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Rahafrooz et al.

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(54) **SINGLE ANCHOR RESONATORS**

(71) Applicant: **Panasonic Intellectual Property Management Co., Ltd.**, Osaka (JP)

(72) Inventors: **Amir Rahafrooz**, Shaker Heights, OH (US); **Diego Emilio Serrano**, Alpharetta, GA (US); **Thomas Kieran Nunan**, Carlisle, MA (US); **Ijaz Jafri**, Holliston, MA (US)

(73) Assignee: **Panasonic Intellectual Property Management Co., Ltd.**, Osaka (JP)

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See application file for complete search history.

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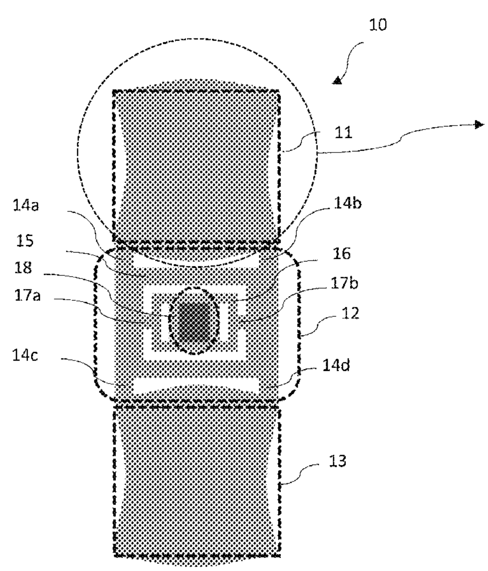
Primary Examiner — Ahmed Elnakib
(74) *Attorney, Agent, or Firm* — McDonald Hopkins LLC

(57) **ABSTRACT**

A mechanical resonator includes two identical plates, and a decoupling structure comprising at least two first connectors, each first connector connecting the decoupling structure to a respective one of the two identical plates, and an anchor disposed at a center of the decoupling structure. Each of the two identical plates may be a square plate adapted to resonate in Lamé-mode. Further, each of the two identical plates may comprise a plurality of square plates, each square plate disposed next to one another. The decoupling structure further comprises a first ring connected to each of the two identical plates via a respective one of the at least two first connectors. The decoupling structure may further comprise a second ring connected to an inside of the first ring via at least two second connectors, wherein the anchor is disposed at a center of the second ring.

14 Claims, 5 Drawing Sheets



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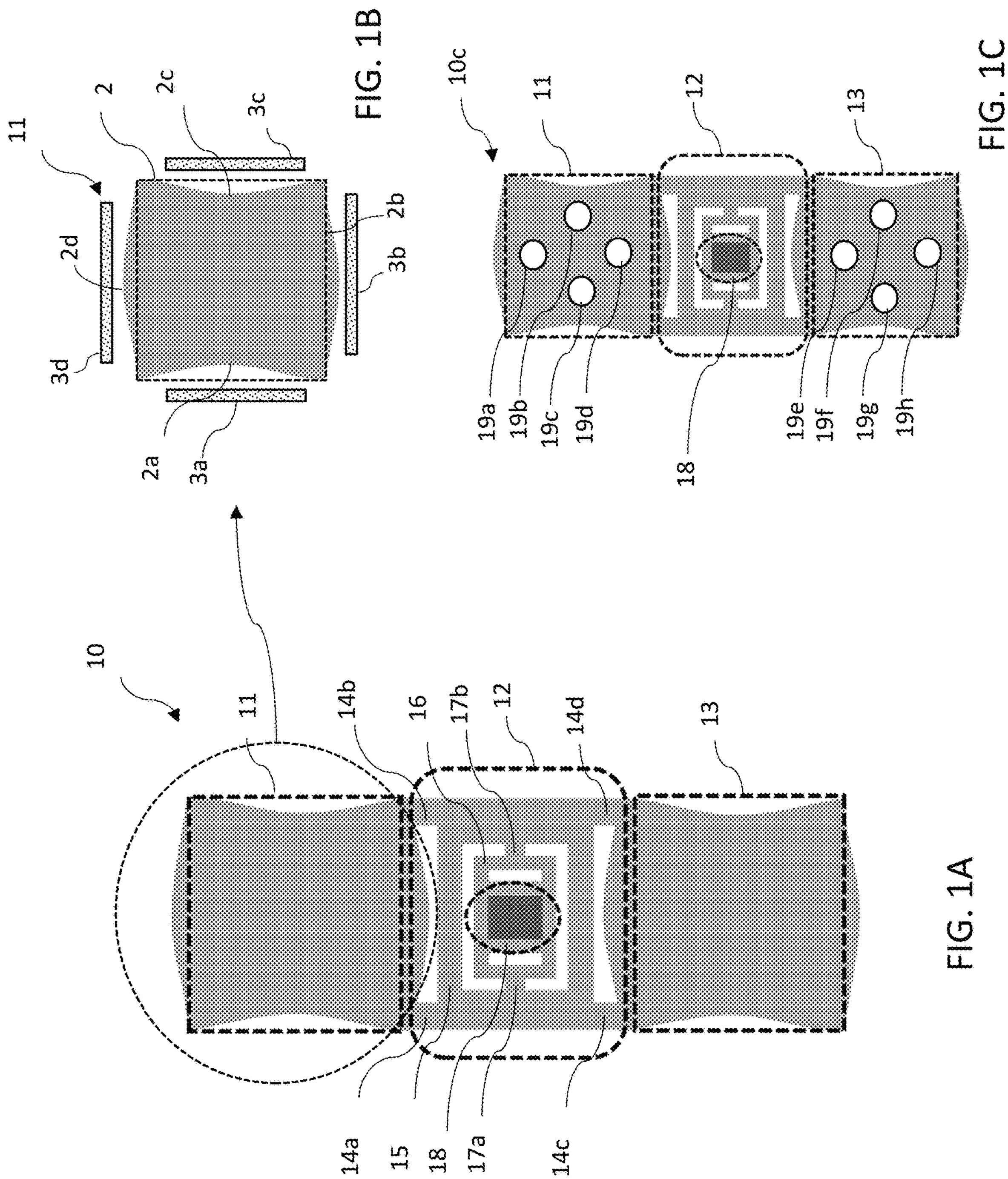
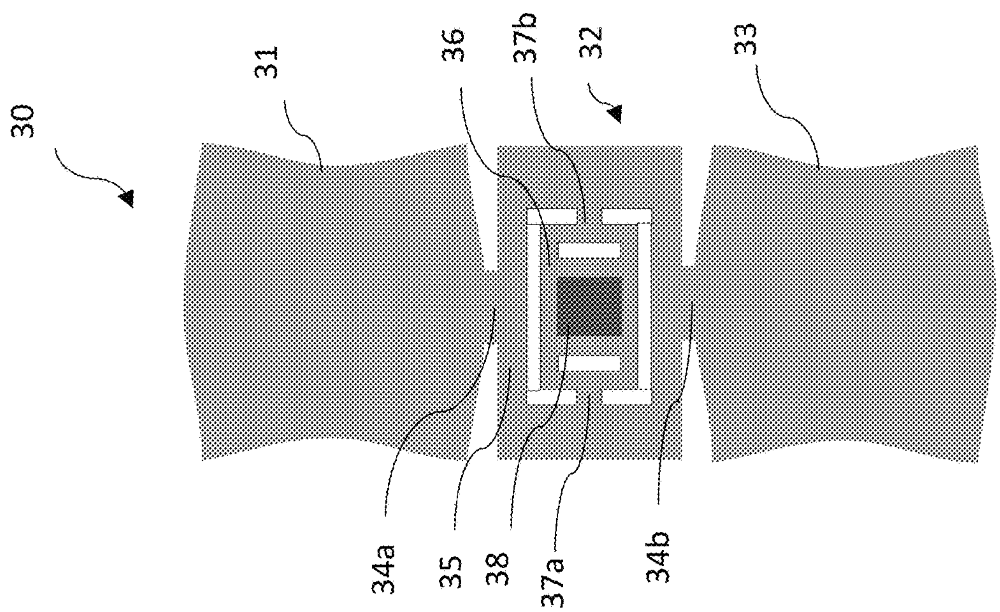


FIG. 1B

FIG. 1C

FIG. 1A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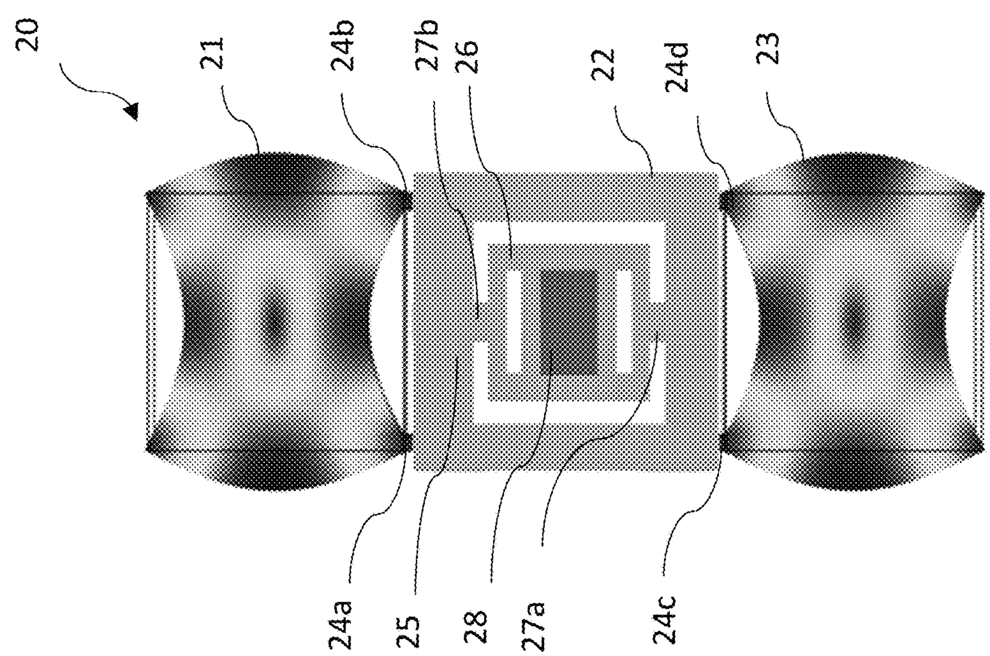
31
36
37b
32
33
34a
35
38
37a
34b

FIG. 3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24d
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27a
24c

FIG. 2

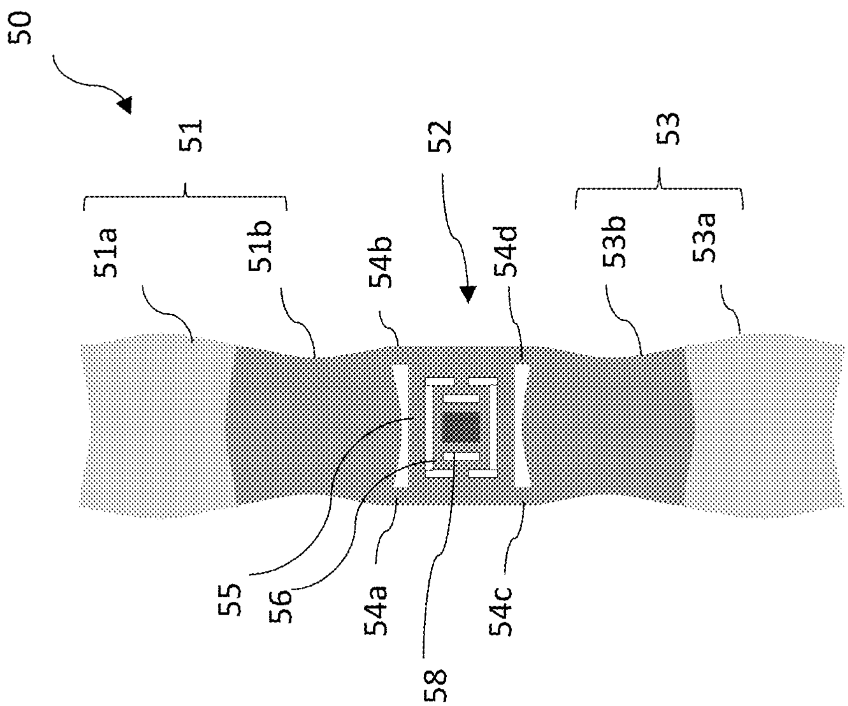

50
51
51a
51b
52
53
53b
53a
54b
54d
54a
54c
55
56
58

FIG. 5

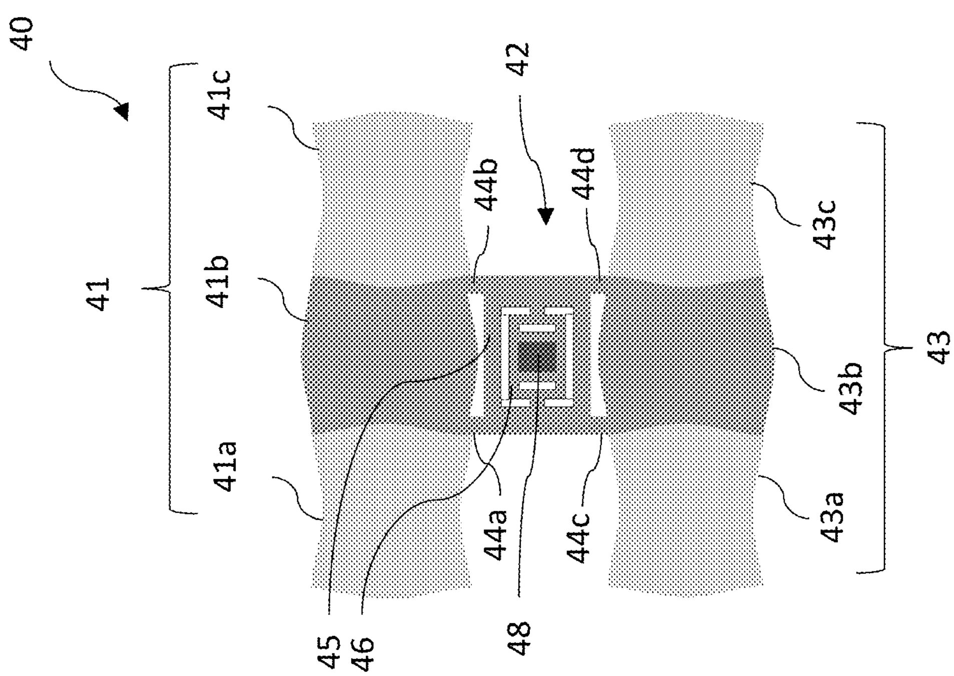
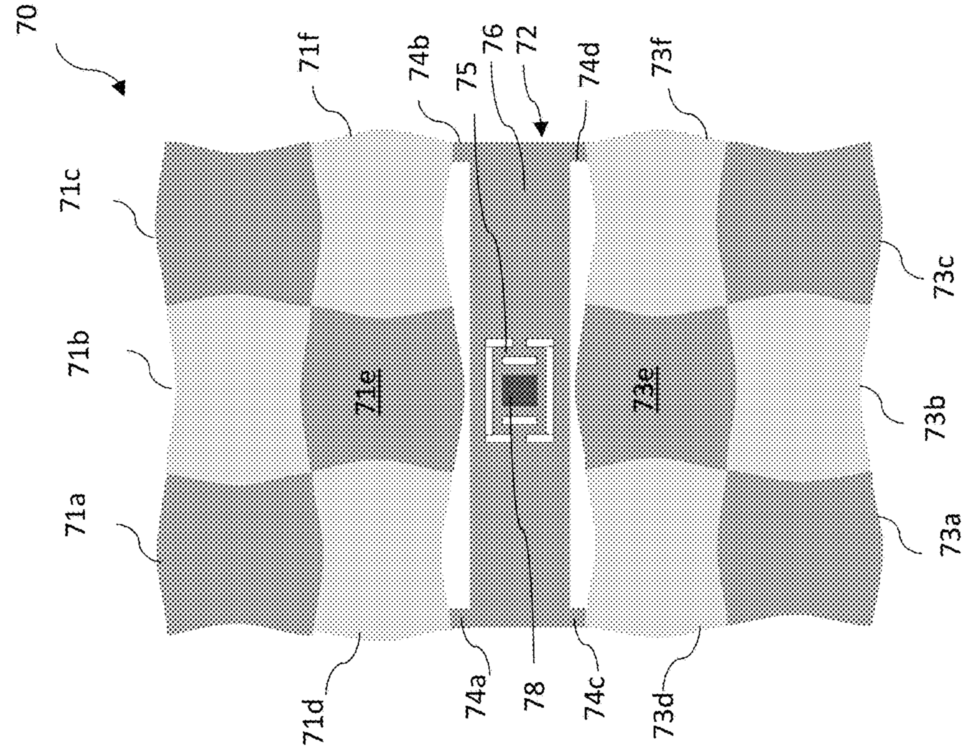
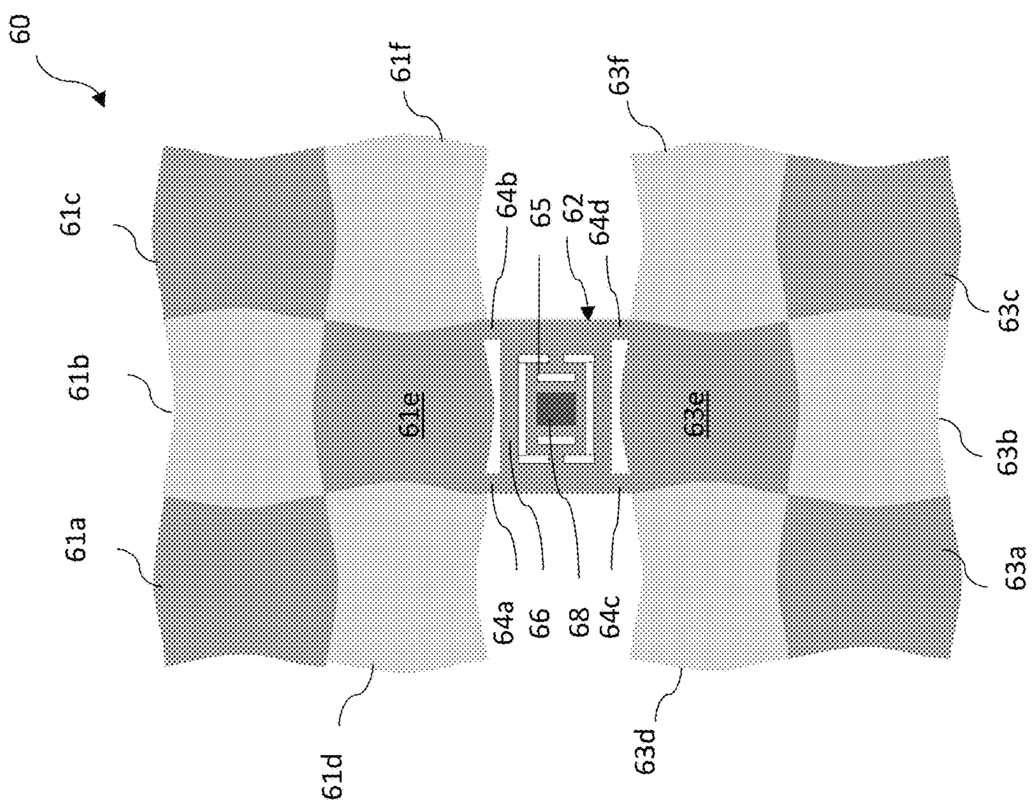

40
41
41a
41b
41c
42
43
43a
43b
43c
44a
44b
44c
44d
45
46
48

FIG. 4



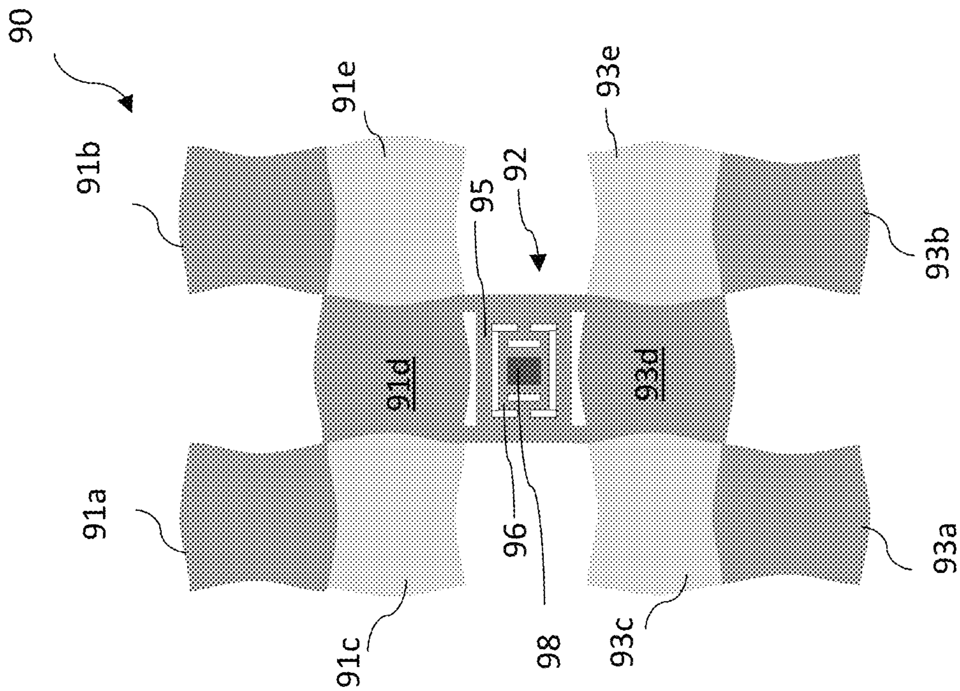
70
71a
71b
71c
71d
71e
71f
72
73a
73b
73c
73d
73e
73f
74a
74b
74c
74d
75
76
78

FIG. 7



60
61a
61b
61c
61d
61e
61f
62
63a
63b
63c
63d
63e
63f
64a
64b
64c
64d
65
66
68

FIG. 6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91e
93e
92
95
93b
91d
93d
91a
96
93a
91c
98
93c

FIG. 9

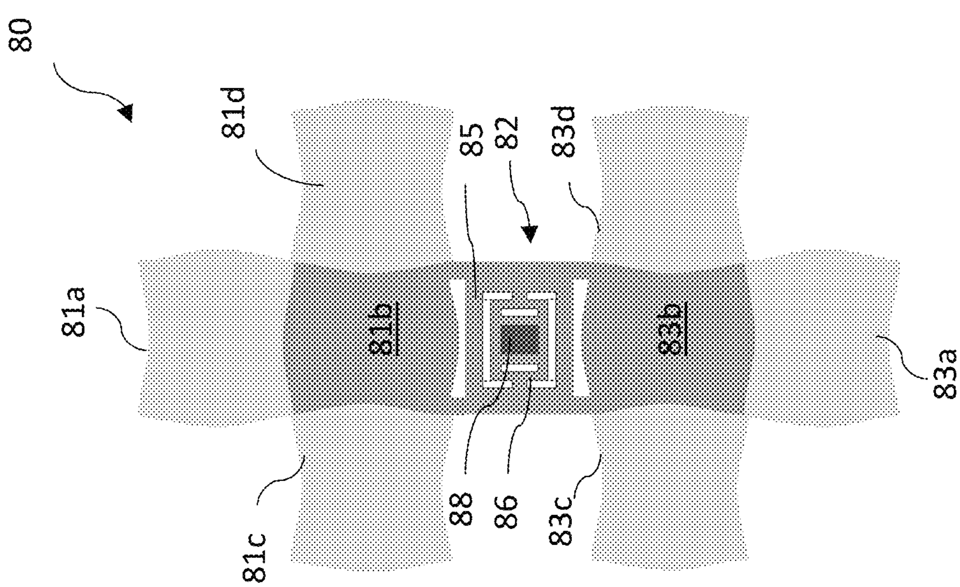
80
81d
85
82
83d
81a
81b
83b
83a
81c
88
86
83c

FIG. 8

SINGLE ANCHOR RESONATORS

TECHNICAL FIELD

The present disclosure relates to bulk acoustic width (BAW) mode (e.g., Lamé mode) resonators with less anchor loss. In particular, the resonators include two identical plates and a decoupling structure therebetween. Each of the two identical plates may comprise a plurality of square plates, each square plate disposed next to one another.

BACKGROUND

Resonators are popular and widely being used for different applications, but they have relatively high anchor loss which degrades their quality factor. As the resonator is vibrating, part of the acoustic energy leaks into the substrate and gets dissipated.

Anchor loss can impact the resonator in several ways. First, it can reduce the overall quality factor of the resonator, and it can make a quality factor of the resonator dependent on substrate boundary conditions and stress. Second, the anchor loss makes the resonator susceptible to repeatability and hysteresis issues.

There has been extensive effort to reduce anchor loss by either making changes to the anchor(s) or the resonant body and/or even the substrate. However, there are still some highly popular resonators that may not have low enough anchor loss.

Hence, there is a need for the technique for reducing anchor losses in mechanical resonators.

SUMMARY

The present disclosure provides the mechanical resonators designed to reduce the anchor losses during the BAW mode (e.g., Lamé mode).

In one aspect, a mechanical resonator includes two identical plates, and a decoupling structure comprising at least two first connectors, each first connector connecting the decoupling structure to a respective one of the two identical plates, and an anchor disposed at a center of the decoupling structure.

In one embodiment, the decoupling structure further comprises a first ring connected to each of the two identical plates via a respective one of the at least two first connectors.

The decoupling structure may further comprise a second ring connected to an inside of the first ring via at least two second connectors, wherein the anchor is disposed at a center of the second ring.

Also, the first ring may have a first rectangular ring shape, and the second ring may have a second rectangular ring shape, the first rectangular ring shape being larger than the second rectangular ring shape.

The two identical plates may be two identical proof-mass plates.

Specifically, each of the two identical plates may be a square plate adapted to resonate in Lamé-mode.

Further, each of the two identical plates may comprise a plurality of square plates, each square plate disposed next to one another.

In another embodiments, each of the two identical plates may comprise two square plates disposed next to each other in line with the decoupling structure.

Each of the two identical plates may comprise three square plates disposed next to one another in a row.

In one example, the two identical plates may comprise an upper plate comprising six square plates, arranged three-by-two square plates, and a lower plate comprising six square plates, arranged three-by-two square plates.

In another example, the decoupling structure may be connected to both corners of a square plate located in a middle and inside of three-by-two square plates of the upper plate, and both corners of a square plate located in a middle and inside of three-by-two square plates of the lower plate.

In yet another example, the decoupling structure may be connected to one outer corner of a square plate located in a left side and inside of the three-by-two square plates of the upper plate, one outer corner of a square plate located in a right side and inside of the three-by-two square plates of the upper plate, one outer corner of a square plate located in a left side and inside of the three-by-two square plates of the lower plate, and one outer corner of a square plate located in a right side and inside of the three-by-two square plates of the lower plate.

In a different example, the two identical plates may comprise an upper plate comprising four square plates including two square plates in a middle and one square plate in a right side and one square plate in a left side thereof, and a lower plate comprising four square plates including two square plates in a middle and one square plate in a right side and one square plate in a left side thereof.

Alternatively, the two identical plates may comprise an upper plate comprising four square plates including one square plate in a middle and two square plates in a right side and two square plates in a left side thereof, and a lower plate comprising four square plates including one square plates in a middle and two square plates in a right side and two square plates in a left side thereof.

Further, each of the two identical plates include at least one release perforation thereon.

Furthermore, a portion of the plurality of resonating plates is capacitively actuated into the Lamé resonance mode.

In one embodiment, the single anchor may include two or more sub-anchors.

Other aspects, advantages, and salient features of the disclosure will become apparent to those skilled in the art from the following detailed description, which, taken in conjunction with the annexed drawings, discloses exemplary embodiments of the disclosure.

Before undertaking the DETAILED DESCRIPTION below, it may be advantageous to set forth definitions of certain words and phrases used throughout this patent document: the terms "include" and "comprise," as well as derivatives thereof, mean inclusion without limitation; the term "or," is inclusive, meaning and/or; the phrases "associated with" and "associated therewith," as well as derivatives thereof, may mean to include, be included within, interconnect with, contain, be contained within, connect to or with, coupled to or with, be communicable with, cooperate with, interleave, juxtapose, be proximate to, be bound to or with, have, have a property of, or the like. It should be noted that the functionality associated with any particular controller may be centralized or distributed, whether locally or remotely. Definitions for certain words and phrases are provided throughout this patent document, those of ordinary skill in the art should understand that in many, if not most instances, such definitions apply to prior, as well as future uses of such defined words and phrases.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the present disclosure and its advantages, reference is now made to the following description taken in conjunction with the accompanying drawings, in which like reference numerals represent like parts:

FIGS. **1**A to **1**C illustrate example schematic diagrams of a mechanical resonator according to embodiments of the present disclosure.

FIG. **2** illustrates another example schematic diagram of a mechanical resonator according to one embodiment of the present disclosure.

FIG. **3** illustrates yet another example schematic diagram of a mechanical resonator according to one embodiment of the present disclosure.

FIG. **4** illustrates an example schematic diagram of a mechanical resonator with horizontally extended resonance plates according to one embodiment of the present disclosure.

FIG. **5** illustrates another example schematic diagram of a mechanical resonator with vertically extended resonance plates according to one embodiment of the present disclosure.

FIG. **6** illustrates an example schematic diagram of a mechanical resonator with upper and lower resonance plates extended in two rows according to one embodiment of the present disclosure.

FIG. **7** illustrates another example schematic diagram of a mechanical resonator with upper and lower resonance plates extended in two rows according to one embodiment of the present disclosure.

FIG. **8** illustrates another example schematic diagram of a mechanical resonator with "T" shape extended resonance plates according to one embodiment of the present disclosure.

FIG. **9** illustrates an example schematic diagram of a mechanical resonator with "U" shape extended resonance plates according to one embodiment of the present disclosure.

Throughout the drawings, it should be noted that like reference numbers are used to depict the same or similar elements, features, and structures.

DETAILED DESCRIPTION

FIGS. **1**A through **9**, discussed below, and the various embodiments used to describe the principles of the present disclosure in this patent document are by way of illustration only and should not be construed in any way to limit the scope of the disclosure. Those skilled in the art will understand that the principles of the present disclosure may be implemented in any suitably arranged system and method. The following description with reference to the accompanying drawings is provided to assist in a comprehensive understanding of various embodiments of the present disclosure as defined by the claims and their equivalents. It includes various specific details to assist in that understanding but these are to be regarded as mere examples. Accordingly, those of ordinary skill in the art will recognize that various changes and modifications of the various embodiments described herein can be made without departing from the scope and spirit of the present disclosure. In addition, descriptions of well-known functions and constructions may be omitted for clarity and conciseness.

It should be apparent to those skilled in the art that the following description of various embodiments of the present disclosure is provided for illustration purpose only and not for the purpose of limiting the present disclosure as defined by the appended claims and their equivalents.

Although ordinal numbers such as "first," "second," and so forth will be used to describe various components, those components are not limited herein. The terms are used only for distinguishing one component from another component. For example, a first component may be referred to as a second component and likewise, a second component may also be referred to as a first component, without departing from the teaching of the inventive concept.

The terminology used herein is for the purpose of describing various embodiments only and is not intended to be limiting. As used herein, the singular forms are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "comprises" and/or "has," when used in this specification, specify the presence of a stated feature, number, step, operation, component, element, or a combination thereof, but do not preclude the presence or addition of one or more other features, numbers, steps, operations, components, elements, or combinations thereof.

FIG. **1**A illustrates an example schematic diagram of mechanical resonator vibrating **10** in Lamé mode according to embodiments of the present disclosure. Lamé mode resonance is a combination of two shear waves, and it is known to exist in several crystal orientations of silicon.

As illustrated, mechanical resonator **10** includes resonance plates **11**, **13** and decoupling structure **12** disposed between resonance plates **11**, **13**. Resonance plates **11**, **13** and decoupling structure **12** may be etched out from a substrate; for example, a substrate with silicon, doped silicon, N-type silicon, P-type silicon, silicon oxide, silicon carbide, germanium, or the like. Each of resonance plates **11**, **13** has a shape of a square with a length L of each side.

Two resonance plates **11**, **13** are two identical proof-masses in various sizes, for example, between a 10 μm×10 μm square and 1 mm×1 mm square.

Decoupling structure **12** includes four outer connectors **14***a* to **14***d*, outer ring **15**, two inner connectors **17***a*, **17***b*, inner ring **16**, and anchor **18**. Four outer connectors **14***a* to **14***d* connect outer ring **15** to resonance plates **11**, **13** vertically, and two inner connectors **17***a*, **17***b* connect inner ring **16** to outer ring **15** horizontally.

Anchor **18** is disposed at the center of inner ring **16** horizontally. Anchor **18** can be etched into a substrate made of various materials, such as N or P-type silicon, silicon oxide, silicon carbide, germanium, or the like.

The horizontal and vertical directions in this disclosure are relative directions, and may be switched with each other according to a viewpoint.

Each of resonance plates **11**, **13** includes at least two electrodes for applying resonance signals to vertical and horizontal sides of the plates. As resonance plates **11**, **13** vibrate according to the resonance signals, acoustic energy leaking from each of two resonance plates **11**, **13** into decoupling structure **12** are in an equal magnitude but opposite in direction, and thus cancel each other out at anchors **18**. Thus, the center of the connecting beam is a good place to anchor the resonator **20** because anchor loss can be minimized due to the cancellation of each acoustic energy leaking from two resonance plates **11**, **13**.

FIG. **1**B illustrates an enlarged view of one resonance plate **11** vibrating in the Lamé mode resonance according to embodiments of the present disclosure.

As illustrated, each of resonance plates **11**, **13** is capacitively actuated into a Lamé resonance mode by means of electrodes disposed along the sides of the resonance plate. Specifically, electrodes **3***a*, **3***c*, which are disposed along both vertical sides of resonance plate **11**, are connected to a first actuating signal potential and; and electrodes **3***b*, **3***d*, which are disposed along both horizontal sides of resonance plate **11**, are connected to a second actuating signal potential. The gap between the electrodes and the resonance plates may be narrow enough to provide a good coupling for actuation, such as less than 200 nm.

The first and second actuating signal potentials may be alternating signals with 180 degrees phase difference from each other. The resonance plate is electrically conductive, and the alternating actuation signals actuates an oscillation of Lamé mode in the resonance plate.

As illustrated, dashed line **2** indicates the oscillation phase 0° or 180°, in which the sides of the resonance plate **11** are in a rest position. Sides **2***b*, **2***d* are convex, indicating the oscillation phase of 90°, while sides **2***a*, **2***c* are concave, indicating the oscillation phase of 270°. The resonance plate maintains the same volume in all instants of oscillation of the Lamé resonance mode.

The above electrode arrangements may be applied to each and every one of the resonance plates in the mechanical resonators described in this disclosure. It is also possible to use only two electrodes for each resonance plate, one for a vertical side and the other for a horizontal side of a resonance plate, instead of four electrodes.

FIG. **1**C illustrates another example schematic diagram of mechanical resonator **10***c* according to embodiments of the present disclosure. Mechanical resonator **10***c* additionally includes release perforations **19***a* to **19***h* on resonance plates **11** and **13**, as compared to mechanical resonator **10**. The repetitive descriptions of the same components are omitted for brevity.

FIG. **2** illustrates an example image of the vibrating mechanical resonator **20** according to one embodiment of the present disclosure.

Similar to FIG. **1**A, mechanical resonator **20** includes identical resonance plates **21**, **23** and decoupling structure **22** disposed between resonance plates **21**, **23**. The repetitive descriptions of the same components will be omitted for brevity.

Decoupling structure **22** may have various shapes with a single anchor. As an example, decoupling structure **22** includes four outer connectors **24***a* to **24***d*, outer ring **25**, two inner connectors **27***a*, **27***b*, inner ring **26**, and anchor **28**. Specifically, two outer connectors **24***a*, **24***b* connect outer ring **25** to resonance plate **21** vertically, and two outer connectors **24***c*, **24***d* connect outer ring **25** to resonance plate **23** vertically. Two inner connectors **27***a*, **27***b* connect inner ring **26** to outer ring **25** vertically. Anchor **28** is disposed at the center of inner ring **16** horizontally.

FIG. **3** illustrates another example schematic diagram of a mechanical resonator **30** according to one embodiment of the present disclosure.

Similar to FIG. **1**A, mechanical resonator **30** includes resonance plates **31**, **33** and decoupling structure **32** disposed between resonance plates **31**, **33**. The repetitive descriptions of the same components will be omitted for brevity.

In this embodiment, decoupling structure **32** includes two outer connectors **34***a*, **34***b* for connecting outer ring **35** to resonance plates **31**, **33**, instead of the four outer connectors **14***a* to **14***d* illustrated in FIG. **1**A. Specifically, outer connector **34***a* connects one side of outer ring **35** to the middle of resonance plate **31**, and outer connector **34***b* connects the opposite side of outer ring **35** to the middle of resonance plate **33**.

Two inner connectors **37***a*, **37***b* connect inner ring **36** to outer ring **35** horizontally, and anchor **38** is disposed at the center of inner ring **36** vertically.

FIGS. **4**-**10** illustrate mechanical resonators with extended resonance plates which include a plurality of square plates, each square plate disposed next to one another.

FIG. **4** illustrates an example schematic diagram of mechanical resonator **40** with horizontally extended resonance plates, according to one embodiment of the present disclosure.

Mechanical resonator **40** includes upper extended resonance plate **41** and lower extended resonant **43** and decoupling structure **42** disposed between upper and lower extended resonance plates **41**, **43**.

In this embodiment, upper extended resonance plate **41** comprises three resonating plates **41***a* to **41***c* arranged in a row, and lower extended resonance plate **43** comprises three resonating plates **43***a* to **43***c* arranged in a row. One or more of resonating plates **41***a* to **41***c*, **43***a* to **43***c* is capacitively actuated into a Lamé resonance mode by means of electrodes (not shown) disposed along the sides of the resonance plate, as described above.

Decoupling structure **42** may have various shapes with an anchor. As an example, decoupling structure **42** may include four outer connectors **44***a* to **44***d*, outer ring **45**, two inner connectors **47***a*, **47***b*, inner ring **46**, and anchor **48**. Specifically, two outer connectors **44***a*, **44***b* connect outer ring **45** to resonance plate **41***b*, and two outer connectors **44***c*, **44***d* connect outer ring **45** to resonance plates **43***b*. Two inner connectors **47***a*, **47***b* connect inner ring **46** to outer ring **45**. Anchor **48** is disposed at the center of inner ring **46**.

FIG. **5** illustrates another example schematic diagram of a mechanical resonator **50** with vertically extended resonance plates, according to one embodiment of the present disclosure.

Mechanical resonator **50** includes extended upper plate **51** and extended lower plate **53** and decoupling structure **52** disposed between extended upper and lower plates **51**, **53**.

Specifically, extended resonance plate **51** comprises two resonating plates **51***a*, **51***b* arranged in parallel, and extended resonance plate **43** comprises three resonating plates **53***a*, **53***b* arranged in the vertical direction. One or more of resonating plates **51***a*, **51***b* and **53***a*, **53***b* may be capacitively actuated into a Lamé resonance mode by means of electrodes disposed along the sides of the resonance plate, as described above. The resonating plates are well connected to one another, so actuating only a portion of the resonating plates results in actuating the whole resonating plates.

Also, two outer connectors **54***a*, **54***b* connect outer ring **55** to resonance plate **51***b*, and two outer connectors **54***c*, **54***d* connect outer ring **55** to resonance plates **53***b*. Two inner connectors **57***a*, **57***b* connect inner ring **56** to outer ring **55**. Anchor **58** is disposed at the center of inner ring **56**.

FIG. **6** illustrates an example schematic diagram of a mechanical resonator **60** with upper and lower resonance plates extended in two rows, according to one embodiment of the present disclosure.

Mechanical resonator **60** includes upper extended resonance plate **61** and lower extended resonance plate **63**, and decoupling structure **62** disposed between upper and lower extended resonance plates **61**, **63**.

Specifically, upper extended resonance plate **61** comprises six resonating plates **61***a* to **61***f* arranged in three-by-two square plates, and lower extended resonance plate **63** comprises six resonating plates **63***a* to **63***f* arranged in three-by-two square plates. One or more of resonating plates **61***a* to **61***f*, **63***a* to **63***f* may be capacitively actuated into a Lamé resonance mode by means of electrodes (not shown) disposed along the sides of the resonance plate, as described above.

Decoupling structure **62** may have various shapes with a single anchor. As an example, two outer connectors **64***a*, **64***b* of outer ring **65** are connected to both corners of resonant plate **61***b* located in the middle and inside of upper three-by-two square plates. Also, two outer connectors **64***c*, **64***d* of outer ring **65** are connected to both corners of resonant plate **63***b* located in the middle and inside of the lower three-by-two square plates. Anchor **68** is disposed at the center of inner ring **66**.

FIG. **7** illustrates still another example schematic diagram of a mechanical resonator **70** with upper and lower resonance plates extended in two rows according to one embodiment of the present disclosure.

Similar to FIG. **6**, mechanical resonator **70** includes upper extended resonance plate **71** and lower extended resonance plate **73**, and decoupling structure **72** disposed between upper and lower extended resonance plates **71**, **73**.

Specifically, upper extended resonance plate **71** comprises six resonating plates **71***a* to **71***f* arranged in three-by-two square plates, and lower extended resonance plate **73** comprises six resonating plates **73***a* to **73***f* arranged in three-by-two square plates. One or more of resonating plates **71***a* to **71***f*, **73***a* to **73***f* is capacitively actuated into a Lamé resonance mode by means of electrodes (not shown) disposed along the sides of the resonance plate, as described above.

Decoupling structure **72** may have various shapes with a single anchor. As an example, connector **74***a* is connected to one outer corner of resonant plate **71***d* located in the left side and inside of the upper three-by-two square plates; connector **74***b* is connected to one outer corner of resonant plate **71***f* located in the right side and inside of the upper three-by-two square plates; connector **74***c* is connected to one outer corner of resonant plate **73***d* located in the left side and inside of the lower three-by-two square plates; and connector **74***d* is connected to one outer corner of resonant plate **73***f* located in the right side and inside of the lower three-by-two square plates.

FIG. **8** illustrates still another example schematic diagram of a mechanical resonator **80** with "T" shape extended resonance plates according to one embodiment of the present disclosure.

Mechanical resonator **80** includes upper extended resonance plate **81** and lower extended resonance plate **83**, and decoupling structure **82** disposed between upper and lower extended resonance plates **81**, **83**.

Specifically, upper extended resonance plate **81** comprises four resonating plates **81***a* to **81***d*: two resonance plates **81***a*, **81***d* in the middle and one resonance plate **81***c* in a left side and one resonance plate **81***d* in a right side thereof.

Similarly, lower extended resonance plate **83** comprises four resonating plates **83***a* to **83***d*: two resonance plates **83***a*, **83***d* in the middle and one resonance plate **83***c* in a left side and one resonance plate **83***d* in a right side thereof. One or more of resonating plates may be capacitively actuated into a Lamé resonance mode by means of electrodes (not shown) disposed along the sides of the resonance plate, as described above.

Decoupling structure **82** may have various shapes with a single anchor. As an example, decoupling structure **22** includes outer ring **85** connected to both corners of resonance plate **81***b* and to both corners of resonance plate **83***b*, and inner ring **86** disposed inside outer ring **85**. Anchor **88** is disposed at the center of inner ring **86**.

FIG. **9** illustrates still another example schematic diagram of a mechanical resonator **70** with "U" shape extended resonance plates according to one embodiment of the present disclosure.

Mechanical resonator **90** includes upper extended resonance plate **91** and lower extended resonance plate **93**, and decoupling structure **92** disposed between upper and lower extended resonance plates **91**, **93**.

Specifically, upper extended resonance plate **91** comprises four resonating plates **91***a* to **91***e*: one resonant plate **91***d* in the middle and two resonant plates **91***a*, **91***c* in a left side and two resonant plates **91***b*, **91***e* in a left side thereof. Lower extended resonant plate **93** comprises four resonating plates **93***a* to **93***e*: one resonant plate **93***d* in the middle and two resonant plates **93***a*, **93***c* in a left side and two resonant plates **93***b*, **93***e* in a left side thereof. One or more of resonating plates may be capacitively actuated into a Lamé resonance mode by means of electrodes (not shown) disposed along the sides of the resonance plate, as described above.

Decoupling structure **92** may have various shapes with a single anchor. As an example, decoupling structure **92** includes outer ring **95** connected to both inner corners of resonant plate **91***d* and to both inner corners of resonant plate **93***d*, and inner ring **96** disposed inside outer ring **95**. Anchor **88** is disposed at the center of inner ring **86**.

The above mechanical resonators may be proof-mass resonators made of a single semiconductor material (e.g., a single crystalline-silicon) vibrating in their bulk acoustic width/length extensional mode. These resonators can function in the first extensional mode or any of the higher modes. Such resonators made of silicon are called Silicon Bulk Acoustic Wave Resonator (SiBAR).

Although the present disclosure has been described with an exemplary embodiment, various changes and modifications may be suggested to one skilled in the art. It is intended that the present disclosure encompass such changes and modifications as fall within the scope of the appended claims.

What is claimed is:

1. A mechanical resonator comprising:

two identical plates; and

a decoupling structure comprising:

at least two first connectors, each first connector being connected to a respective one of the two identical plates;

an anchor disposed at a center of the decoupling structure;

a first ring connected to each of the two identical plates via a respective one of the at least two first connectors; and

a second ring connected to an inside of the first ring via at least two second connectors, wherein the anchor is disposed at a center of the second ring.

2. The mechanical resonator according to claim **1**, wherein the first ring has a first rectangular ring shape, and the second ring has a second rectangular ring shape, the first rectangular ring shape being larger than the second rectangular ring shape.

3. The mechanical resonator according to claim **1**, wherein the two identical plates are two identical proof-mass plates.

4. The mechanical resonator according to claim **1**, wherein each of the two identical plates is a square plate adapted to resonate in Lamé-mode.

5. The mechanical resonator according to claim **1**, wherein each of the two identical plates comprises a plurality of square plates, each square plate disposed next to one another.

6. The mechanical resonator according to claim 5, wherein

a portion of the plurality of square plates is capacitively actuated into a Lamé resonance mode.

7. The mechanical resonator according to claim 1, wherein each of the two identical plates comprises two square plates disposed next to each other in line with the decoupling structure.

8. The mechanical resonator according to claim 1, wherein each of the two identical plates comprises three square plates disposed next to one another in a row.

9. The mechanical resonator according to claim 1, wherein the two identical plates comprise:

an upper plate comprising six square plates, arranged as three-by-two square plates; and

a lower plate comprising six square plates, arranged as three-by-two square plates.

10. The mechanical resonator according to claim 9, wherein the decoupling structure is connected to:

both corners of a square plate located in a middle and inside of three-by-two square plates of the upper plate; and

both corners of a square plate located in a middle and inside of three-by-two square plates of the lower plate.

11. The mechanical resonator according to claim 10, wherein the decoupling structure is connected to:

one outer corner of a square plate located in a left side and inside of the three-by-two square plates of the upper plate;

one outer corner of a square plate located in a right side and inside of the three-by-two square plates of the upper plate;

one outer corner of a square plate located in a left side and inside of the three-by-two square plates of the lower plate; and

one outer corner of a square plate located in a right side and inside of the three-by-two square plates of the lower plate.

12. The mechanical resonator according to claim 9, wherein the two identical plates comprise:

an upper plate comprising four square plates including two square plates in a middle and one square plate in a right side and one square plate in a left side thereof, and

a lower plate comprising four square plates including two square plates in a middle and one square plate in a right side and one square plate in a left side thereof.

13. The mechanical resonator according to claim 9, wherein the two identical plates comprise:

an upper plate comprising four square plates including one square plate in a middle and two square plates in a right side and two square plates in a left side thereof; and

a lower plate comprising four square plates including one square plates in a middle and two square plates in a right side and two square plates in a left side thereof.

14. The mechanical resonator according to claim 1, wherein each of the two identical plates include at least one release perforation thereon.

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