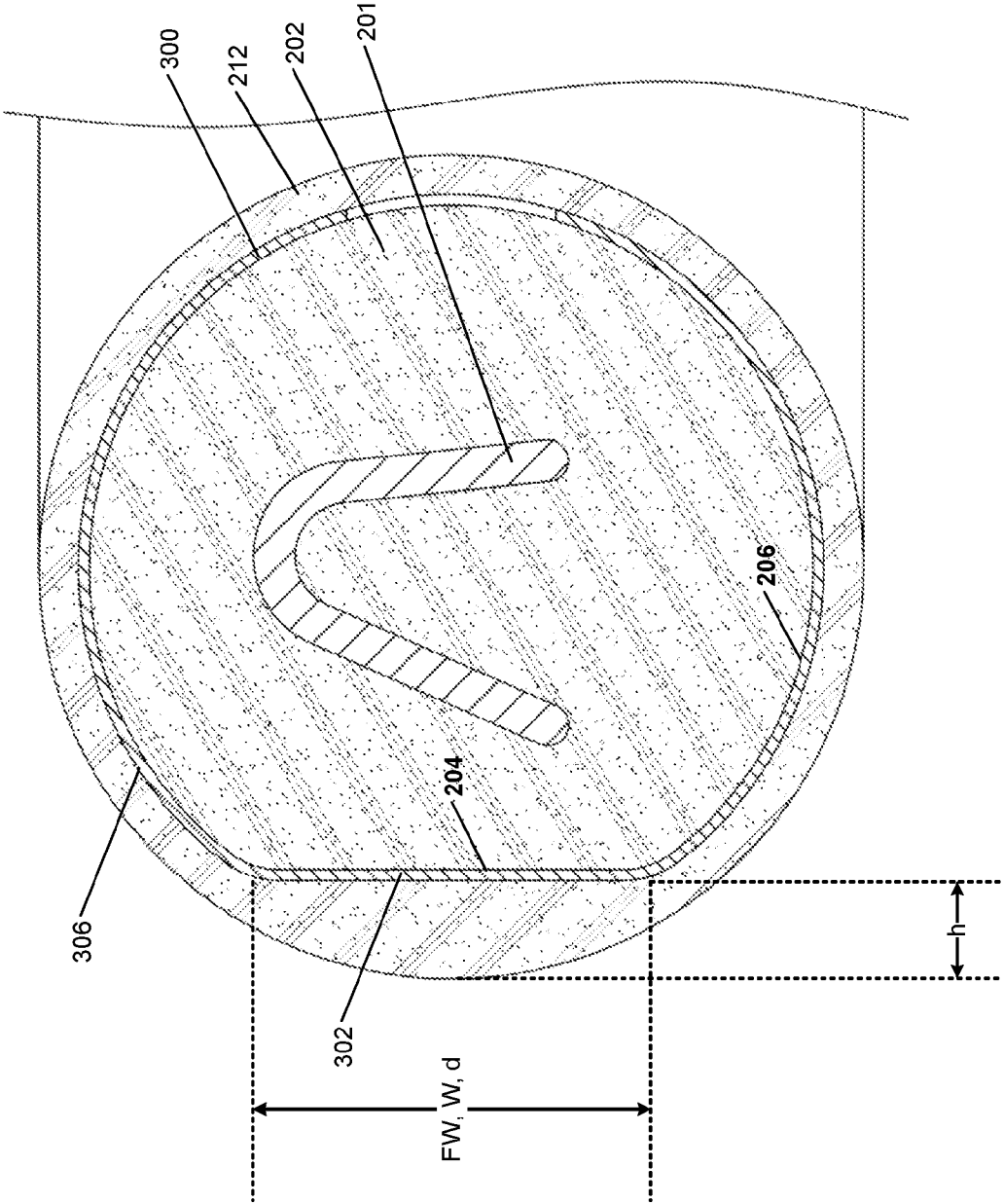


FIG. 7A

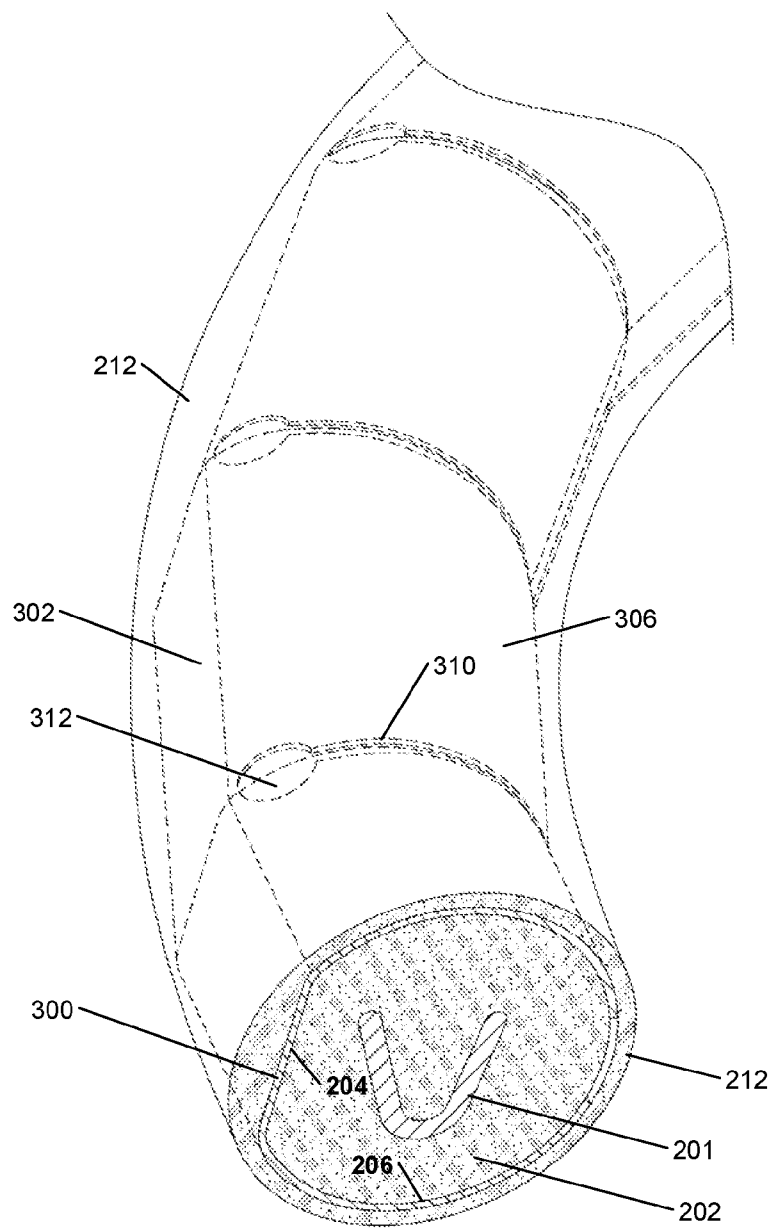


FIG. 7B

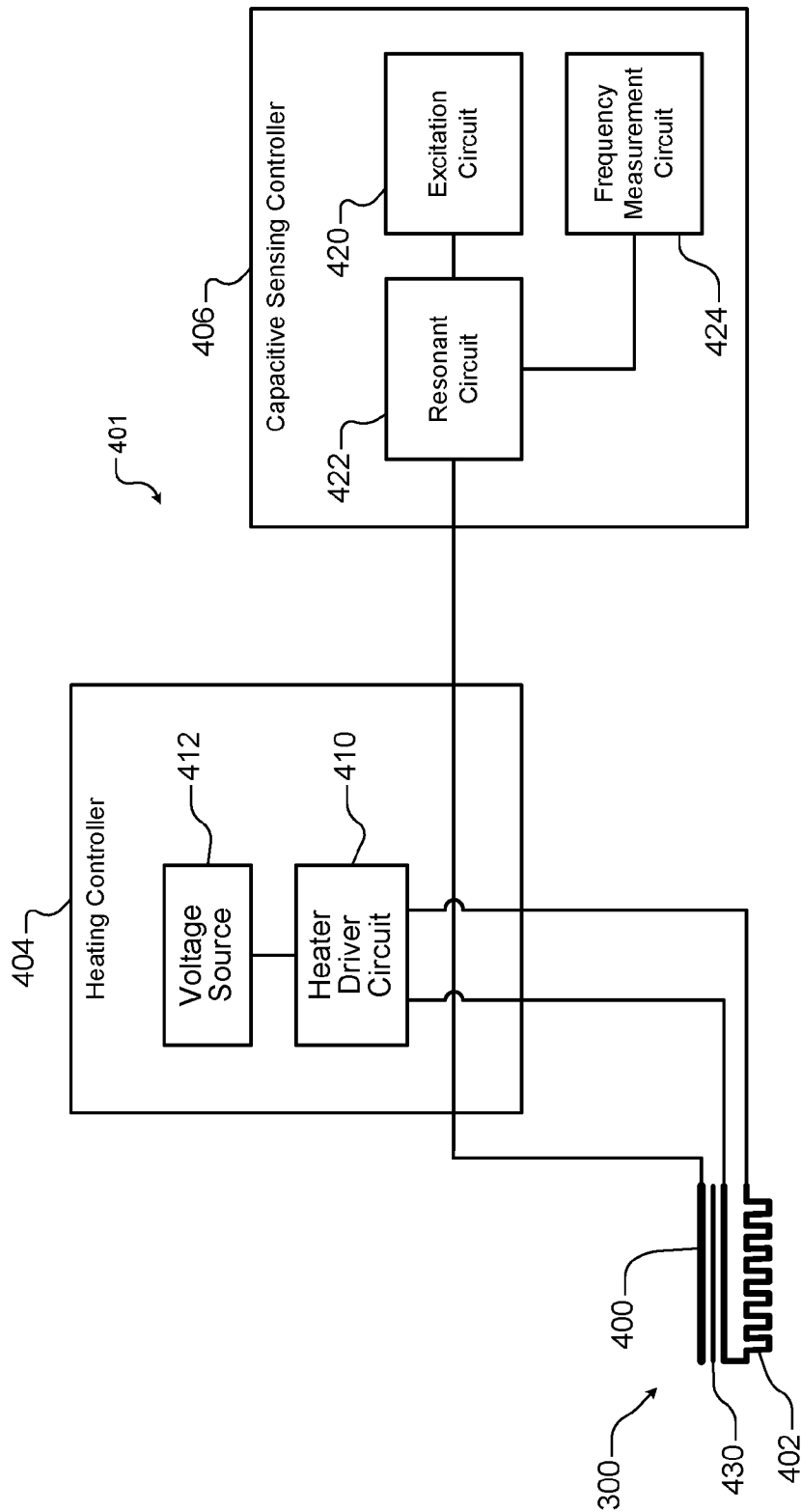


FIG. 8

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2023/027482

A. CLASSIFICATION OF SUBJECT MATTER

INV. B60R21/015 G01D5/24

ADD.

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)

B60R G01D

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2015/369633 A1 (KARASAWA NORIYUKI [JP] ET AL) 24 December 2015 (2015-12-24)	1-9
A	paragraphs [0042], [0043]; claim 1; figures 1-27 -----	10-22
A	WO 2016/096815 A1 (IEE SARL [LU]) 23 June 2016 (2016-06-23) paragraphs [0059], [0071]; figures 4-7 -----	4
A	KR 2014 0058624 A (SABIC INNOVATIVE PLASTICS IP [NL]) 14 May 2014 (2014-05-14) paragraphs [0021] - [0025]; figures 1-10 -----	7



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 application or patent but published on or after the international filing date

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

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

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search

15 October 2023

Date of mailing of the international search report

24/10/2023

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2

NL - 2280 HV Rijswijk

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Authorized officer

Hutter, Manfred

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2023/027482

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