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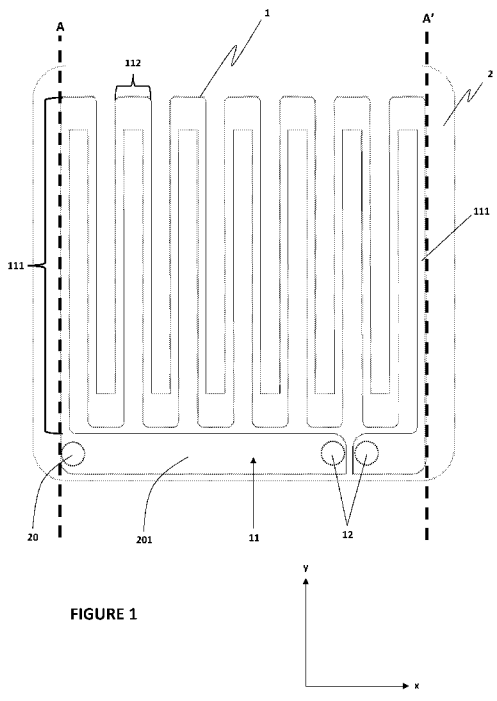


FIGURE 1

(57) Abstract: The present invention relates to a flexible circuit and an electrically conductive laminated sheet comprising the same having a soft and flexible structure with a circuitry trace. The circuitry trace has an improved design which allows multi-direction stretchability and robustness. The circuitry trace is designed to have a pulse wave shape having repeating waves and forming a row along a horizontal direction, said circuitry trace comprising elongated lines corresponding to pulse amplitude and extending in vertical direction and shorter lines corresponding to pulse length and extending in horizontal direction; whereby each of the waves consists of two elongated lines arranged substantially parallel to each other and one shorter line substantially perpendicular to the neighboring elongated lines.

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INTERNATIONAL PATENT APPLICATION UNDER THE PATENT COOPERATION TREAT

A STRETCHABLE SOFT SHEET COMPRISING FLEXIBLE CIRCUIT

Technical Field

The present invention relates to a flexible circuit and an electrically conductive laminated sheet comprising the same which is stretchable in one or multiple directions and supporting a range of functionalties such as heating, capacitive touch sensing and cabling.

Background of the Invention

Electric heating is used in a range of industries such as medical and automotive to bring comfort or therapy to patients and passengers. In many of these applications, it is desirable to have a heating element integrated easily into a textile. For example, in the automotive industry, one may have the desire to heat a steering wheel with a soft, flexible circuit layer that can be easily wrapped around the steering wheel. It is a requirement for many of these applications that the heating element can have 2-way or 4-way stretch of up to 50% and that the heating element can be easily integrated using bonding or sewing into the substrate good. These requirements make traditional flexible electronics and wire-based heating methods unsatisfactory for many applications.

Disclosures have been made, for example in US11528780B2, which describes a process for making a thin and flexible PTC hybrid heater. The heater suggested in this patent is made with a soft, flexible conductive fabric that acts as the conductor. For this purpose, conductive ink in tandem with a conductive planar material is used, which is actually not specified as a conductive fabric or textile. The electrically conductive heater lines comprise a carbon black material having an electrical resistivity with a positive temperature coefficient (PTC) in order to reduce silver usage in the conductive ink. This patent, however bears several limitations in terms of stretchability over surfaces having a complex geometry due to the production technique which requires depositing of adhesive material without masking, use of bridge members and the material used in different layers.

Likewise, US10490507B1, US10716341B2, US10925168B2 and US11342271B2 disclose flexible circuitry layers comprising a conductive mesh including a circuitry trace and an interfacing component. Further disclosed are the specific methods for manufacturing of flexible circuitry layers comprising, for instance, providing a conductive mesh, applying a masking thereon in order to form a circuitry trace and selectively removing of the mask with mechanical or chemical means.

These patents do not specify the conductive trace design as a contributor to mechanical properties, such as stretchability.

WO 2014/184743 discloses a combination heater and sensor comprising: a heating layer and a sensing layer wherein the heating layer is a nonwoven layer that is comprised of a plurality of metallized fibers. The combined system suggested herein can be implemented in a seat or steering wheel of a vehicle, but it relies only on a serpentine trace for stretchability, not the combination of trace patterning and a stretchable carrier, and it requires multiple layers of circuitry in order to achieve heating and sensing together, which inhibits mechanical properties.

As seen above, flexible materials comprising heating elements, cabling and antenna (for capacitive touch sensing, for example) have certain limitations in creating a very thin, flexible and stretchable circuit that is soft in nature. The present invention solves existing drawbacks of the prior art with a flexible circuit and an electrically conductive laminated sheet having this flexible circuit which have higher degree of stretchability and robustness as presented in the appended claims.

Summary of the Invention

The present invention relates to a flexible circuit having a planar circuitry sheet (2) and a circuitry trace (1) having conductive lines (11).

The circuitry trace (1) is designed to have a pulse wave shape having repeating waves and forming a row along a horizontal direction (x), said circuitry trace (1) comprising elongated lines (111) corresponding to pulse amplitude and extending in vertical direction (y) and shorter lines (112) corresponding to pulse length and extending in horizontal direction (x), whereby each of the waves consists of two elongated lines (111) arranged substantially parallel to eachother and one shorter line (112) substantially perpendicular to the neighbouring elongated lines (111),

The elongated lines (111) mentioned hereinabove forming the waves in outermost edge of the circuitry trace (1) have a bending portion (20), whereby a horizontally elongated line (201) extending in horizantal direction (x) is connected with said elongated line (111), and said horizontally elongated line (201) extends inwardly between the borderlines (A, A') forming the outermost edges of the circuitry trace (1), and whereby the length of the horizontally elongated line (201) is more than the shorter line (112) of the waves.

Brief Description of the Figures

Figure 1 presents a circuitry trace according to the present invention.

Figure 2 shows the circuitry trace according to another embodiment of the present invention.

Detailed Description of the Invention

Soft and flexible sheets containing electronic circuits for a range of applications such as heating and sensing properties are known in the art. The circuit may also include dual functionalities such as sensing and heating combined. In this case, the circuit produces an electric field through an antenna (which can double as a heater), whereby an object (i.e. human finger or hand) interfere with said electric field lines decreasing the mutual capacitances and causing a signal to be generated based on the aforementioned change in the capacitance. This phenomena generally doesn't require a physical touch on the circuit but it may produce a response as soon as the object approaches and interferes with electrical field lines.

This technology is therefore promising for the provision of functional surfaces in automotive industry such as steering wheels, seats, door trims etc. However, certain limitations render the flexible circuits inapplicable in the automotive industry. Especially, the automotive parts having higher geometric complexity such as steering wheels and seats require extra flexibility and stretchability as well as robustness of the circuitry during application in the course of the production.

Therefore, it would be desirable to provide a circuitry trace, an electrically conductive laminated sheet and a production method for producing the same compatible with the foregoing objectives. It is also desirable to provide a superior design of the circuitry allowing it to be stretchable enough without deterioration of the conductive lines in the circuitry.

Thus, in one aspect of the present invention, there is provided a flexible circuit having a planar circuitry sheet (2) and a circuitry trace (1), said circuitry trace (1) comprising conductive lines (11) and electrode regions (12), wherein:

the circuitry trace (1) is designed to have a pulse wave shape having repeating waves along a horizontal direction (x), said circuitry trace (1) comprising elongated lines (111) corresponding to pulse amplitude and extending in vertical direction (y) and shorter lines (112) corresponding to pulse length and extending in horizontal direction (x), whereby each of the waves consists of two elongated lines (111) arranged substantially parallel to

eachother and one shorter line (112) substantially perpendicular to the neighbouring elongated lines (111),

wherein:

the elongated lines (111) forming the waves in outermost edge of the circuitry trace (1) have a bending portion (20), whereby a horizontally elongated line (201) extending in horizantal direction (x) is connected with said elongated line (111), and said horizontally elongated line (201) extends inwardly between the borderlines (A, A') forming the outermost edges of the circuitry trace (1), and whereby the length of the horizontally elongated line (201) is more than the shorter line (112) of the waves.

In another aspect of the present invention, an electrically conductive laminated sheet comprising the above-mentioned flexible circuit is provided. Said electrically conductive laminated sheet basically comprises:

- a planar carrier sheet made of a polymeric film
- a planar circuitry sheet (2) on top of the planar carrier sheet, the planar circuitry sheet (2) comprising above mentioned flexible circuit having a circuitry trace (1),
- auxiliary electronic components connected with the circuitry trace (1), and
- a top layer polymeric film laminated on the foregoing combination.

In a further aspect of the present invention, there is provided a method for producing an electrically conductive laminated sheet having a flexible circuit as defined above, comprising the steps of:

- providing a planar carrier sheet made of a polymeric film,
- printing a desired circuit pattern with adhesive onto the polymeric film by using a screen,
- sheeting of a planar circuitry sheet (2) mentioned above and placing the same onto the polymeric film so that it overlays the surface of the film and lays on top of the screened adhesive,
- curing this combination to ensure bonding with the adhesive,
- cutting of the planar circuitry sheet (2) so that the material not bonded by the adhesive can be removed,
- placing auxiliary electronic components and connecting them with the circuitry trace (1) of the planar circuitry sheet (2) by using a binder,
- optionally providing a secondary layer of planar circuitry sheet (2) as described by the previous steps, and

- providing a top layer polymeric film and laminating the same on the foregoing combination to obtain a stretchable product.

The conductive lines (11) of the circuitry trace (1) in between the polymeric planar carrier sheet and the polymeric top layer can be configured to function as the capacitive sensing means because the polymeric layers behave as dielectric (i.e., insulating) layers. Therefore, a control circuitry (not shown) can be provided for receiving electrical signals received from the circuitry trace (1) and producing a control signal for controlling supply of electricity to the circuitry trace (1). For this purpose, the control circuitry is calibrated so that electrically conductive laminated sheet is made sensitive to a desired electromagnetic field threshold signal.

The polymeric film used in the planar carrier sheet and the top layer as mentioned hereinabove is a dielectric material advantageously stretchable in multiple directions according to the objectives of the invention. More particularly, the polymer material mentioned herein is selected from the group consisting of polyethylene terephthalate (PET), polyimide (PI), polyetherimide (PEI), polyethylene naphthalate (PEN), polyoxymethylene (POM), polyamide (PA), polyphthalamide (PPA), polyether ether ketone (PEEK), thermoplastic olefins (TPO), silicone and polyurethane (PU). The polymer material is most preferably thermoplastic polyurethane (TPU) which is highly stretchable and flexible being also suitable for use in automotive. However, the top layer polymeric film, in any case, is selected as a dielectric polymeric film that is heat sealed to close the layer with auxiliary electronic components and circuitry. The film may be hot melt, or have an adhesive layer inside.

Application of the desired circuit pattern with adhesive onto the planar carrier sheet by using a screen and masking is advantageous because of the controlled usage of the adhesive. Otherwise, without masking, excessive adhesive reduces stretchability and flexibility of the polymeric film. It is also noted that applying the adhesive to the planar circuitry sheet (2) and then bonding it with the planar carrier sheet causes irregularities in the polymeric film and limited stretchability of the planar circuitry sheet (2).

The planar circuitry sheet (2) having the flexible circuit is preferably a conductive fabric or conductive textile which may have a polymeric core material that is woven or knit. This material is preferably electroplated with an electrically conductive material such as copper and/or nickel. Deposition of copper and/or nickel by electroplating is advantageous because of the highly intense and homogenous conductivity which is substantially not affected by the stretching forces

in any direction. This also alleviates the drawbacks of the alternative techniques such as conductive ink which generally require more conductive and expensive material such as silver.

The adhesive used in the method mentioned above is preferable curable with UV. Alternatively, the adhesive may have been pre-applied by lining covered with a mask in a ready to use form such that the mask is removed just before bonding with the planar circuitry sheet (2).

Cutting of the planar circuitry sheet (2) for removing the material not bonded by the adhesive, can be carried out by kiss cutting which can be advantageously automatized and carry out a sensitive cutting without deteriorating the circuit.

The auxiliary electronic components added to the circuit include any desired component such as terminations, wires, PCBs, switches and control circuitry necessary for the control and power supply to the flexible circuitry. In preferred embodiments, the auxiliary electronic components may include also an illumination means such as LED either for indication of functionality of heating, solely for lighting the environment or a combination thereof. The illumination means can be located in an appropriate area of the electrically conductive laminated sheet such that when the user approaches or touches a particular area on the electrically conductive laminated sheet, illumination means are activated. A control circuitry for this purpose is designed and placed into the electrically conductive laminated sheet. The auxiliary electronic components can be fixed to the electrically conductive laminated sheet by using electrically conductive or non-conductive adhesive or epoxy.

The electrically conductive laminated sheet according to the present invention can be formed with a multi-layer circuit by repetition of the sheeting step whereby a further planar circuitry sheet is laminated to the initial conductive planar sheet.

In the electrically conductive laminated sheet having a flexible circuit used in the present invention, the circuit is designed to allow maximum stretchability while providing sufficient durability and circuit intensity per area.

Typically, a serpentine pattern for obtaining stretch within a heating element of the circuitry consists of a sinusoidal wave shape that either snakes around a volume, or is connected by parallel bars to create several heating lines (i.e. resistors) in parallel. This technique is not suitable for this method of making a soft, flexible circuit from conductive fabric because it may not adequately fill

space and trace-width for kiss cutting which results in wider conductive traces that require different space filling approaches. This invention improves on this approach with a more angular "space filling" approach to circuit design. It is possible to create space filling geometries that result in multi directional stretch (Figures 1 and 2).

This space filling approach can also be used to create cabling, antennas, or capacitive touch sensors within a soft, flexible circuit. It is also possible to combine functions (such as cabling and capacitive touch sensing) by designing an external electronic system to switch between the desired functions quickly. This approach is particualy useful for cost-savings and for improved mechanical features over multi-layer electronics.

Referring now to Figure 1, a circuitry trace (1) is provided with electrically cunductive lines (11) and regions (12) for a plurality of electrodes according to an embodiment of the present invention. The conductive line (11) is configured to form a pulse wave form, more particularly a rectangular pulse wave form having elongated lines (111) corresponding to pulse amplitude and extending in vertical direction (y) and shorter lines (112) corresponding to pulse length extending in horizontal direction (x). In this embodiment, the shorter lines (112) are substantially perpendicular to the elongated lines (111) and said elongated lines (111) are arranged in a row being substantially parallel to eachother so that a plurality of waves can be formed in a row extending in horizontal direction (x) in order to ensure stretchability in that direction (x). Each wave consists of two elongated lines (111) arranged substantially parallel to eachother and one shorter line (112) perpendicular to the neighbouring elongated lines (111). The elongated lines (111) are arranged to have a length much more than the shorter lines (112) (e.g. at least two fold), and width (w) of the conductive lines (11) ranges from 0.05" to 3" (1.27 mm to 76.20 mm).

Furthermore, at least one of the elongated lines (111) forming the waves in outermost edge of the circuitry trace (1) has a bending portion (20) whereby a horizontally elongated line (201) extending in horizantal direction (x) is connected with said elongated line (111). The horizontally elongated line (201) extends inwardly between the borderlines (A, A') forming the outermost edges of the circuitry trace (1). In other words, the horizontally elongated line (201) extends in the direction of the waves and in an area thereunder. Additionally, the length of the horizontally elongated line (201) is much more than the length of the shorter lines (112). The ratio of the length of the horizontally elongated line (201) to the length of the shorter lines (112) ranges from 1.5 to 50, more preferably from 2 to 20 and most preferably from 2 to 10. Horizontally elongated line (201) is preferably a straight line but it can also be a curved line terminating at an electrode (not shown). With the foregoing arrangement, stretchability in the vertical direction (y) is improved.

While the length of the shorter lines (112) are generally contemplated to be substantially equal throughout the circuitry trace (1), in the event that the length of the shorter lines (112) differ from eachother, above mentioned ratios are calculated based on the longest one of the shorter lines (112) forming the each wave. Likewise, elongated lines (111) extending in vertical direction (y), except the ones in outermost edges in borderlines (A, A'), are designed substantially to have equal length.

In another embodiment as shown in Figure 2, the circuitry trace (1) is provided on a polymeric planar carrier sheet (2) as in the previous embodiment. This embodiment also provides a plurality of electrode regions (12), and conductive lines (11) configured to form a pulse wave form, more particularly a rectangular pulse wave form having elongated lines (111) corresponding to pulse amplitude and extending in vertical direction (y) and shorter lines (112) corresponding to pulse length extending in horizontal direction (x).

In this embodiment, however, at least two rows of waves are arranged one under the other with a spacing therebetween wherein the horizontally elongated line (201) extending in horizantal direction (x) is discontinued and bended towards the vertical direction (y) to form a vertical line (113) and eventually to form a complete wave with another horizontally elongated line (201) which is either connected directly to an electrode or to the other wave row. There may be two waves side by side extending in horizontal direction (x) through the length of the wave rows as shown in Figure 2. In this embodiment, again the length of the horizontally elongated line (201) is more than the length of the shorter lines (112). The ratio of the length of the horizontally elongated line (201) to the length of the shorter lines (112) ranges from 1.5 to 50, more preferably from 2 to 20 and most preferably from 2 to 10. Horizontally elongated line (201) is preferably a straight line but it can also be a curved line. With the foregoing arrangement, a perfect stretchability both in the vertical direction (y) and horizontal direction (x) is ensured.

The flexible circuit and the method according to the present invention are perfectly convenient for the applications in wellness, such as therapeutic heating pads and beds, and automotive, such as upholstery work in vehicles including trims and steering wheel. The flexible circuit and the method according to the present invention are particularly suitable for medical products or vehicle parts that require wrapping with a textile or leather such as seats, steering wheels and door panels. The flexible circuit technique is also ideal for multi-function applications, such as combining heating and capapcitive touch sensing, because the functionality can be executed in a single layer, saving cost and improving mechanical properties.

CLAIMS

1. A flexible circuit having a planar circuitry sheet (2) and a circuitry trace (1), said circuitry trace (1) comprising conductive lines (11) and a number of electrode regions (12), wherein:

the circuitry trace (1) is designed to have a pulse wave shape having repeating waves and forming a row along a horizontal direction (x), said circuitry trace (1) comprising elongated lines (111) corresponding to pulse amplitude and extending in vertical direction (y) and shorter lines (112) corresponding to pulse length and extending in horizontal direction (x), whereby each of the waves consists of two elongated lines (111) arranged substantially parallel to eachother and one shorter line (112) substantially perpendicular to the neighbouring elongated lines (111),

characterized in that;

the elongated lines (111) forming the waves in outermost edge of the circuitry trace (1) have a bending portion (20), whereby a horizontally elongated line (201) extending in horizantal direction (x) is connected with said elongated line (111), and said horizontally elongated line (201) extends inwardly between the borderlines (A, A') forming the outermost edges of the circuitry trace (1), and whereby the length of the horizontally elongated line (201) is more than the shorter line (112) of the waves.

2. The flexible circuit according to claim 1 wherein the planar circuitry sheet (2) comprises conductive fabric or conductive textile.

3. The flexible circuit according to claim 1 wherein the circuitry trace (1) of the flexible circuit is formed by electroplating an electrically conductive material onto the planar circuitry sheet (2).

4. The flexible circuit according to claim 3 wherein the electrically conductive material comprises a metal selected from copper and nickel.

5. The flexible circuit according to claim 1 wherein the conductive lines (11) are configured to have a functionality of heating and/or capacitive touch sensing means.

6. The flexible circuit according to claim 1 or 5 wherein the flexible circuit further comprises auxiliary electronic components selected from terminations, wires, PCBs, switches and a control circuitry.

7. The flexible circuit according to claim 6 wherein the auxiliary electronic components further comprise illumination means controlled by the control circuitry for indication of functionality of heating and/or for illuminating the environment.

8. The flexible circuit according to claim 7 wherein the auxiliary electronic components comprise a control circuitry receiving electrical signals from capasitive sensing means and producing a control signal based on a threshold value of the electrical signals depending on a change of the magnetic field, for controlling power supply to the conductive lines (11).

9. The flexible circuit according to claim 1 wherein the cunductive lines (11) of the circuitry trace (1) are configured to form a rectangular pulse wave shape.

10. The flexible circuit according to claim 1 wherein the the ratio of the length of the horizontally elongated line (201) to the length of the shorter lines (112) ranges from 1.5 to 50.

11. The flexible circuit according to claim 10 wherein the the ratio of the length of the horizontally elongated line (201) to the length of the shorter lines (112) ranges from 2 to 10.

12. The flexible circuit according to claim 10 wherein at least two rows of waves are arranged one under the other with a spacing therebetween wherein the horizontally elongated line (201) extending in horizantal direction (x) is discontinued and bended towards the vertical direction (y) in said spacing to form a vertical line (113) and eventually to form a complete wave with another horizontally elongated line (201) which is either connected directly to an electrode or to the other wave row.

13. An electrically conductive laminated sheet comprising:

- a planar carrier sheet made of a polymeric film,
- a flexible circuit having a circuitry trace (1) as defined in claim 1 on top of the planar carrier sheet,
- auxiliary electronic components connected with the circuitry trace (1), and
- a top layer polymeric film laminated on the foregoing combination.

14. The electrically conductive laminated sheet according to claim 13 wherein the polymeric film used in the planar carrier sheet and the top layer are dielectric polymeric films.

15. The electrically conductive laminated sheet according to claim 14 wherein polymeric film is selected from the group consisting of polyethylene terephthalate (PET), polyimide (PI), polyetherimide (PEI), polyethylene naphthalate (PEN), polyoxymethylene (POM), polyamide (PA), polyphthalamide (PPA), polyether ether ketone (PEEK), thermoplastic olefins (TPO), silicone and polyurethane (PU).

16. The electrically conductive laminated sheet according to claim 15 wherein the polymeric film comprises thermoplastic polyurethane (TPU).

17. A method for producing an electrically conductive laminated sheet as defined in claim 13, comprising the steps of:

- providing a planar carrier sheet made of a polymeric film,
- printing a desired circuit pattern with adhesive onto the polymeric film by using a screen,
- sheeting of the flexible circuit comprising a planar circuitry sheet (2) and placing the same onto the polymeric film so that it overlays the surface of the film and lays on top of the screened adhesive,
- curing this combination to ensure bonding with the adhesive,
- cutting of the planar circuitry sheet (2) so that the material not bonded by the adhesive can be removed,
- placing auxiliary electronic components and connecting them with the circuitry trace (1) of the planar circuitry sheet (2), and
- providing a top layer polymeric film and laminating the same on the foregoing combination to obtain a stretchable product.

18. The method according to claim 17 wherein cutting of the planar circuitry sheet (2) is carried out by kiss cutting for removing the material not bonded by the adhesive.

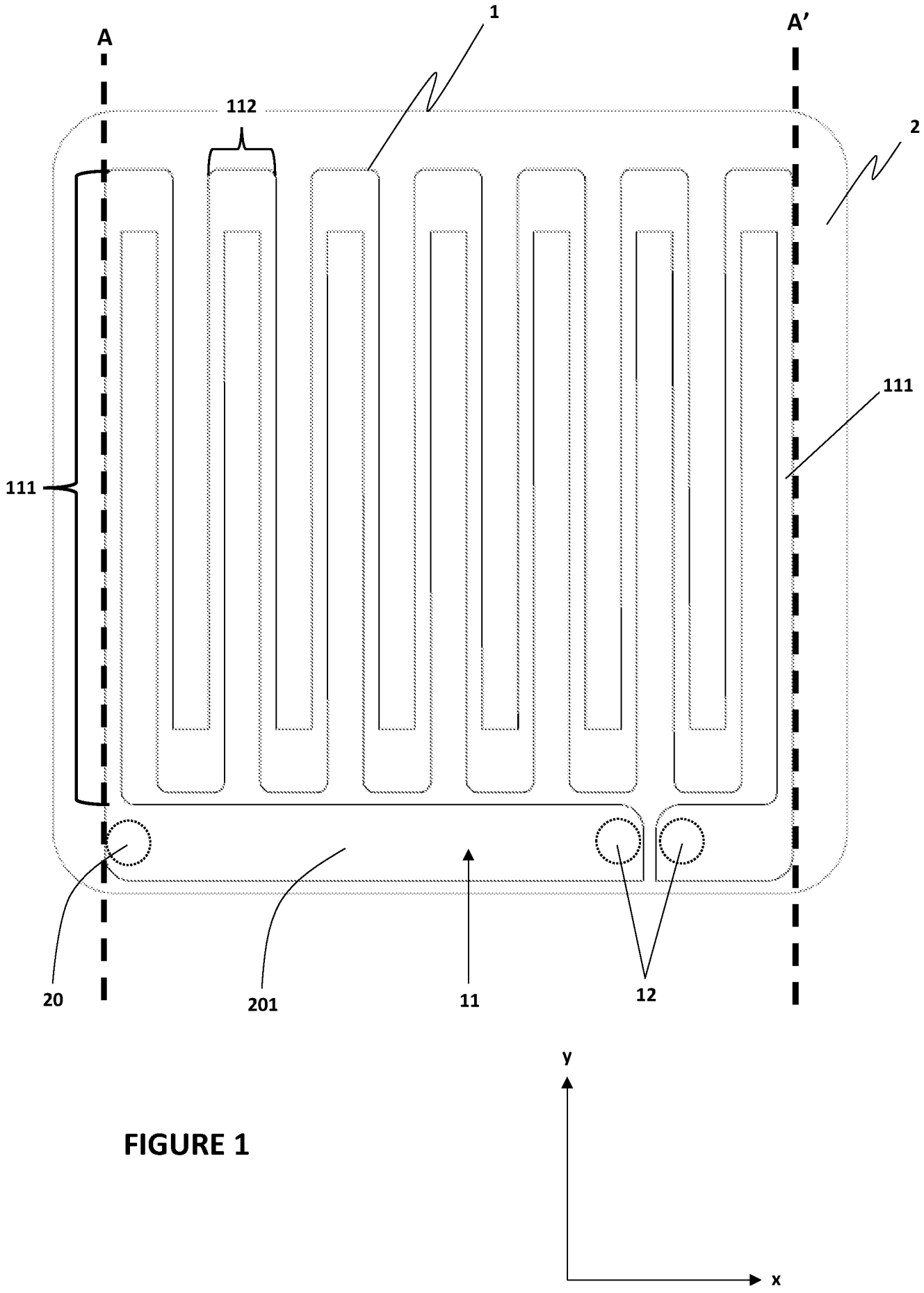


FIGURE 1

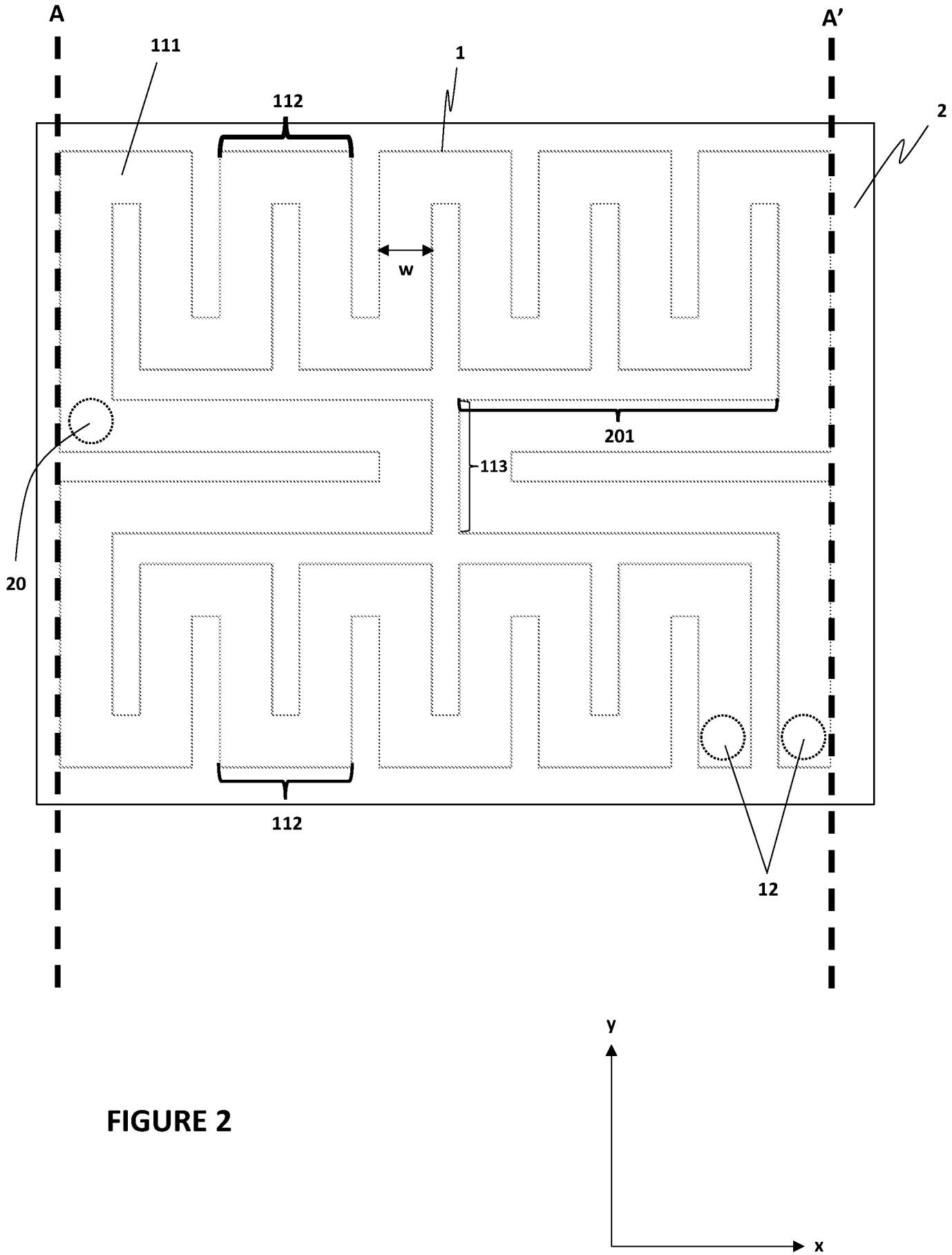


FIGURE 2

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US23/24840

A. CLASSIFICATION OF SUBJECT MATTER

IPC - INV. H05K 1/02; H03K 17/96; H05K 1/18; H05K 3/20 (2023.01)
ADD.
CPC - INV. H05K 1/0283; H03K 17/962; H05K 1/189; H05K 3/20
ADD. H03K 2217/960755

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)
See Search History document

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

Electronic database consulted during the international search (name of database and, where practicable, search terms used)
See Search History document

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	US 2021/0144858 A1 (LOOMIA TECHNOLOGIES INC.) 13 May 2021; abstract; figure 1; para [0005]-[0050]	1, 2, 5-12 --- 3, 4, 13-18
Y	US 2019/0297729 A1 (SECOND SIGHT MEDICAL PRODUCTS INC.) 26 September 2019; para [0089]	3, 4
Y	US 2022/0201850 A1 (PANASONIC INTELLECTUAL PROPERTY MANAGEMENT CO. LTD.) 23 June 2022; para [0005]-[0101]	13-18
Y	US 2021/0076485 A1 (CELLINK CORPORATION) 11 March 2021; para [0050]-[0059]	18

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
25 August 2023 (25.08.2023)	SEP 20 2023
Name and mailing address of the ISA/ Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-8300	Authorized officer Shane Thomas Telephone No. PCT Helpdesk: 571-272-4300