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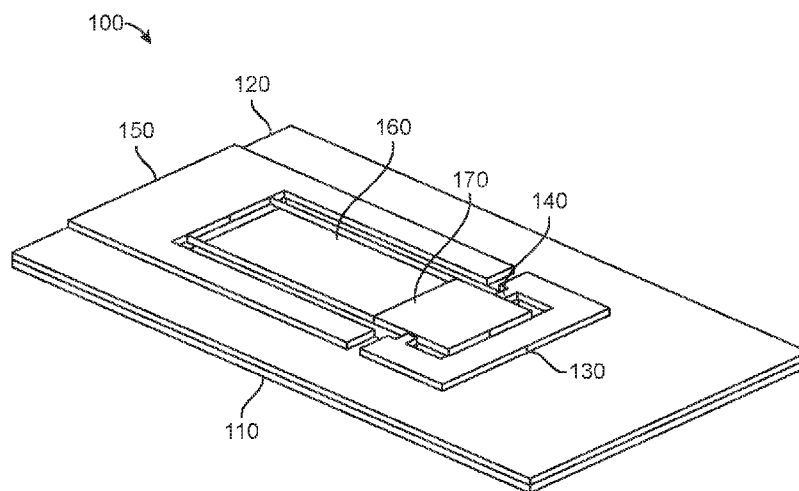


FIG. 1A

(57) Abstract: The problems of high costs and lack of flexibility in accelerometers is addressed by inexpensive flexible threshold accelerometer systems and methods for manufacturing them. The accelerometer systems are generally formed from a flexible substrate such as polyethylene terephthalate (PET). The accelerometers generally utilize a proof mass coupled to an electrical ground. The proof mass is generally separated from one or more contact points on an electrical output by some distance. When the accelerometer experiences an impulse, the proof mass moves toward a contact point in response to the impulse. If the impulse exceeds a threshold (the threshold acceleration to which the accelerometer is sensitive), the proof mass makes contact with the contact point, generating an electrical signal. The electrical signal is detected by a controller or an indicator, which registers an indication that the impulse exceeded the threshold acceleration. In this manner, harmful events can be quickly detected.

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FLEXIBLE ACCELEROMETER CONFIGURED TO DETECT THRESHOLD ACCELERATION**BACKGROUND OF THE INVENTION**

[0001] Numerous products (such as vehicles, smartphones, and laptop computers, among others) utilize conventional continuous accelerometers to detect harmful events such as sudden impacts or crashes. Typically, an onboard computer continuously logs the output of an accelerometer and makes decisions in real time based on this output. For example, in the event of a vehicle experiencing a high-speed, head-on crash, the vehicle's onboard accelerometer senses a high deceleration, triggering the vehicle's computer to activate an airbag system. Beyond these products and examples, many more applications would benefit from having an ability to sense acceleration. However, conventional continuous accelerometers are often not suitable for such applications due to their relatively high costs or their rigidity, which makes it difficult or impossible to attach them to non-planar surfaces. Accordingly, presented herein are inexpensive flexible threshold accelerometer systems and methods for manufacturing them.

BRIEF DESCRIPTION OF THE DRAWINGS

[0002] Various embodiments of the invention are disclosed in the following detailed description and the accompanying drawings.

[0003] FIG. 1A shows a schematic depicting an isometric view of a first exemplary flexible threshold accelerometer system.

[0004] FIG. 1B shows a schematic depicting a cross-sectional view of the first exemplary flexible threshold accelerometer system of FIG. 1A.

[0005] FIG. 2A shows a schematic depicting an isometric view of a second exemplary flexible threshold accelerometer system.

[0006] FIG. 2B shows a schematic depicting a cross-sectional view of the second exemplary flexible threshold accelerometer system of FIG. 2A.

[0007] FIG. 3 shows a flowchart for a first method for manufacturing the first exemplary flexible threshold accelerometer system of FIGs. 1A and 1B.

[0008] FIG. 4 shows a flowchart for a second method for manufacturing the second exemplary flexible threshold accelerometer system of FIGs. 2A and 2B.

[0009] FIG. 5 shows an exemplary Simulink equivalent mass-spring-damper model used to model the performance of the first exemplary flexible threshold accelerometer system described herein with respect to FIGs. 1A and 1B.

[0010] FIG. 6 shows the simulated performance of a flexible threshold accelerometer designed to respond to a 100 G impulse.

DETAILED DESCRIPTION

[0011] The invention can be implemented in numerous ways, including as a process; an apparatus; a system; a composition of matter; a computer program product embodied on a computer readable storage medium; and/or a processor, such as a processor configured to execute instructions stored on and/or provided by a memory coupled to the processor. In this specification, these implementations, or any other form that the invention may take, may be referred to as techniques. In general, the order of the steps of disclosed processes may be altered within the scope of the invention. Unless stated otherwise, a component such as a processor or a memory described as being configured to perform a task may be implemented as a general component that is temporarily configured to perform the task at a given time or a specific component that is manufactured to perform the task. As used herein, the term “processor” refers to one or more devices, circuits, and/or processing cores configured to process data, such as computer program instructions.

[0012] A detailed description of one or more embodiments of the invention is provided below along with accompanying Figures that illustrate the principles of the invention. The invention is described in connection with such embodiments, but the invention is not limited to any embodiment. The scope of the invention is limited only by the claims and the invention encompasses numerous alternatives, modifications and equivalents. Numerous specific details are set forth in the following description in order to provide a

thorough understanding of the invention. These details are provided for the purpose of example and the invention may be practiced according to the claims without some or all of these specific details. For the purpose of clarity, technical material that is known in the technical fields related to the invention has not been described in detail so that the invention is not unnecessarily obscured.

[0013] As used herein, the term “or” shall convey both disjunctive and conjunctive meanings. For instance, the phrase “A or B” shall be interpreted to include element A alone, element B alone, and the combination of elements A and B.

[0014] In the Figures (also “FIGs.”), like numbers shall refer to like elements.

[0015] Conventional accelerometers have been used to detect harmful events such as sudden impacts or crashes in vehicles, smartphones, and laptop computers, among other products. For continuous accelerometers, an onboard computer continuously logs the output of the accelerometer and makes decisions in real time based on this output (such as triggering an airbag system in response to a high deceleration). Threshold accelerometers generally obviate the need for continuous computer monitoring by outputting a signal only when an acceleration exceeding some threshold value occurs. Regardless of their operational principle (continuous or threshold), conventional accelerometers are typically fabricated using hard, non-flexible substrates such as silicon or glass. This limits their applicability to curved surfaces, such as a helmet of a soldier or sports player. Moreover, these prior accelerometers have typically been constructed using traditional silicon and/or glass microfabrication processes (such as metal deposition, lithography, and etching), making such prior accelerometers relatively expensive.

[0016] Accordingly, the problems of high costs and lack of flexibility in accelerometers is addressed by the inexpensive flexible threshold accelerometer systems and methods for manufacturing them presented herein. The accelerometer systems described herein are generally formed from a flexible substrate such as polyethylene terephthalate (PET). The accelerometers generally utilize a proof mass coupled to an electrical ground. The proof mass is generally separated from one or more contact points on an electrical output by some distance. When the accelerometer experiences an impulse, the proof mass moves toward a contact point in response to the impulse. If the impulse exceeds a threshold (the product of a threshold acceleration to which the accelerometer is sensitive and a threshold

duration of time), the proof mass makes contact with the contact point, generating an electrical signal. The electrical signal is detected by a controller or indicator, which registers an indication that the impulse exceeded the threshold acceleration. In this manner, harmful events can be quickly detected.

[0017] A flexible threshold accelerometer system is disclosed herein. The system generally comprises: a flexible substrate; a photolithographically patterned electrically insulating layer; a photolithographically patterned first electrically conducting region comprising at least one contact point; and a photolithographically patterned second electrically conducting region, at least one cantilever beam coupled to the second electrically conducting region, and a proof mass coupled to the at least one cantilever beam, the proof mass configured to move in response to an impulse, the proof mass separated from the at least one contact point by a distance. In some embodiments, the system further comprises a controller coupled to the first or second electrically conducting region and configured to output an electrical signal when the proof mass moves by at least the distance in response to the impulse and makes electrical contact with the at least one contact point, the electrical signal indicating that the impulse exceeds a threshold value. In some embodiments, the flexible substrate comprises a material selected from the group consisting of: polyethylene terephthalate (PET), polyimide, silicone, polydimethylsiloxane (PDMS), polymethyl methacrylate (PMMA), and any combination thereof. In some embodiments, the electrically insulating layer comprises a material selected from the group consisting of: SU-8 photoresist, PET, polyimide, silicone, PDMS, silicon dioxide, and any combination thereof. In some embodiments, the electrically insulating layer comprises at least one hole over which the proof mass or the at least one cantilever is located. In some embodiments, the at least one cantilever comprises one, two, three, or four cantilevers. In some embodiments, the first or second electrically conducting region comprises a material selected from the group consisting of: copper, aluminum, silver, gold, chrome, indium gallium zinc oxide, indium tin oxide, titanium, germanium, palladium, tin, tungsten, and any combination thereof. In some embodiments, the at least one contact point comprises a first contact point separated from a first face of the proof mass by the distance and a second contact point separated from a second face of the proof mass by the distance. In some embodiments, the threshold value is predetermined based on a combination of a size of the proof mass, the distance, and a material composition of the second electrically conducting region. In some embodiments, the first and second electrically conducting regions are located above the electrically insulating

layer. In some embodiments, the first and second electrically conducting regions are located in a single plane above the electrically insulating layer and the proof mass is configured to move laterally in the single plane in response to the impulse. In some embodiments, the first electrically conducting region is located in a first plane, the second electrically conducting region is located in a second plane, the second plane is different from the first plane, and the proof mass is configured to move between the first and second planes in response to the impulse. In some embodiments, the first plane is below the electrically insulating layer. In some embodiments, the second plane is above the electrically insulating layer. In some embodiments, the controller is configured to output the electrical signal at most 1 millisecond (ms) after the impulse. In some embodiments, the flexible substrate is applied on a surface of or an inside of a product selected from the group consisting of: a helmet, a sports helmet, a military helmet, a bumper of a vehicle, an item of luggage, a suitcase, a shipping container, a shipping box, a military munition, or any combination thereof.

[0018] A first method for manufacturing a flexible threshold accelerometer system is disclosed herein. The method generally comprises: depositing, photolithographically patterning, and etching an electrically insulating material on a flexible substrate to thereby obtain an electrically insulating layer; depositing, photolithographically patterning, and etching a first electrically conducting material to thereby obtain a first electrically conducting region comprising at least one contact point above the electrically insulating layer; and depositing, photolithographically patterning, and etching a second electrically conducting material above the electrically insulating layer to thereby obtain a second electrically conducting region, at least one cantilever beam coupled to the second electrically conducting region, and a proof mass coupled to the at least one cantilever beam, the proof mass separated from the at least one contact point by a distance. In some embodiments, the flexible substrate comprises a material selected from the group consisting of: PET, polyimide, silicone, PDMS, PMMA, and any combination thereof. In some embodiments, the electrically insulating layer comprises a material selected from the group consisting of: SU-8 photoresist, PET, polyimide, silicone, PDMS, silicon dioxide, and any combination thereof. In some embodiments, the electrically insulating layer comprises at least one hole over which the proof mass or the at least one cantilever is located. In some embodiments, the at least one cantilever comprises one, two, three, or four cantilevers. In some embodiments, the first or second electrically conducting region comprises a material selected from the group consisting of: copper, aluminum, silver, gold, chrome, indium gallium zinc oxide, indium tin oxide,

titanium, germanium, palladium, tin, tungsten, and any combination thereof. In some embodiments, the at least one contact point comprises a first contact point separated from a first face of the proof mass by the distance and a second contact point separated from a second face of the proof mass by the distance. In some embodiments, the first and second electrically conducting regions are located in a single plane above the electrically insulating layer and the proof mass is configured to move laterally in the single plane in response to the impulse.

[0019] A second method for manufacturing a flexible threshold accelerometer system is disclosed herein. The method generally comprises: depositing, photolithographically patterning, and etching a first electrically conducting material on a flexible substrate to thereby obtain a first electrically conducting region comprising at least one contact point; depositing, photolithographically patterning, and etching an electrically insulating material to thereby obtain an electrically insulating layer above the first electrically conducting region; depositing and photolithographically patterning a photoresist layer above at least a portion of the electrically insulating layer; depositing, photolithographically patterning, and etching a second electrically conducting material above the electrically insulating layer and the photoresist layer to thereby obtain a second electrically conducting region, at least one cantilever beam coupled to the second electrically conducting region, and a proof mass coupled to the at least one cantilever beam, the proof mass separated from the at least one contact point by a distance; and etching the photoresist layer to thereby permit the proof mass to move in response to an impulse. In some embodiments, the flexible substrate comprises a material selected from the group consisting of: PET, polyimide, silicone, PDMS, PMMA, and any combination thereof. In some embodiments, the electrically insulating layer comprises a material selected from the group consisting of: SU-8 photoresist, PET, polyimide, silicone, PDMS, silicon dioxide, and any combination thereof. In some embodiments, the at least one cantilever comprises one, two, three, or four cantilevers. In some embodiments, the first or second electrically conducting region comprises a material selected from the group consisting of: copper, aluminum, silver, gold, chrome, indium gallium zinc oxide, indium tin oxide, titanium, germanium, palladium, tin, tungsten, and any combination thereof. In some embodiments, the first electrically conducting region is located in a first plane, the second electrically conducting region is located in a second plane, the second plane is different from the first plane, and the proof mass is configured to move between the first and second planes in response to the impulse.

[0020] FIG. 1A shows a schematic depicting an isometric view of a first exemplary flexible threshold accelerometer system 100. In the example shown, the system 100 comprises a flexible substrate 110. In some embodiments, the flexible substrate is selected from the group consisting of: PET, polyimide, silicone, PDMS, PMMA, and any combination thereof.

[0021] In the example shown, the system 100 comprises an electrically insulating layer 120. In some embodiments, the electrically insulating layer 120 comprises a photolithographically patterned electrically insulating layer. In some embodiments, the electrically insulating layer 120 comprises a material selected from the group consisting of: SU-8 photoresist, PET, polyimide, silicone, PDMS, silicon dioxide, and any combination thereof. In some embodiments, the electrically insulating layer 120 comprises at least one hole. In some embodiments, the electrically insulating layer 120 has a thickness of at least about 1 micrometer (μm), 2 μm , 3 μm , 4 μm , 5 μm , 6 μm , 7 μm , 8 μm , 9 μm , 10 μm , 20 μm , 30 μm , 40 μm , 50 μm , 60 μm , 70 μm , 80 μm , 90 μm , 100 μm , or more, at most about 100 μm , 90 μm , 80 μm , 70 μm , 60 μm , 50 μm , 40 μm , 30 μm , 20 μm , 10 μm , 9 μm , 8 μm , 7 μm , 6 μm , 5 μm , 4 μm , 3 μm , 2 μm , 1 μm , or a thickness that is within a range defined by any two of the preceding values.

[0022] In the example shown, the system 100 comprises a first electrically conducting region 130. In some embodiments, the first electrically conducting region 130 comprises a photolithographically patterned electrically conducting region. In some embodiments, the first electrically conducting region 130 comprises a material selected from the group consisting of: copper, aluminum, silver, gold, chrome, indium gallium zinc oxide, indium tin oxide, titanium, germanium, palladium, tin, tungsten, and any combination thereof. In some embodiments, the first electrically conducting region 130 comprises at least one contact point 140. In some embodiments, the first electrically conducting region 130 is located above the electrically insulating layer 120. In some embodiments, the first electrically conducting region 130 has a thickness of at least about 1 μm , 2 μm , 3 μm , 4 μm , 5 μm , 6 μm , 7 μm , 8 μm , 9 μm , 10 μm , 20 μm , 30 μm , 40 μm , 50 μm , 60 μm , 70 μm , 80 μm , 90 μm , 100 μm , or more, at most about 100 μm , 90 μm , 80 μm , 70 μm , 60 μm , 50 μm , 40 μm , 30 μm , 20 μm , 10 μm , 9 μm , 8 μm , 7 μm , 6 μm , 5 μm , 4 μm , 3 μm , 2 μm , 1 μm , or a thickness that is within a range defined by any two of the preceding values. In some embodiments, the first electrically conducting region 130 is configured as an electrical anode of the system 100. In some

embodiments, the first electrically conducting region 130 is configured as an electrical cathode of the system 100. In some embodiments, the first electrically conducting region 130 is configured as an electrical ground of the system 100.

[0023] In the example shown, the system 100 comprises a second electrically conducting region 150. In some embodiments, the second electrically conducting region 150 comprises a photolithographically patterned electrically conducting region. In some embodiments, the second electrically conducting region 150 comprises a material selected from the group consisting of: copper, aluminum, silver, gold, chrome, indium gallium zinc oxide, indium tin oxide, titanium, germanium, palladium, tin, tungsten, and any combination thereof. In some embodiments, the second electrically conducting region 140 is located above the electrically insulating layer 120. In some embodiments, the second electrically conducting region 150 has a thickness of at least about 1 μm , 2 μm , 3 μm , 4 μm , 5 μm , 6 μm , 7 μm , 8 μm , 9 μm , 10 μm , 20 μm , 30 μm , 40 μm , 50 μm , 60 μm , 70 μm , 80 μm , 90 μm , 100 μm , or more, at most about 100 μm , 90 μm , 80 μm , 70 μm , 60 μm , 50 μm , 40 μm , 30 μm , 20 μm , 10 μm , 9 μm , 8 μm , 7 μm , 6 μm , 5 μm , 4 μm , 3 μm , 2 μm , 1 μm , or a thickness that is within a range defined by any two of the preceding values. In some embodiments, the second electrically conducting region 150 is configured as an electrical anode of the system 100. In some embodiments, the second electrically conducting region 150 is configured as an electrical cathode of the system 100. In some embodiments, the second electrically conducting region 150 is configured as an electrical ground of the system 100.

[0024] In the example shown, the system 100 comprises at least one cantilever beam 160. In some embodiments, the at least one cantilever beam is coupled to the second electrically conducting region 150. For example, in some embodiments, the at least one cantilever beam 160 is mechanically coupled to the second electrically conducting region 150. In some embodiments, the at least one cantilever beam 160 is electrically coupled to the second electrically conducting region 150. In some embodiments, the at least one cantilever beam 160 is electrically conducting. In some embodiments, the at least one cantilever beam 160 comprises a material selected from the group consisting of: copper, aluminum, silver, gold, chrome, indium gallium zinc oxide, indium tin oxide, titanium, germanium, palladium, tin, tungsten, and any combination thereof. In some embodiments, the at least one cantilever beam 160 is electrically insulating. In some embodiments, the at least one cantilever beam 160 comprises a material selected from the group consisting of: SU-8 photoresist, PET,

polyimide, silicone, PDMS, silicon dioxide, and any combination thereof. In some embodiments, the at least one cantilever beam 160 has a length of at least about 100 μm , 200 μm , 300 μm , 400 μm , 500 μm , 600 μm , 700 μm , 800 μm , 900 μm , 1,000 μm , 2,000 μm , 3,000 μm , 4,000 μm , 5,000 μm , or more, at most about 5,000 μm , 4,000 μm , 3,000 μm , 2,000 μm , 1,000 μm , 900 μm , 800 μm , 700 μm , 600 μm , 500 μm , 400 μm , 300 μm , 200 μm , 100 μm , or less, or a length that is within a range defined by any two of the preceding values. In some embodiments, the at least one cantilever beam 160 has a width of at least about 1 μm , 2 μm , 3 μm , 4 μm , 6 μm , 7 μm , 8 μm , 9 μm , 10 μm , 20 μm , 30 μm , 40 μm , 50 μm , 60 μm , 70 μm , 80 μm , 90 μm , 100 μm , or more, at most about 100 μm , 90 μm , 80 μm , 70 μm , 60 μm , 50 μm , 40 μm , 30 μm , 20 μm , 10 μm , 9 μm , 8 μm , 7 μm , 6 μm , 5 μm , 4 μm , 3 μm , 2 μm , 1 μm , or less, or a width that is within a range defined by any two of the preceding values. In some embodiments, the at least one cantilever beam 160 has a thickness of at least about 1 μm , 2 μm , 3 μm , 4 μm , 5 μm , 6 μm , 7 μm , 8 μm , 9 μm , 10 μm , 20 μm , 30 μm , 40 μm , 50 μm , 60 μm , 70 μm , 80 μm , 90 μm , 100 μm , or more, at most about 100 μm , 90 μm , 80 μm , 70 μm , 60 μm , 50 μm , 40 μm , 30 μm , 20 μm , 10 μm , 9 μm , 8 μm , 7 μm , 6 μm , 5 μm , 4 μm , 3 μm , 2 μm , 1 μm , or a thickness that is within a range defined by any two of the preceding values.

Although depicted as comprising two cantilever beams 160 in FIG. 1A, in some embodiments, the system 100 comprises at least about 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, or more cantilever beams, at most about 10, 9, 8, 7, 6, 5, 4, 3, 2, or 1 cantilever beams, or a number of cantilever beams that is within a range defined by any two of the preceding values. In some embodiments, the at least one cantilever beam 160 is located over or above the hole.

[0025] In the example shown, the system 100 comprises a proof mass 170 coupled to the at least one cantilever beam 160. For example, in some embodiments, the proof mass 170 is mechanically coupled to the at least one cantilever beam 160. In some embodiments, the proof mass 170 is electrically coupled to the at least one cantilever beam 160. In some embodiments, the proof mass 170 is electrically conducting. In some embodiments, the proof mass 170 comprises a material selected from the group consisting of: copper, aluminum, silver, gold, chrome, indium gallium zinc oxide, indium tin oxide, titanium, germanium, palladium, tin, tungsten, and any combination thereof. In some embodiments, the proof mass 170 is configured to move in response to an impulse. In some embodiments, the proof mass 170 is separated from the at least one contact point 140 by a distance. In some embodiments, the distance is at least about 1 μm , 2 μm , 3 μm , 4 μm , 5 μm , 6 μm , 7 μm , 8 μm , 9 μm , 10 μm , 20 μm , 30 μm , 40 μm , 50 μm , 60 μm , 70 μm , 80 μm , 90 μm , 100 μm , or more, at most about

100 μm , 90 μm , 80 μm , 70 μm , 60 μm , 50 μm , 40 μm , 30 μm , 20 μm , 10 μm , 9 μm , 8 μm , 7 μm , 6 μm , 5 μm , 4 μm , 3 μm , 2 μm , 1 μm , or less, or a distance that is within a range defined by any two of the preceding values. In some embodiments, the proof mass 170 has a maximum length of at least about 100 μm , 200 μm , 300 μm , 400 μm , 500 μm , 600 μm , 700 μm , 800 μm , 900 μm , 1,000 μm , 2,000 μm , 3,000 μm , 4,000 μm , 5,000 μm , or more, at most about 5,000 μm , 4,000 μm , 3,000 μm , 2,000 μm , 1,000 μm , 900 μm , 800 μm , 700 μm , 600 μm , 500 μm , 400 μm , 300 μm , 200 μm , 100 μm , or less, or a length that is within a range defined by any two of the preceding values. In some embodiments, the proof mass 170 has a maximum width of at least about 1 μm , 2 μm , 3 μm , 4 μm , 6 μm , 7 μm , 8 μm , 9 μm , 10 μm , 20 μm , 30 μm , 40 μm , 50 μm , 60 μm , 70 μm , 80 μm , 90 μm , 100 μm , or more, at most about 100 μm , 90 μm , 80 μm , 70 μm , 60 μm , 50 μm , 40 μm , 30 μm , 20 μm , 10 μm , 9 μm , 8 μm , 7 μm , 6 μm , 5 μm , 4 μm , 3 μm , 2 μm , 1 μm , or less, or a width that is within a range defined by any two of the preceding values. In some embodiments, the proof mass 170 has a thickness of at least about 1 μm , 2 μm , 3 μm , 4 μm , 5 μm , 6 μm , 7 μm , 8 μm , 9 μm , 10 μm , 20 μm , 30 μm , 40 μm , 50 μm , 60 μm , 70 μm , 80 μm , 90 μm , 100 μm , or more, at most about 100 μm , 90 μm , 80 μm , 70 μm , 60 μm , 50 μm , 40 μm , 30 μm , 20 μm , 10 μm , 9 μm , 8 μm , 7 μm , 6 μm , 5 μm , 4 μm , 3 μm , 2 μm , 1 μm , or a thickness that is within a range defined by any two of the preceding values. In some embodiments, the proof mass 170 is located over or above the hole.

[0026] In the example shown, the at least one contact point 140 comprises a first contact point separated from a first face of the proof mass 170 by the distance and a second contact point separated from a second face of the proof mass 170 by the distance. However, other configurations are possible. For instance, in some embodiments, the first electrically conducting region comprises at least about 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, or more contact points, at most about 10, 9, 8, 7, 6, 5, 4, 3, 2, or 1 contact points, or a number of contact points that is within a range defined by any two of the preceding values.

[0027] In some embodiments, the system 100 comprises a controller (not shown in FIG. 1A) coupled to the first electrically conducting region 130 or the second electrically conducting region 150. In some embodiments, the controller is electrically coupled to the first electrically conducting region 130 or the second electrically conducting region 150. In some embodiments the controller is configured to output an electrical signal when the proof mass 170 moves by at least the distance in response to the impulse. In some embodiments, when

the proof mass 170 moves by the distance, the proof mass 170 makes electrical contact with the at least one contact point 140, thereby completing an electrical circuit and generating the electrical signal. In some embodiments, the electrical signal indicates that the impulse exceeds a threshold value. Thus, in some embodiments, generation of the electrical signal indicates that the system 100 has experienced an impulse exceeding the threshold value, while failure to generate the electrical signal indicates that the system 100 has not experienced such an impulse. Thus, the system 100 functions as a threshold accelerometer. In some embodiments, the threshold value is predetermined based on a combination of a size (such as a length, width, or thickness) of the proof mass 170, the distance, and a material composition of the second electrically conducting region 150. In some embodiments, the controller is configured to output the electrical signal at least about 0.1 milliseconds (ms), 0.2 ms, 0.3 ms, 0.4 ms, 0.5 ms, 0.6 ms, 0.7 ms, 0.8 ms, 0.9 ms, 1 ms, 2 ms, 3 ms, 4 ms, 5 ms, 6 ms, 7 ms, 8 ms, 9 ms, 10 ms, or more after the impulse, at most about 10 ms, 9 ms, 8 ms, 7 ms, 6 ms, 5 ms, 4 ms, 3 ms, 2 ms, 1 ms, 0.9 ms, 0.8 ms, 0.7 ms, 0.6 ms, 0.5 ms, 0.4 ms, 0.3 ms, 0.2 ms, 0.1 ms, or less after the impulse, or an amount of time after the impulse that is within a range defined by any two of the preceding values.

[0028] In some embodiments, the controller is replaced or supplemented by a simple indicator that produces an audible, visual, or tactile signal when the impulse exceeds the threshold value. For example, in some embodiments, the system 100 comprises a sound source or a light source configured to output the audible or visual signal when the impulse exceeds the threshold value.

[0029] FIG. 1B shows a schematic depicting a cross-sectional view of the first exemplary flexible threshold accelerometer system 100 of FIG. 1A. In the example shown, the first electrically conducting region 130 and the second electrically conducting region 150 are located in a single plane above the electrically insulating layer 120. In the example shown, the proof mass 170 is configured to move laterally toward the at least one contact point 140 in response to the impulse.

[0030] FIG. 2A shows a schematic depicting an isometric view of a second exemplary flexible threshold accelerometer system 200. Similar to the first second exemplary flexible threshold accelerometer system 100 of FIGs. 1A and 1B, the second exemplary flexible threshold accelerometer system 200 comprises a flexible substrate 110, a photolithographically patterned electrically insulating layer 120, a photolithographically

patterned first electrically conducting region 130 comprising at least one contact point 140, a photolithographically patterned second electrically conducting region 150, at least one cantilever beam 160 coupled to the second electrically conducting region 150, and a proof mass 170 coupled to the at least one cantilever beam 160, as described herein with respect to FIGs. 1A and 1B. In some embodiments, the system 200 further comprises the controller described herein with respect to FIGs. 1A and 1B.

[0031] FIG. 2B shows a schematic depicting a cross-sectional view of the second exemplary flexible threshold accelerometer system 200 of FIG. 2A. In comparison with the system 100 of FIGs. 1A and 1B, the system 200 of FIGs. 2A and 2B is configured such that the first electrically conducting region 130 is located in a first plane and the second electrically conducting region 150 is located in a second plane. In some embodiments, the second plane is different from the first plane. In some embodiments, the proof mass 170 is configured to move between the first and second planes in response to the impulse. In some embodiments, the first plane is above the second plane. In some embodiments, the first plane is below the second plane. In some embodiments, the first plane is above the electrically insulating layer 120. In some embodiments, the first plane is below the electrically insulating layer 120. In some embodiments, the second plane is above the electrically insulating layer 120. In some embodiments, the second plane is below the electrically insulating layer 120.

[0032] In some embodiments, the flexible substrate 110 (of FIGs. 1A and 1B, or of FIGs. 2A and 2B) is configured to be applied on a surface of or an inside of a product. In some embodiments, the product is selected from the group consisting of: a helmet, a sports helmet, a military helmet, a bumper of a vehicle, an item of luggage, a suitcase, a shipping container, a shipping box, a military munition, or any combination thereof. In this manner, the system 100 of FIGs. 1A and 1B (or the system 200 of FIGs. 2A and 2B) can be used to determine whether the product has experienced a problematic impulse. For instance, if a sports helmet is subjected to an impulse of at least 80 G, this may indicate a strong likelihood that a sports player wearing the sports helmet is likely to sustain a concussion.

[0033] The arrangement of the electrically insulating layer, first electrically conductive region, second electrically conducting region, cantilever beam, and proof mass depicted in FIGs. 1A, 1B, 2A, and 2B is illustrative only. One having skill in the art will recognize that other arrangements are possible and within the scope of this disclosure.

[0034] FIG. 3 shows a flowchart for a first method 300 for manufacturing the first exemplary flexible threshold accelerometer system 100 of FIGs. 1A and 1B. At 310, an electrically insulating layer is deposited on a flexible substrate, photolithographically patterned, and etched to thereby obtain an electrically insulating layer. In some embodiments, the flexible substrate comprises any flexible substrate described herein with respect to FIGs. 1A and 1B. In some embodiments, the electrically insulating layer comprises any electrically insulating layer described herein with respect to FIGs. 1A and 1B.

[0035] At 320, a first electrically conducting material is deposited above the electrically insulating layer, photolithographically patterned, and etched to thereby obtain a first electrically conducting region comprising at least one contact point. In some embodiments, the first electrically conducting material comprises any electrically conducting material described herein with respect to FIGs. 1A and 1B. In some embodiments, the first electrically conducting region comprises any first electrically conducting region described herein with respect to FIGs. 1A and 1B. In some embodiments, the at least one contact point comprises any contact point described herein with respect to FIGs. 1A and 1B.

[0036] At 330, a second electrically conducting material is deposited above the electrically insulating layer, photolithographically patterned, and etched to thereby obtain a second electrically conducting region, at least one cantilever beam coupled to the second electrically conducting region, and a proof mass coupled to the at least one cantilever beam. In some embodiments, the second electrically conducting material comprises any electrically conducting material described herein with respect to FIGs. 1A and 1B. In some embodiments, the second electrically conducting region comprises any second electrically conducting region described herein with respect to FIGs. 1A and 1B. In some embodiments, the at least one cantilever beam comprises any at least one cantilever beam described herein with respect to FIGs. 1A and 1B. In some embodiments, the proof mass comprise any proof mass described herein with respect to FIGs. 1A and 1B. In some embodiments, the proof mass is separated from the at least one contact point by a distance. In some embodiments, the distance is any distance described herein with respect to FIGs. 1A and 1B.

[0037] In some embodiments, the first and second electrically conducting regions are located in a single plane above the electrically insulating layer. In some embodiments, the proof mass is configured to move laterally in the single plane in response to the impulse.

[0038] FIG. 4 shows a flowchart for a method 400 for manufacturing the second exemplary flexible threshold accelerometer system 200 of FIGs. 2A and 2B. At 410, a first electrically conducting material is deposited on a flexible substrate, photolithographically patterned, and etched to thereby obtain a first electrically conducting region comprising at least one contact point. In some embodiments, the flexible substrate comprises any flexible substrate described herein with respect to FIGs. 2A and 2B. In some embodiments, the first electrically conducting material comprises any electrically conducting material described herein with respect to FIGs. 2A and 2B. In some embodiments, the first electrically conducting region comprises any first electrically conducting region described herein with respect to FIGs. 2A and 2B. In some embodiments, the at least one contact point comprises any at least one contact point described herein with respect to FIGs. 2A and 2B.

[0039] At 420, an electrically insulating material is deposited, photolithographically patterned, and etched to thereby obtain an electrically insulating layer above the first electrically conducting region. In some embodiments, the electrically insulating material comprises any electrically insulating material described herein with respect to FIGs. 2A and 2B. In some embodiments, the electrically insulating layer comprises any electrically insulating layer described herein with respect to FIGs. 2A and 2B.

[0040] At 430, a photoresist layer is deposited above at least a portion of the electrically insulating layer and photolithographically patterned.

[0041] At 440, a second electrically conducting material is deposited above the electrically insulating layer and the photoresist layer, photolithographically patterned, and etched to thereby obtain a second electrically conducting region, at least one cantilever beam coupled to the second electrically conducting region, and a proof mass coupled to the at least one cantilever beam. In some embodiments, the second electrically conducting material comprises any electrically conducting material described herein with respect to FIGs. 2A and 2B. In some embodiments, the second electrically conducting region comprises any second electrically conducting region described herein with respect to FIGs. 2A and 2B. In some embodiments, the at least one cantilever beam comprises any at least one cantilever beam described herein with respect to FIGs. 2A and 2B. In some embodiments, the proof mass comprises any proof mass described herein with respect to FIGs. 2A and 2B. In some embodiments, the proof mass is separated from the at least one contact point by a distance. In some embodiments, the distance comprises any distance described herein with respect to

FIGs. 2A and 2B.

[0042] At 450, the photoresist layer is etched to thereby permit the proof mass to move in response to an impulse.

[0043] In some embodiments, the first electrically conducting region is located in a first plane. In some embodiments, the second electrically conducting region is located in a second plane. In some embodiments, the second plane is different from the first plane. In some embodiments, the proof mass is configured to move between the first and second planes in response to the impulse.

EXAMPLES

Example 1: Flexible Threshold Accelerometer Simulations

[0044] The behavior of the first exemplary flexible threshold accelerometer system described herein with respect to FIGs. 1A and 1B was simulated using finite elements analysis (FEA) using the MATLAB and Simulink software packages. FIG. 5 shows an exemplary Simulink equivalent mass-spring-damper model used to model the performance of the first exemplary flexible threshold accelerometer system described herein with respect to FIGs. 1A and 1B. In the model, critical damping was assumed. The model utilized a millimeter-order scaling. Thus, all results provided below are scaled by a factor of 1:1000 to provide simulated results for threshold accelerometers utilizing components having characteristic lengths on the micrometer scale. The first exemplary flexible threshold accelerometer was tuned to different threshold values by altering the distance between the proof mass and the at least one contact point.

[0045] FIG. 6 shows the simulated performance of a flexible threshold accelerometer designed to respond to a 100 G impulse. As shown in the top panel, an impulse of 100 G (980 meters/second²) was imparted to the flexible threshold accelerometer for a period of 4 milliseconds (ms). A distance of 6 millimeters (6 μ m for a flexible threshold accelerometer having characteristic lengths on the micrometer scale) was assumed. As shown in the bottom panel, a period of 0.575 ms was required for the proof mass to make contact with the at least one contact. Such a response time is comparable to impact sensors currently used in motor

vehicle, which can sense 100 G impulses within a few milliseconds.

[0046] Similar modeling studies were conducted for flexible threshold accelerometers designed to respond to 1.5 G, 10 G, and 50 G impulses. Table 1 shows the geometries of the components utilized in 1.5 G, 10 G, 50 G, and 100 G designs.

Table 1: Geometries of components utilized in 1.5 G, 10 G, 50 G, and 100 G flexible threshold accelerometer systems

Threshold	Parameter	Value (μm)
1.5 G	Cantilever length	1,731
	Cantilever width	6
	Cantilever thickness	20
	Proof mass length	420
	Proof mass width	1,000
	Proof mass thickness	20
10 G	Cantilever length	991
	Cantilever width	6
	Cantilever thickness	20
	Proof mass length	420
	Proof mass width	800
	Proof mass thickness	20
50 G	Cantilever length	719
	Cantilever width	6

	Cantilever thickness	20
	Proof mass length	420
	Proof mass width	420
	Proof mass thickness	20
100 G	Cantilever length	719
	Cantilever width	6
	Cantilever thickness	20
	Proof mass length	290
	Proof mass width	305
	Proof mass thickness	20

RECITATION OF EMBODIMENTS

[0047] Embodiment 1. A flexible threshold accelerometer system, comprising:
a flexible substrate;
a photolithographically patterned electrically insulating layer;
a photolithographically patterned first electrically conducting region
comprising at least one contact point; and
a photolithographically patterned second electrically conducting region, at
least one cantilever beam coupled to the second electrically conducting region, and a
proof mass coupled to the at least one cantilever beam, the proof mass configured to
move in response to an impulse, the proof mass separated from the at least one contact
point by a distance.

[0048] Embodiment 2. The system of Embodiment 1, further comprising a controller
coupled to the first or second electrically conducting region and configured to output an
electrical signal when the proof mass moves by at least the distance in response to the

impulse and makes electrical contact with the at least one contact point, the electrical signal indicating that the impulse exceeds a threshold value.

[0049] Embodiment 3. The system of Embodiment 1 or 2, wherein the flexible substrate comprises a material selected from the group consisting of: polyethylene terephthalate (PET), polyimide, silicone, polydimethylsiloxane (PDMS), polymethyl methacrylate (PMMA), and any combination thereof.

[0050] Embodiment 4. The system of any one of Embodiments 1-3, wherein the electrically insulating layer comprises a material selected from the group consisting of: SU-8 photoresist, PET, polyimide, silicone, PDMS, silicon dioxide, and any combination thereof.

[0051] Embodiment 5. The system of any one of Embodiments 1-4, wherein the electrically insulating layer comprises at least one hole over which the proof mass or the at least one cantilever is located.

[0052] Embodiment 6. The system of any one of Embodiments 1-5, wherein the at least one cantilever comprises one, two, three, or four cantilevers.

[0053] Embodiment 7. The system of any one of Embodiments 1-6, wherein the first or second electrically conducting region comprises a material selected from the group consisting of: copper, aluminum, silver, gold, chrome, indium gallium zinc oxide, indium tin oxide, titanium, germanium, palladium, tin, tungsten, and any combination thereof.

[0054] Embodiment 8. The system of any one of Embodiments 1-7, wherein the at least one contact point comprises a first contact point separated from a first face of the proof mass by the distance and a second contact point separated from a second face of the proof mass by the distance.

[0055] Embodiment 9. The system of any one of Embodiments 2-8, wherein the threshold value is predetermined based on a combination of a size of the proof mass, the distance, and a material composition of the second electrically conducting region.

[0056] Embodiment 10. The system of any one of Embodiments 1-9, wherein the first and second electrically conducting regions are located above the electrically insulating layer.

[0057] Embodiment 11. The system of Embodiment 10, wherein the first and second electrically conducting regions are located in a single plane above the electrically insulating layer and wherein the proof mass is configured to move laterally in the single plane in response to the impulse.

[0058] Embodiment 12. The system of any one of Embodiments 1-9, wherein the first electrically conducting region is located in a first plane, wherein the second electrically conducting region is located in a second plane, wherein the second plane is different from the

first plane, and wherein the proof mass is configured to move between the first and second planes in response to the impulse.

[0059] Embodiment 13. The system of Embodiment 12, wherein the first plane is below the electrically insulating layer.

[0060] Embodiment 14. The system of Embodiment 12 or 13, wherein the second plane is above the electrically insulating layer.

[0061] Embodiment 15. The system of any one of Embodiments 2-14, wherein the controller is configured to output the electrical signal at most 1 millisecond (ms) after the impulse.

[0062] Embodiment 16. The system of any one of Embodiments 1-15, wherein the flexible substrate is applied on a surface of or an inside of a product selected from the group consisting of: a helmet, a sports helmet, a military helmet, a bumper of a vehicle, an item of luggage, a suitcase, a shipping container, a shipping box, a military munition, or any combination thereof.

[0063] Embodiment 17. A method for manufacturing a flexible threshold accelerometer system, comprising:

depositing, photolithographically patterning, and etching an electrically insulating material on a flexible substrate to thereby obtain an electrically insulating layer;

depositing, photolithographically patterning, and etching a first electrically conducting material to thereby obtain a first electrically conducting region comprising at least one contact point above the electrically insulating layer; and

depositing, photolithographically patterning, and etching a second electrically conducting material above the electrically insulating layer to thereby obtain a second electrically conducting region, at least one cantilever beam coupled to the second electrically conducting region, and a proof mass coupled to the at least one cantilever beam, the proof mass separated from the at least one contact point by a distance.

[0064] Embodiment 18. The method of Embodiment 17, wherein the flexible substrate comprises a material selected from the group consisting of: PET, polyimide, silicone, PDMS, and any combination thereof.

[0065] Embodiment 19. The method of Embodiment 17 or 18, wherein the electrically insulating layer comprises a material selected from the group consisting of: SU-8 photoresist, PET, polyimide, silicone, PDMS, silicon dioxide, and any combination thereof.

[0066] Embodiment 20. The method of any one of Embodiments 17-19, wherein the electrically insulating layer comprises at least one hole over which the proof mass or the at least one cantilever is located.

[0067] Embodiment 21. The method of any one of Embodiments 17-20, wherein the at least one cantilever comprises one, two, three, or four cantilevers.

[0068] Embodiment 22. The method of any one of Embodiments 17-21, wherein the first or second electrically conducting region comprises a material selected from the group consisting of: copper, aluminum, silver, gold, chrome, indium gallium zinc oxide, indium tin oxide, titanium, germanium, palladium, tin, tungsten, and any combination thereof.

[0069] Embodiment 23. The method of any one of Embodiments 17-22, wherein the at least one contact point comprises a first contact point separated from a first face of the proof mass by the distance and a second contact point separated from a second face of the proof mass by the distance.

[0070] Embodiment 24. The method of any one of Embodiments 17-23, wherein the first and second electrically conducting regions are located in a single plane above the electrically insulating layer and wherein the proof mass is configured to move laterally in the single plane in response to the impulse.

[0071] Embodiment 25. A method for manufacturing a flexible threshold accelerometer system, comprising:

depositing, photolithographically patterning, and etching a first electrically conducting material on a flexible substrate to thereby obtain a first electrically conducting region comprising at least one contact point;

depositing, photolithographically patterning, and etching an electrically insulating material to thereby obtain an electrically insulating layer above the first electrically conducting region;

depositing and photolithographically patterning a photoresist layer above at least a portion of the electrically insulating layer;

depositing, photolithographically patterning, and etching a second electrically conducting material above the electrically insulating layer and the photoresist layer to thereby obtain a second electrically conducting region, at least one cantilever beam coupled to the second electrically conducting region, and a proof mass coupled to the at least one cantilever beam, the proof mass separated from the at least one contact point by a distance; and

etching the photoresist layer to thereby permit the proof mass to move in response to an impulse.

[0072] Embodiment 26. The method of Embodiment 25, wherein the flexible substrate comprises a material selected from the group consisting of: PET, polyimide, silicone, PDMS, PMMA, and any combination thereof.

[0073] Embodiment 27. The method of Embodiment 25 or 26, wherein the electrically insulating layer comprises a material selected from the group consisting of: SU-8 photoresist, PET, polyimide, silicone, PDMS, silicon dioxide, and any combination thereof.

[0074] Embodiment 28. The method of any one of Embodiments 25-27, wherein the at least one cantilever comprises one, two, three, or four cantilevers.

[0075] Embodiment 29. The method of any one of Embodiments 25-28, wherein the first or second electrically conducting region comprises a material selected from the group consisting of: copper, aluminum, silver, gold, chrome, indium gallium zinc oxide, indium tin oxide, titanium, germanium, palladium, tin, tungsten, and any combination thereof.

[0076] Embodiment 30. The method of any one of Embodiments 25-29, wherein the first electrically conducting region is located in a first plane, wherein the second electrically conducting region is located in a second plane, wherein the second plane is different from the first plane, and wherein the proof mass is configured to move between the first and second planes in response to the impulse.

CLAIMS

1. A flexible threshold accelerometer system, comprising:
 - a flexible substrate;
 - a photolithographically patterned electrically insulating layer;
 - a photolithographically patterned first electrically conducting region comprising at least one contact point; and
 - a photolithographically patterned second electrically conducting region, at least one cantilever beam coupled to the second electrically conducting region, and a proof mass coupled to the at least one cantilever beam, the proof mass configured to move in response to an impulse, the proof mass separated from the at least one contact point by a distance.
2. The system of claim 1, further comprising a controller coupled to the first or second electrically conducting region and configured to output an electrical signal when the proof mass moves by at least the distance in response to the impulse and makes electrical contact with the at least one contact point, the electrical signal indicating that the impulse exceeds a threshold value.
3. The system of claim 1, wherein the flexible substrate comprises a material selected from the group consisting of: polyethylene terephthalate (PET), polyimide, silicone, polydimethylsiloxane (PDMS), polymethyl methacrylate (PMMA), and any combination thereof.
4. The system of claim 1, wherein the electrically insulating layer comprises a material selected from the group consisting of: SU-8 photoresist, PET, polyimide, silicone, PDMS, silicon dioxide, and any combination thereof.
5. The system of claim 1, wherein the electrically insulating layer comprises at least one hole over which the proof mass or the at least one cantilever is located.
6. The system of claim 1, wherein the at least one cantilever comprises one, two, three, or four cantilevers.

7. The system of claim 1, wherein the first or second electrically conducting region comprises a material selected from the group consisting of: copper, aluminum, silver, gold, chrome, indium gallium zinc oxide, indium tin oxide, titanium, germanium, palladium, tin, tungsten, and any combination thereof.
8. The system of claim 1, wherein the at least one contact point comprises a first contact point separated from a first face of the proof mass by the distance and a second contact point separated from a second face of the proof mass by the distance.
9. The system of claim 2, wherein the threshold value is predetermined based on a combination of a size of the proof mass, the distance, and a material composition of the second electrically conducting region.
10. The system of claim 1, wherein the first and second electrically conducting regions are located above the electrically insulating layer.
11. The system of claim 10, wherein the first and second electrically conducting regions are located in a single plane above the electrically insulating layer and wherein the proof mass is configured to move laterally in the single plane in response to the impulse.
12. The system of claim 1, wherein the first electrically conducting region is located in a first plane, wherein the second electrically conducting region is located in a second plane, wherein the second plane is different from the first plane, and wherein the proof mass is configured to move between the first and second planes in response to the impulse.
13. The system of claim 12, wherein the first plane is below the electrically insulating layer.
14. The system of claim 12, wherein the second plane is above the electrically insulating layer.

15. The system of claim 2, wherein the controller is configured to output the electrical signal at most 1 millisecond (ms) after the impulse.
16. The system of claim 1, wherein the flexible substrate is applied on a surface of or an inside of a product selected from the group consisting of: a helmet, a sports helmet, a military helmet, a bumper of a vehicle, an item of luggage, a suitcase, a shipping container, a shipping box, a military munition, or any combination thereof.
17. A method for manufacturing a flexible threshold accelerometer system, comprising:
 depositing, photolithographically patterning, and etching an electrically insulating material on a flexible substrate to thereby obtain an electrically insulating layer;
 depositing, photolithographically patterning, and etching a first electrically conducting material to thereby obtain a first electrically conducting region comprising at least one contact point above the electrically insulating layer; and
 depositing, photolithographically patterning, and etching a second electrically conducting material above the electrically insulating layer to thereby obtain a second electrically conducting region, at least one cantilever beam coupled to the second electrically conducting region, and a proof mass coupled to the at least one cantilever beam, the proof mass separated from the at least one contact point by a distance.
18. A method for manufacturing a flexible threshold accelerometer system, comprising:
 depositing, photolithographically patterning, and etching a first electrically conducting material on a flexible substrate to thereby obtain a first electrically conducting region comprising at least one contact point;
 depositing, photolithographically patterning, and etching an electrically insulating material to thereby obtain an electrically insulating layer above the first electrically conducting region;
 depositing and photolithographically patterning a photoresist layer above at least a portion of the electrically insulating layer;
 depositing, photolithographically patterning, and etching a second electrically conducting material above the electrically insulating layer and the photoresist layer to thereby obtain a second electrically conducting region, at least one cantilever beam coupled to the second electrically conducting region, and a proof mass coupled to the

at least one cantilever beam, the proof mass separated from the at least one contact point by a distance; and

etching the photoresist layer to thereby permit the proof mass to move in response to an impulse.

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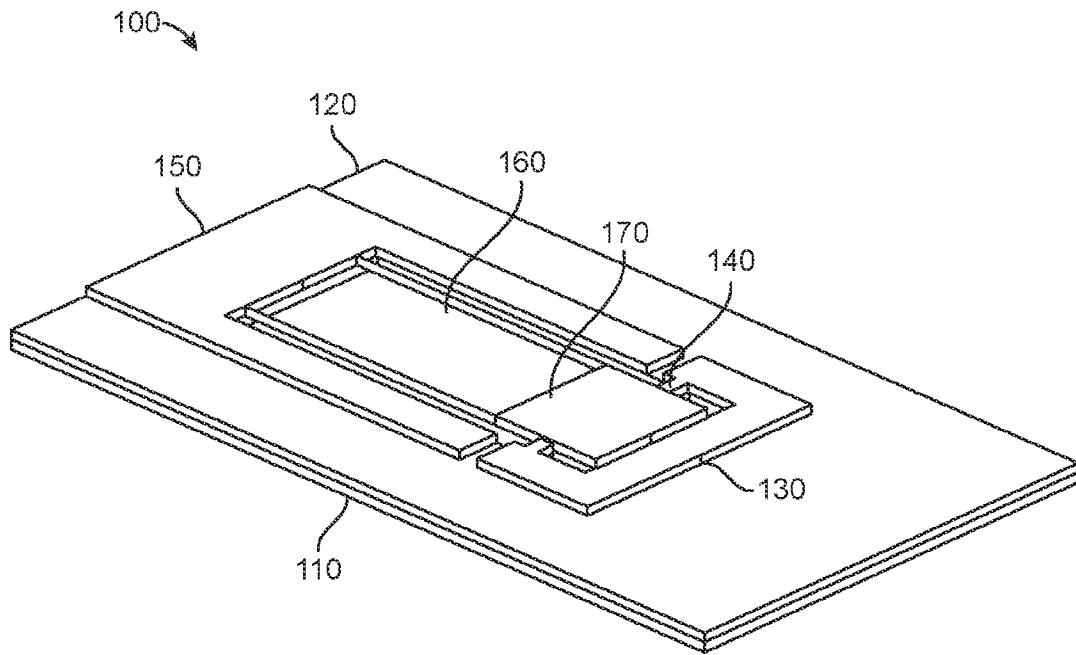


FIG. 1A

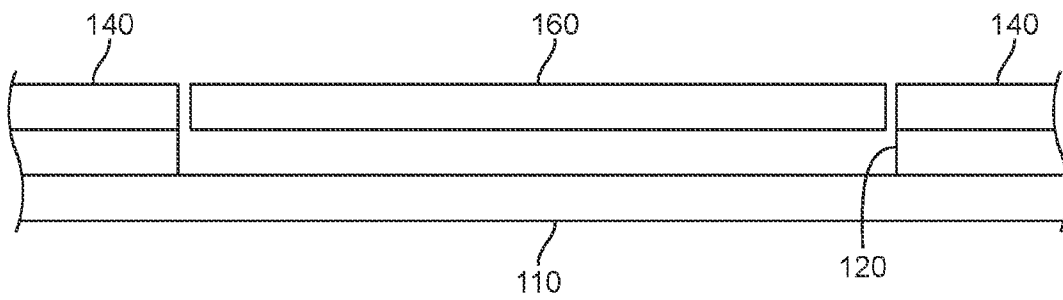


FIG. 1B

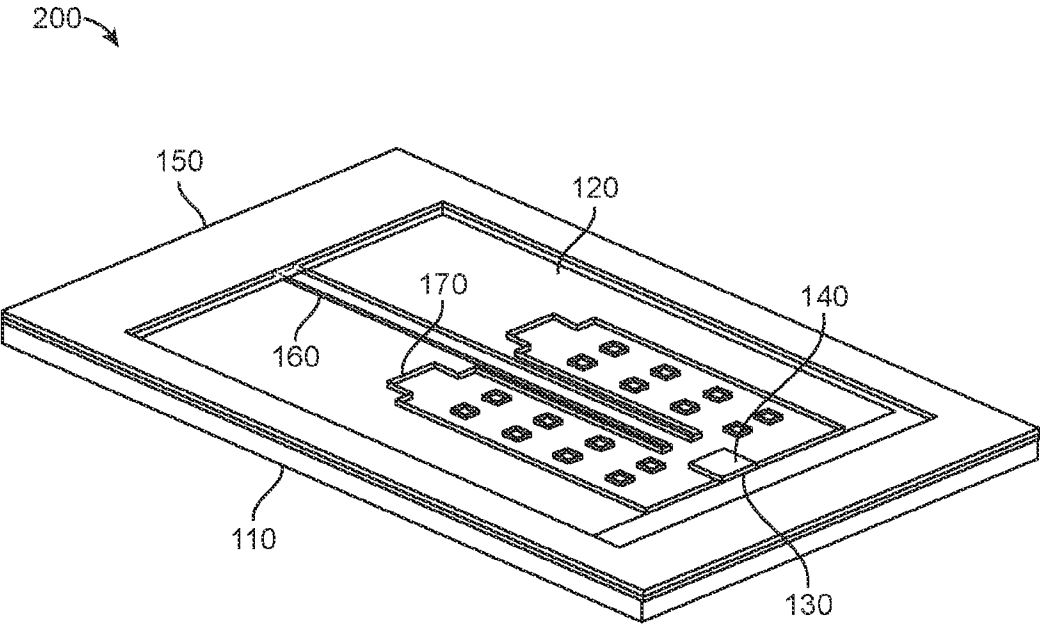


FIG. 2A

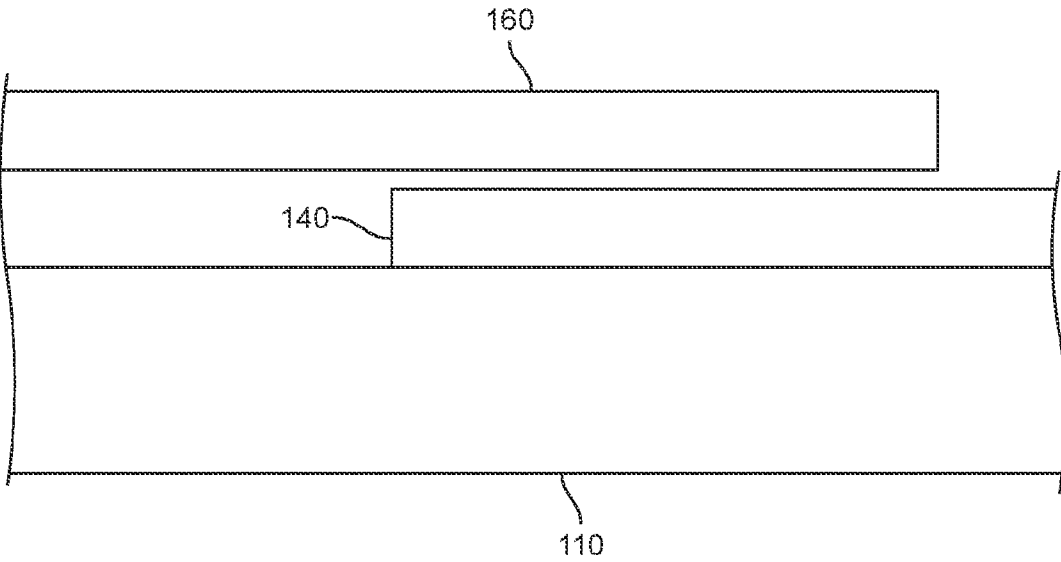


FIG. 2B

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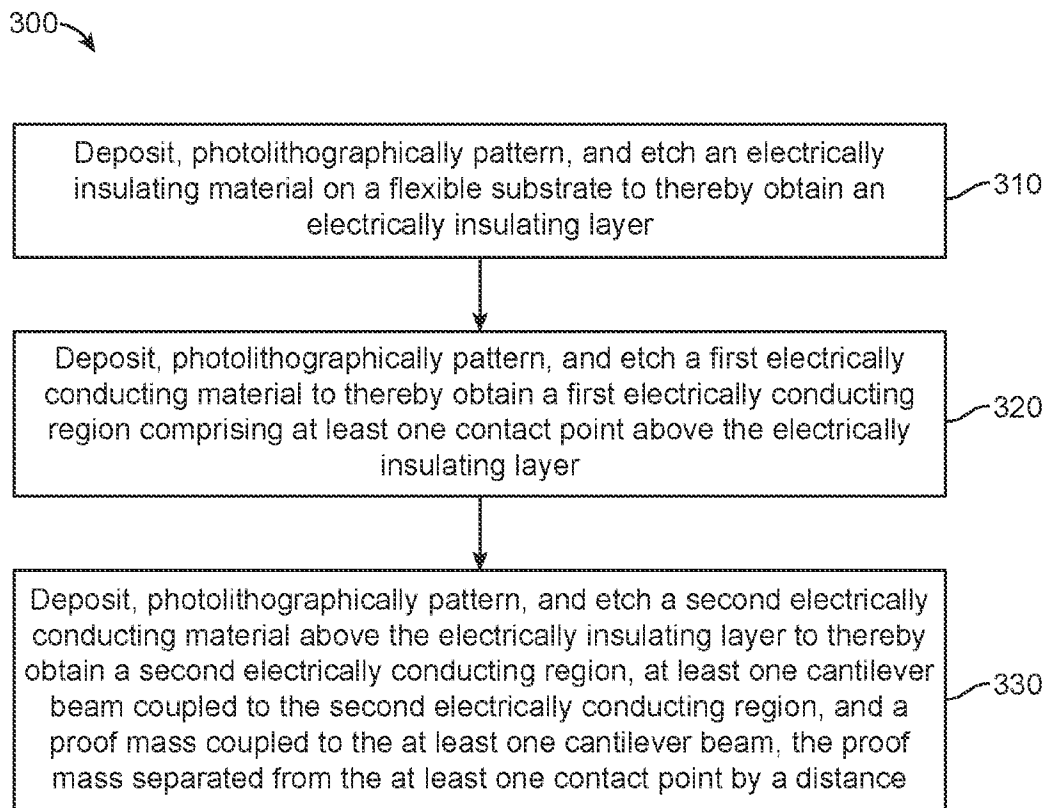


FIG. 3

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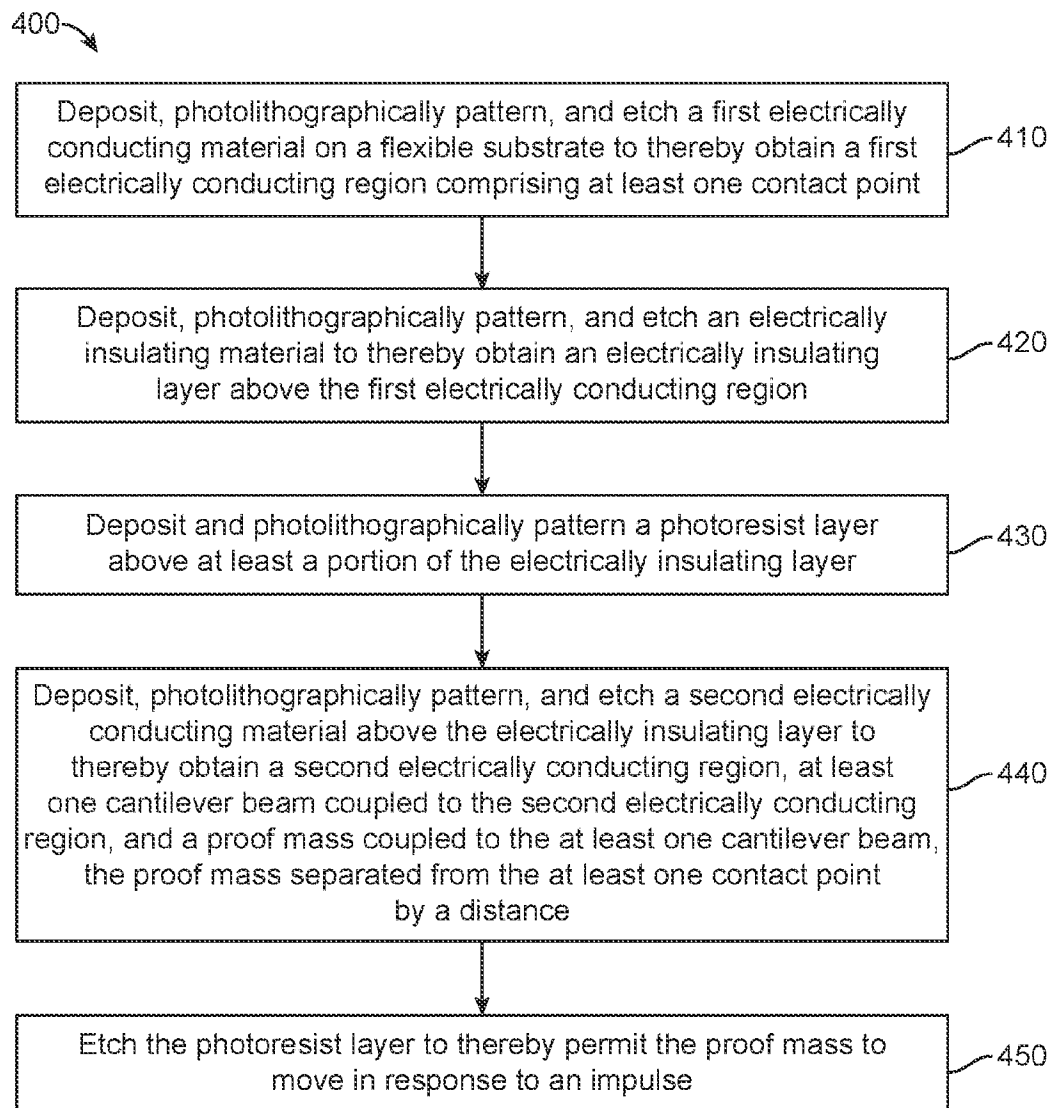


FIG. 4

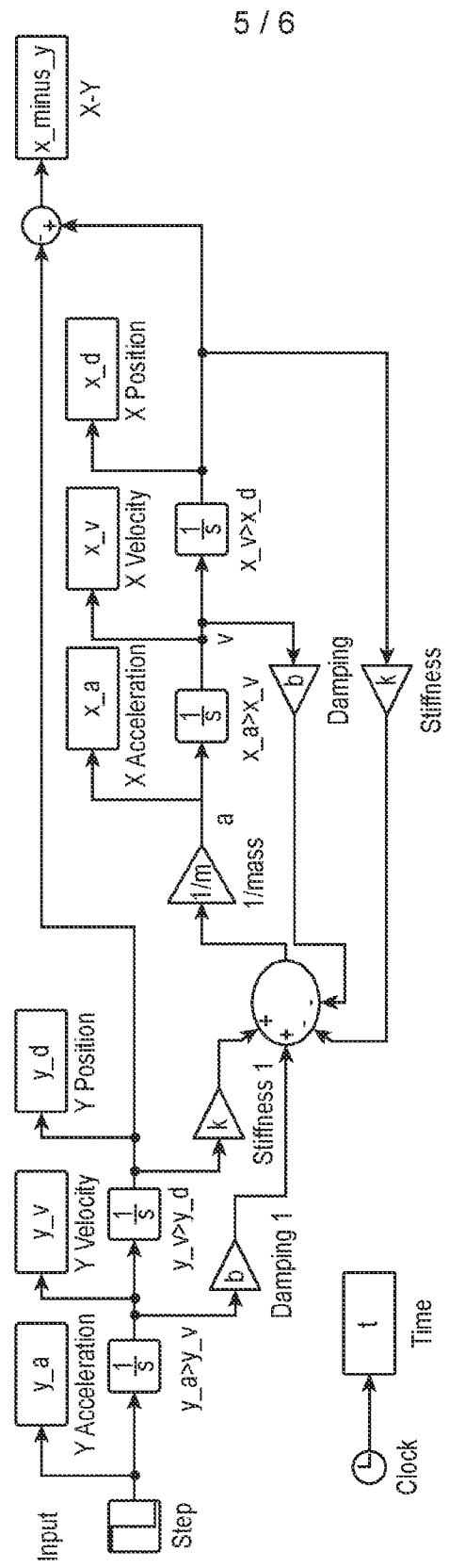


FIG. 5

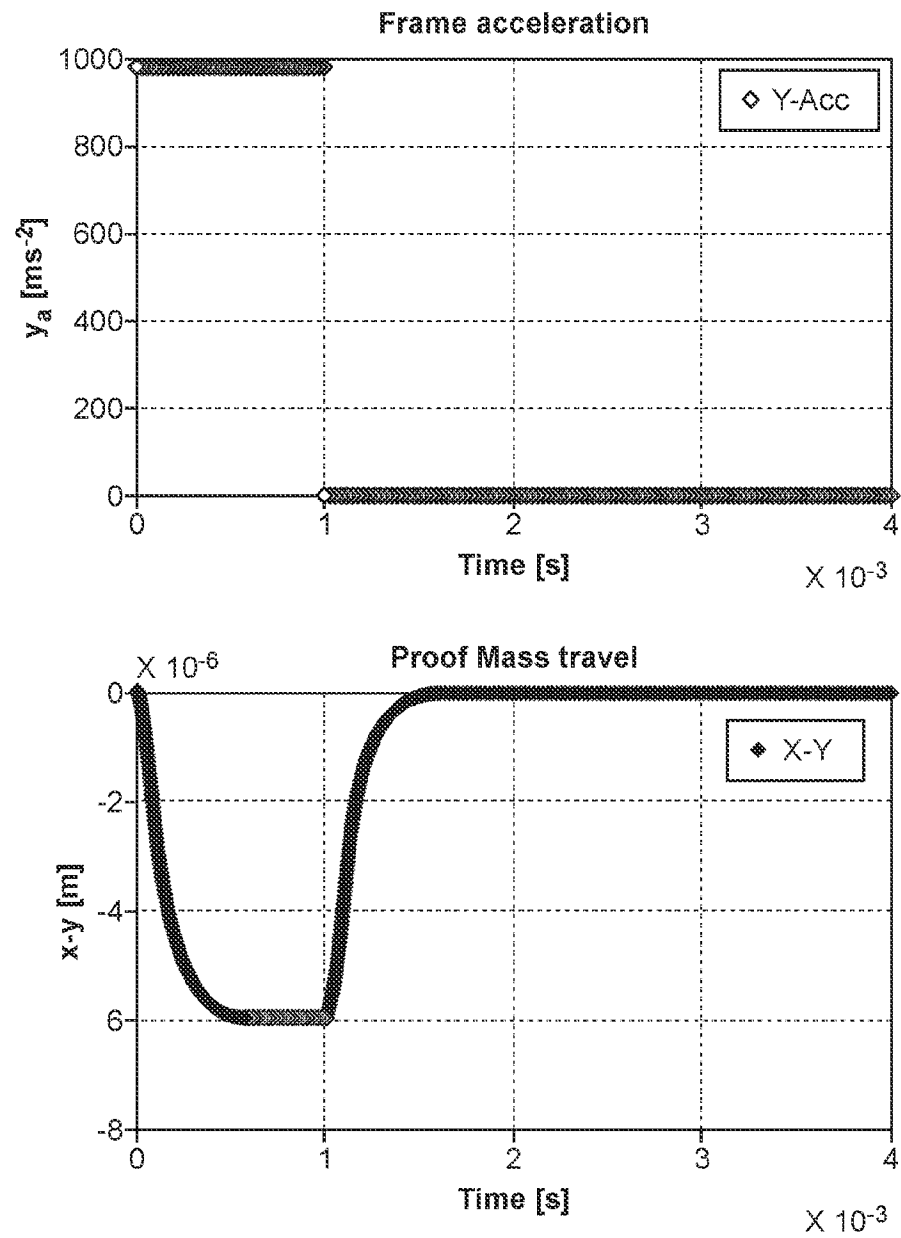


FIG. 6

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2022/026481

A. CLASSIFICATION OF SUBJECT MATTER

INV. G01P15/08

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)

G01P B82B B81B

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, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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X	US 2020/084892 A1 (MARSH STEPHEN A [US]) 12 March 2020 (2020-03-12)	1, 17, 18
Y	paragraphs [0003], [0032] - [0034], [0043], [0066] - [0069], [0081] - [0083], [0088], [0094]; figures 1-9 -----	1-16
Y	US 5 712 609 A (MEHREGANY MEHRAN [US] ET AL) 27 January 1998 (1998-01-27) columns 9, 10 -----	11
A	US 2010/143848 A1 (JAIN KANTI [US] ET AL) 10 June 2010 (2010-06-10) the whole document -----	1-18

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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"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

29 November 2022

Date of mailing of the international search report

07/12/2022

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Authorized officer

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2022/026481

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