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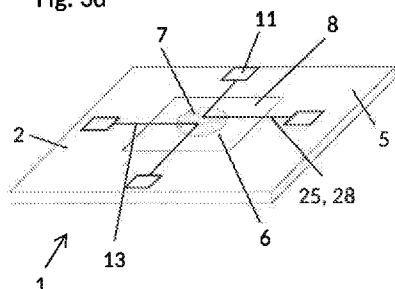
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(54) Title: INFRARED DETECTOR

Fig. 3d



(57) Abstract: Infrared detector (1), comprising a mechanical resonator (2) having a frame (5) and a membrane (6) supported by the frame (5), wherein the membrane (6) comprises an absorption area (7), wherein the detector (1) comprises a readout means (3) for sensing a frequency change of the resonance frequency of the membrane (6), wherein the detector (1) comprises a tuning means (25) for adjusting the tensile stress of the membrane (6).

Infrared detector

The invention concerns an infrared detector, more specifically a thermal infrared detector, comprising a mechanical resonator having a frame and a membrane supported by the frame, wherein the membrane comprises an absorption area, wherein the detector comprises a readout means for detecting a frequency change of the resonance frequency of the membrane. Specifically, the mechanical resonator may be a micromechanical or nanomechanical device. The readout means may comprise excitation means for exciting a vibration or oscillation of the membrane. In the present context, infrared refers to electromagnetic radiation with wavelengths from 0.75 μm to 3 mm.

Different types of nanomechanical infrared detectors have been published. Zhang et al (X. C. Zhang, E. B. Myers, J. E. Sader, and M. L. Roukes, "Nanomechanical torsional resonators for frequency-shift infrared thermal sensing.," Nano Lett., vol. 13, no. 4, pp. 1528-34, Apr. 2013.) have demonstrated the nanomechanical infrared detector based on torsional paddle supported on two nanorods acting as linear torsional springs. The detector uses a frequency shift of the resonance frequency of the torsional oscillation of the paddle caused by the IR power absorbed by the paddle and the resulting temperature change to detect low energy photons. The responsivity of the detector is defined as the ratio of the frequency shift over the power of the incident IR radiation. The responsivity is dependent on the temperature coefficient of a frequency shift, which in turn depends on the linear thermal expansion coefficient and the temperature coefficient of Young's modulus characterising the two nanorods. The thermal stress parallel to the torsional axis generates zero torque and thus has negligible influence on the resonant frequency of the torsional oscillation used in that disclosure.

Another detector based on the measurement of torsional vibrations is disclosed in US 9,400,218 B2. This type of detector does not have a membrane within the meaning of the present invention as defined in the outset.

DE 10 2013 019 560 A1 concerns a micromechanical resonator in the form of a thin bar or rod, e.g. made of silicon, strained on one or both sides, which is excited to vibrate out of the substrate plane. These are again torsional or flexural oscillations, i.e. no membrane is shown here either.

A resonator using a nanomechanical silicon nitride membrane has been studied by Luhmann et al (N. Luhmann, A. Jachimowicz, J. Schalko, P. Sadeghi, M. Sauer, A. Foelske-Schmitz, and S. Schmid, "Effect of oxygen plasma on nanomechanical silicon nitride resonators," Appl. Phys. Lett., vol. 111, p. 63103, 2017.). When used as a spectrochemical sensor based on the photothermal heating of a silicon nitride resonator, the responsivity of the sensor directly depends on the magnitude of tensile stress of the membrane. They show how the use of oxygen plasma for creation of silicon dioxide layers on the surface of the membrane causes a reduction in the effective tensile stress.

In connection with an entirely different application, namely the use of string-based temperature sensors, Larsen et al (T. Larsen, S. Schmid, and A. Boisen, "Micro string resonators as temperature sensors," in AIP Conference Proceedings, 2013, vol. 1552 8, pp. 931-936.) have studied the influence of the string temperature on the sensitivity of silicon nitride and aluminium microstrings by simulating different temperature settings with a Peltier device and measuring a shift in the resonance frequency of the strings with a laser-Doppler vibrometer. Such string-based detectors are unsuitable for use as an infrared detector, because of the small absorbing surface of each string. The string characteristics published by Larsen et al cannot be transferred to the nanorods used by Zhang et al, because the latter exploits torsional oscillations whereas the former concerns transverse oscillations.

US 2013/112876 A1 describes a "resonator", but it is a conventional bolometer in which the measuring principle is based on a resistance measurement of a thermoelectric element. The term "resonance" does not refer to a mechanical oscillation mode of a membrane, but to a plasmon resonance and is intended to enable particularly good light absorption. US 2013/112876 A1

thus concerns a fundamentally different solution than the present invention. WO 2015/053720 A1 concerns an infrared detector of the kind as defined in the outset. However, it does not disclose any means to adapt the responsivity of the detector.

DE 10 2015 214 586 A1 discloses a radiation sensor based on the measurement of a resonance frequency of a mechanical oscillation. The incident radiation changes that temperature and thereby the Young's modulus of a holding arm. The resulting oscillation frequency of an element supported only by said holding arm is measured capacitively. No means to adapt the responsivity of the detector are disclosed.

It is an object of the present invention, to provide a membrane-based infrared detector having a wider dynamic range than the prior art.

The invention proposes an infrared detector of the kind stated in the outset, the detector comprising a tuning means for adjusting the tensile stress of the membrane. The tuning means may comprise components for thermoelastically controlling the tensile stress in the membrane. By adjusting the tensile stress of the membrane, the tuning means adjusts the temperature coefficient of a frequency shift (TCF). In further consequence, this allows to change the responsivity (i.e. the input-output gain of a detector system) of the infrared detector. For example, the responsivity may be adjusted to an expected signal strength of the input signal (i.e. absorbed infrared power). The intrinsic tensile stress of the membrane, i.e. without any influence by the tuning means, can be below 20 mega Pascal (MPa), optionally below 10 MPa. For silicon nitride membranes such values may be achieved by suitable oxygen plasma exposure as disclosed by Luhmann et al. The outline of the membrane may for instance be generally rectangular or round. The membrane may itself act as absorber and/or it may comprise an absorbing film fully or partially covering the surface of the membrane.

The tuning means may comprise tempering means for adjusting a temperature of the membrane and/or the frame. The tempering

means may be a temperature controller. Optionally, the tempering means may be configured for adjusting a temperature difference between the membrane and the frame. Changing the common temperature or the temperature difference or relative temperature between the membrane and the frame, the relative dimensions of the frame and/or the membrane can be changed. On the one hand, by selectively cooling the frame (i.e. the frame and not the membrane), the size of the frame can be reduced relative to the membrane, thereby relaxing the tensile stress induced on the membrane by the frame. A similar effect can be achieved by selectively heating the membrane. On the other hand, for example by heating the frame and/or cooling the membrane, the size of the frame can be increased relative to the membrane, thereby increasing the tensile stress of the membrane.

Optionally, the tempering means may be connected to the frame. In this instance, the tempering means is configured to adjust the temperature of the frame (e.g. heating or cooling the frame). The connection between the tempering means and the frame may be a thermoconducting connection, enabling heat transport between the frame and the tempering means. For example, the tempering means may be contacting or touching the frame.

According to an exemplary embodiment, the tempering means may be a Peltier device (or Peltier heat pump, solid state refrigerator, or thermoelectric cooler). This allows for temperature control in both directions; i.e. cooling the frame relative to the membrane or heating the frame relative to the membrane, by choosing the suitable direction of electrical current.

Additionally or alternatively, the tempering means may optionally comprise a (one or more) bias radiation source(s) directed at the membrane and/or the frame. A bias radiation source can provide controlled emission of thermal radiation for heating the membrane and/or the frame, thereby controlling the relative temperature difference between the two.

In a further optional embodiment, the tempering means comprises a resistive heating element placed on the membrane and/or the

frame.

Different tempering means from the above examples may be combined to achieve and sustain the desired temperature difference between frame and membrane and to compensate the temperature balance by heat conduction between the frame and the membrane.

If membrane and frame have different thermal expansion coefficients (e.g. they can be made each of a different material with a different coefficient of thermal expansion), it is possible to induce a net stress change in the membrane by changing the temperature of the entire ensemble (i.e. the mechanical resonator 2) comprised of frame and membrane. Changing the temperature of the membrane and the frame, if they are made of different materials with different thermal expansion coefficients, causes both membrane and frame to expand or shrink according to their individual thermal expansion coefficient. Due to the difference in thermal expansion coefficient, the resulting strain in membrane and frame is different. This difference in strain creates a change in the stress of the membrane.

According to a further optional variant of the present disclosure, the tuning means may comprise an actuator for stretching or compressing the frame. By compressing the frame, the distance between opposite edges can be decreased, thereby reducing the tensile stress of the membrane in a direction transverse to the bending moment. The tuning means (or specifically, the actuator) may for instance be a piezoelectric element.

Correspondingly and with similar advantages, the tuning means may comprise an actuator for stretching or compressing the membrane. In this instance, the tuning means may comprise one or more integrated piezoelectric elements, wherein the integrated piezoelectric elements are integrated with the membrane. The use of mechanical actuation (stretching or compressing) avoids additional thermal strain on the resonator compared to overall or differential heating or cooling. Also, tuning may be

performed at lower average temperature, thereby keeping the working temperature within a smaller range.

Optionally, the membrane may be intrinsically electrically conductive and/or may comprise one or more conductive elements, wherein the tuning means may comprise one or more electrodes spaced apart from the membrane and configured to create an electrostatic potential difference between said one or more electrodes and the membrane and/or the one or more conductive elements. In this instance, the membrane may be subjected to capacitive stress tuning. The membrane may be biased by electrostatic forces. For example, an attractive potential can be applied between a conductive element attached to the membrane on the one hand and an electrode arranged on a side opposite the absorption area and spaced apart (e.g. [1-10 μm]) from the membrane. Thereby the membrane may assume a slightly domed shape, with an increased tensile stress proportional to the increase of the membrane surface corresponding to the assumed shape.

The membrane may comprise two or more tethers and may be supported by the frame via said tethers. The tethers are part of the membrane. The use of tethers reduces the amount of material making up the membrane, thereby achieving a lighter and more responsive membrane. Also, a membrane comprising tethers can be less rigid than a membrane of the same planar extensions without tethers. As tether we understand e.g. a limb at a border of the membrane. A tether can typically be a narrow, band-shaped portion ("tethered portion") of the membrane, without limitation to a rectangular outline of that portion. The tethers may be made of the same material as other portions of the membrane; in particular, the material of the membrane in the absorption area and the material of any tethered portions of the membrane may be the same material. The use of tethers also facilitates a connection between the membrane and the support frame. Alternatively, or additionally, the membrane may be perforated with through holes to (further) reduce weight and rigidity and increase responsivity.

In this context, the tuning means may be for adjusting the

tensile stress on one or more of the tethers. In particular, the tuning means may be able to adjust the tensile stress on each tether individually. This facilitates achieving a homogeneous tensile stress in all directions within the plane of the membrane.

For example, the tuning means may comprise a piezoelectric element integrated in one or more of the tethers. In this case, the tuning means may be produced at least partially together with the membrane. Accordingly, the presence and location of the tuning means will influence the resonance frequency of the membrane.

The tuning means may comprise a microelectromechanical thermomechanical actuator integrated in the frame. In this case, the tuning means may be produced by the thermomechanical expansion of micromechanical elements whose temperature can be controlled via an electric heating current. The thermomechanical microactuator can be designed to either create a force pulling or pushing the ends of one or several of the tethers. Accordingly, the presence and location of the tuning means will influence the resonance frequency of the membrane. For details and examples see [Lott, Christian D., Timothy W. McLain, John N. Harb, and Larry L. Howell. "Modeling the thermal behavior of a surface-micromachined linear-displacement thermomechanical microactuator." *Sensors and Actuators A: Physical* 101, no. 1-2 (2002): 239-250.] and [Rebecca Cragun and Larry L. Howell. "Linear thermomechanical microactuators." In *Proc. ASME IMECE*, pp. 181-188. 1999.].

The tuning means may comprise a microelectromechanical capacitive element integrated in the frame. In this case, the tuning means may be produced by the attractive force between two conductive microelements of different electric potential. The two elements can e.g. be designed as flat co-planar electrodes or as a comb-drive. Accordingly, the presence and location of the tuning means will influence the resonance frequency of the membrane. For details and examples see [Selcuk Oguz Erbil, Utku Hatipoglu, Cenk Yanik, Mahyar Ghavami, Atakan B. Ari, Mert Yuksel, and M. Selim Hanay, "Full Electrostatic Control of

Nanomechanical Buckling", arXiv:1902.05037 [physics.app-ph].].

An input for the tuning means (i.e. its configuration or settings or other parameters of operation) can be pre-determined based on an expected signal amplitude. For example, if a certain power of infrared radiation is expected to be observed, the tuning means can be controlled accordingly. If – in a further example – a detection of the real presence of any infrared radiation is desired, the tuning means can be controlled to achieve the highest possible and reliable responsivity.

According to an exemplary embodiment of the present method, the controlling of the tuning means includes: evaluating a signal previously obtained from the readout means, and controlling an input for the tuning means based on the evaluated signal. This variant assumes, that a future signal will most likely have similar characteristics (in particular radiation power) as the signals most recently observed.

The input for the tuning means may be determined from a peak or average of the evaluated signal over a predetermined time span. The predetermined time span may for example be between 1 and 100 milliseconds.

Correspondingly, the present invention concerns a method for controlling an infrared detector as defined above, the method comprising: evaluating a signal obtained from the readout means of the infrared detector, and controlling an input for the tuning means based on the evaluated signal.

Specifically, evaluating the signal obtained from the readout means of the infrared detector may comprise determining a peak signal or an average signal of the signal over a predetermined time span, and may comprise controlling the tuning means to increase the tensile stress of the membrane if the peak signal or the average signal exceeds a predetermined upper threshold, and may comprise controlling the tuning means to decrease the tensile stress of the membrane if the peak signal or the average signal drops below a predetermined lower threshold.

Referring now to the drawings, wherein the figures are for purposes of illustrating the present disclosure and not for purposes of limiting the same,

Figures 1a-h schematically show an infrared detector with different options for transduction (actuation and/or readout);

Figures 2a-e schematically show different possible membrane shapes;

Figures 3a-f schematically show different possible tuning means to change the stress inside the membrane;

Fig. 4 schematically shows a diagram of the responsivity as a function of the tensile stress of the membrane; and

Fig. 5 schematically shows functional elements implemented in electronics of an exemplary infrared detector according to the present disclosure.

Fig. 1 shows an infrared detector 1 comprising a micromechanical resonator 2. The infrared detector 1 is provided for uncooled operation (e.g. at normal temperature of 20°C) usually at vacuum. The resonator 2 comprises a frame 5 and a membrane 6 supported by the frame 5. The resonator 2 is fabricated from a silicon wafer coated with typically 50 nm silicon nitride by low-pressure chemical vapour deposition. At this stage, the nominal tensile stress of the membrane 6 is approximately 50-200 MPa. By controlled treatment with oxygen plasma (see above description and references), the intrinsic tensile stress of the membrane 6 is reduced to approximately 2-10 MPa. The present disclosure is not limited to a specific number in material. Other materials for producing the membrane are - without limitation - any 2D materials (e.g. graphene, molybdenum disulphide, et cetera), polymers (e.g. SU-8), pyrolytic carbon, silicon carbide, aluminium nitride, silicon dioxide, silicon, gallium arsenide or titanium nitride.

The membrane 6 has an essentially square outline (but it could also have another shape, examples shown in figures 2a-e) and comprises an essentially circular absorption area 7 in its centre (but it could have an arbitrary shape), covering approximately 20% of the total area of the membrane 6 (the coverage of the absorber can be anything in between 0-100%, e.g. in the extreme cases an absorber film as mentioned below may

cover the entire surface of the membrane or the membrane may do without an additional absorber film and the membrane surface itself forms the absorption area). The area 8 around and outside of the absorption area 7 acts as a thermal isolator between the absorption area 7 and the frame 5. The absorber area 7 may be defined by a thin absorber film on top of the silicon nitride membrane substrate. The thin absorber film can be made of titanium nitride or bismuth for example.

The membrane vibration can be detected by various readout means, a few examples are schematically shown in figures 1a-h. The readout means are each configured for detecting a frequency change of the resonance frequency of the membrane 6.

In the examples shown in figures 1a-d the readout means comprises a transduction means. In fig. 1a a first transduction means comprises a wire 9 meandering along an edge 10 of the membrane 6. The wire 9 acts as a sensor as well as an excitation means for exciting a vibration or oscillation of the membrane 6. The meandering electrode formed by the wire 9 along the edge 10 of the membrane 6 can be used on the one hand to thermoelastically actuate the vibration of the membrane, or on the other hand to piezoresistively detect the vibration of the membrane 6. By alternating current through the wire 9, the temperature of the wire 9 changes and the wire 9 exerts an oscillating mechanical force on the membrane 6, thereby exciting oscillation of the membrane 6 itself. By sensing the resistance of the wire 9, mechanical changes of the wire 9 (in particular its length) caused by the displacement of the membrane 6, to which the wire 9 is attached, can be detected. The wire 9 can be connected to an electric controller via the contact pads 11.

A second transduction means according to figures 1b-d comprises a wire 12 or wires 13, 14, 15, 16 running across the membrane 6 and allowing an inductive transduction. The wires can be connected to an electric controller via respective contact pads 11. In order for this transduction to work, the wires 12-16 have to be placed in a magnetic field. By alternating current through the wires 12-16, an oscillating Lorentz force is created which can be used to actuate the membrane 6. The motion of the wires

12-16 inside the magnetic field induces an electromotive voltage, by which the vibration of the membrane can be readout.

A third transduction means is shown in fig. 1e. In this example, the membrane vibration can be detected optically via interference or deflection of a probing light beam 17 (indicated as an arrow). The detector may comprise a light source for producing the probing light beam and an optical detector for analysing changes to the reflection and/or transmission of the probing light beam 17. Actuation is possible via radiation pressure of the light beam or via thermoelastical strain caused by the local heating due to light absorption of the membrane/frame structure. In general, the light beam may be radiating onto the membrane 6, membrane edge, or frame 5. The photothermal heating of the frame/membrane material causes a thermoelastically induced strain. An amplitude modulated light beam will hence cause an oscillating thermomechanical strain, which can actuate the membrane 6. The thermal relaxation of the membrane 6 is fast enough to support this mechanism at oscillation frequencies of at least up to 20 KHz. The membrane 6 can further be actuated by the radiation pressure exerted by the light beam. The power of the probing beam 17 may be in the micro-Watt range. For actuation by radiation pressure, the probing beam 17 may be pulsed at the (idle) resonance frequency of the membrane 6. The detection of the reflected light can be used to readout the membrane motion.

A fourth transduction means in fig. 1f uses coplanar electrodes 18 to transduce a membrane vibration via electrostatic interaction. In this example, the readout means comprises a set of coplanar electrodes 18 brought close to the membrane 6. Applying an oscillating voltage on the electrodes 18 causes an electrostatic force pulling the membrane 6 closer to the coplanar electrodes 18. This electrostatic force can be used to actuate the membrane 6. If there is a static voltage applied to the co-planar electrodes 18, the motion of the membrane 6 moves charges inside the electrodes 18. This electrostatic current can be used to detect the motion of the membrane 6. The electrodes 18 can be electrically contacted via contact pads 19 arranged on a separate electrode support 20.

A means for mechanical actuation is shown in fig. 1g, where the resonator 2, more specifically the frame 5, is in mechanical contact with a piezoelectric element 21, which shakes the frame 5 in a direction perpendicular to the surface of the membrane 6, resulting in oscillation of the membrane 6.

Another means of transduction is shown in fig. 1h, where the membrane transduction is realized by integrated piezoelectric elements 22 which on the one hand can induce an oscillating strain in order to actuate the membrane. On the other hand, strain induced by the membrane vibration creates a piezoelectric voltage which can be detected. The integrated piezoelectric elements 22 are integrated with the membrane 6. For example, they comprise a first conducting (e.g. metal) layer on the surface of the membrane, a layer of piezoelectric material above the first conducting layer, and a second conducting layer above the layer of piezoelectric material. The contact pads 23 indicated in fig. 1h are schematically simplified; in more detail, two contact pads may be connected to each integrated piezoelectric element, each connected to one of the conducting layers respectively. The orientation of the piezoelectric material may be such that the principal direction of deformation is perpendicular to the surface of the membrane 6. Adjustment of the tensile stress of the membrane is then achieved by the resulting transverse strain, which is parallel to the membrane.

For simplicity figures 1a-h omit an electronic readout circuit that may be connected to the described sensing means (e.g. wires, electrodes, etc.). Such an electronic readout circuit may or may not be provided as a part of the disclosed infrared detector.

The membrane 6 can have different shapes. Figures 2a-e show some examples for membrane shapes, wherein the rest of the detector 1 is omitted for simplicity. In the example shown in fig. 2a, the membrane 6 is essentially square or rectangular. It is further possible to improve the thermal isolation by perforating the membrane, as shown in fig. 2b. In the example shown in fig. 2b, the membrane 6 is perforated. A multiplicity of through holes 24 is arranged in a regular pattern across the entire area of the

membrane 6. An extreme perforation is shown in fig. 2c, where the membrane 6 has an essentially cross-shaped (or trampoline-shaped) footprint with the absorption area 7 arranged in the centre spanned by several tethers. More specifically, the tethers may be spanned between the absorption area 7 of the membrane 6 and the frame 5 supporting the membrane 6. In general, the absorption area may also extend to one or more tethers. The number of tethers is not limited and can vary from a minimum of two to a multitude. Furthermore, the membrane 6 can also be round (circular or oval), as shown in fig. 2d. Also, a round membrane 6 can be perforated (see fig. 2e). In all these different shapes, the absorption area 7 is located in the centre of the membrane 6 and covers different portions of the total membrane surface. Within the scope of the present disclosure, the absorption area may correspond to the surface area of the membrane, i.e. the entire membrane 6 may act as absorber. Optionally, the entire membrane area may be covered evenly with an absorber film.

The detector 1 comprises a tuning means 25 for adjusting the tensile stress of the membrane 6. The tuning means 25 can be an external Peltier device 26 (see fig. 3a), connected to the frame 5. The Peltier device 26 act as tempering means for adjusting a temperature of the frame 5 and membrane 6. Optionally, a heating light 27 similar to the probing beam 17 (see fig. 3e; compare fig 1e), wherein for heating incoherent light of basically any wavelength may be used, can be directed at the membrane 6 acting as bias radiation source and part of a tempering means in order to heat the membrane 6 in a controlled fashion. Alternatively, or additionally, a resistive heating element 28 can be integrated on the membrane 6, providing a tempering means of the membrane 6 and enabling control of the temperature of the membrane 6. The resistive heating element 28 may use the same wires 13, 14 (see fig. 1b) that can be used for readout and actuation, e.g. by applying a constant bias current. Optionally, the stress can further be controlled by inducing mechanical strain on the frame and/or membrane itself. Such strain can be induced e.g. by fixing the frame to an expanding piezoelectric element 29 (see fig 3b) and thereby controlling the strain of the frame, or by integrating one or more expanding piezoelectric

elements 30 directly on the membrane (see fig. 3c), similar to the integrated piezoelectric elements 22 described above, and thereby controlling the strain of the membrane. Alternatively, or additionally, the tensile stress of the membrane 6 can be tuned by applying a capacitive static force acting in normal direction to the membrane. Such a capacitive force can be generated by applying an electric potential difference between the membrane 6 and a set of coplanar electrodes 18. For this purpose, either the membrane is intrinsically conductive, or it is made conductive by adding a conductive element.

Alternatively, or additionally, in the case that the membrane 6 has the shape of a trampoline (Fig. 2c) it is possible to adjust the tensile stress by applying a force at one or several of the trampoline tethers (see fig. 3f, the arrows indicating the effective direction of the applied forces). The required force can be generated by either integrated piezoelectric elements or integrated microelectromechanical thermomechanical actuators, or integrated microelectromechanical capacitive actuators.

The diagram in fig. 4 qualitatively illustrates the responsivity R (in W^{-1}) of a detector 1 according to the present disclosure as a function of the tensile stress σ (in Pa) of the membrane 6. For comparison, the intrinsic tensile stress of the membrane 6 produced by LPCVD 31 and before oxygen plasma treatment is indicated on the right-hand side at 50 MPa. By e.g. the oxygen plasma treatment 32, the intrinsic tensile stress of the membrane 6 is decreased statically to ~ 2 MPa (therefore are indicated as "static stress control" in fig. 4). This intrinsic tensile stress defines the centre of a range 33 of tensile stresses that is accessible by suitable (dynamic) adjustment using the tuning means 25 (indicated as "dynamic stress control" in fig. 4), i.e. the Peltier device 26, the piezoelectric devices 29, 30, the resistive heating elements 28 and/or the bias radiation source with the heating light 27. The left-hand side of this range indicates a maximum responsivity achievable in the illustrated example. At the point where the membrane gets a net compressive stress, no sensible signal could be observed, because the membrane 6 would be in a state of buckling which would yield an unpredictable frequency response.

Fig. 5 schematically shows a control structure 34 of an infrared detector 1 according to the present disclosure. This also illustrates a method for controlling the infrared detector 1 as will be described in more detail below. While this method adjusts the tensile stress during operation ("on-the-fly"), the present disclosure is not limited in this respect and also tuning means supporting a fixed or predetermined setting of the tensile stress of the membrane are within the scope of the present disclosure.

According to the embodiment shown in fig. 5, the infrared detector 1 is part of two control loops 35, 38. The frequency control loop 35 is used to determine the resonance frequency of the resonator 2 of the infrared detector 1. A pre-amplifier 36 is connected to the read-out means 3 of the detector 1. The pre-amplifier 34 is configured to amplify a signal received from the read-out means 3. The output of the pre-amplifier 34 is connected to an oscillator circuit 37 (which can e.g. be a phase-locked loop or a positive feedback), which is configured to receive the pre-amplified signal from the pre-amplifier 36 and to excite the resonator 2 of the detector 1 at its resonance frequency in order to determine the frequency response to the detected electromagnetic radiation (hence, the schematically indicated control flow from the oscillator circuit 37 back to the detector 1).

The second control loop 38 is for dynamic range control, more specifically, for adjusting the tensile stress of the membrane 6 of the detector 1 dependent on the observed signal as determined by the oscillator circuit 37. A dynamic range controller 39 receives the output signal of the oscillator circuit 37 (e.g. a frequency shift of the resonance frequency proportional to the intensity of an infrared signal incident on the infrared detector 1). The dynamic range controller 39 determines a peak signal or an average signal of said output signal over a predetermined time span. It compares the determined peak signal or average signal with a predetermined upper threshold. If the determined peak signal or average signal exceeds the predetermined upper threshold, the dynamic range controller 39 controls the tuning driver 40 to increase the tensile stress of

the membrane. On the other hand, the dynamic range controller 39 also compares the determined peak signal or average signal with a predetermined lower threshold and controls the tuning driver 40 to decrease the tensile stress of the membrane in case the peak signal or average signal drops below said predetermined lower threshold. The dynamic range controller 39 may obtain the predetermined thresholds (i.e. the predetermined upper threshold and the predetermined lower threshold) from a dynamic range setpoint provided to the dynamic range controller 39 as indicated in Fig. 5. The skilled person will be aware, that this example describes only a very basic implementation; any other suitable transfer function can be applied to dynamically control the responsivity of the infrared detector 1 via the tensile stress of the membrane 6 within the scope of the present disclosure. The tuning driver 40 is connected to the tuning means 25 of the detector 1 and controls the tuning means 25 according to the commands received from the dynamic range controller 39.

Claims:

1. Infrared detector (1), comprising
a mechanical resonator (2) having
a frame (5) and
a membrane (6) supported by the frame (5),
wherein the membrane (6) comprises an absorption area (7),
wherein the detector (1) comprises a readout means (3) for
detecting a frequency change of the resonance frequency of the
membrane (6)
characterized in that the detector (1) comprises a tuning
means (25) for adjusting the tensile stress of the membrane (6).
2. Infrared detector (1) according to claim 1, characterized in
that the tuning means (25) comprises tempering means for
adjusting a temperature of the membrane (6) and/or the frame
(5).
3. Infrared detector (1) according to claim 2, characterized in
that the tempering means is connected to the frame (5).
4. Infrared detector (1) according to claim 3, characterized in
that the tempering means is a Peltier device (26).
5. Infrared detector (1) according to one of claims 2 to 4,
characterized in that the tempering means comprises a bias
radiation source directed at the membrane (6) and/or the frame
(5).
6. Infrared detector (1) according to one of claims 2 to 4,
characterized in that the tempering means comprises a resistive
heating element (28) placed on the membrane (6) and/or the frame
(5).
7. Infrared detector (1) according to one of claims 2 to 6,
characterized in that the frame (5) and the membrane (6) have
different thermal expansion coefficients.
8. Infrared detector (1) according to one of claims 1 to 7,
characterized in that the tuning means (25) comprises an

actuator for stretching or compressing the frame (5).

9. Infrared detector (1) according to claim 8, characterized in that the tuning means (25) is a piezoelectric element (29) configured for stretching or compressing the frame (5).

10. Infrared detector (1) according to one of claims 1 to 9, characterized in that the tuning means (25) comprises an actuator for stretching or compressing the membrane (6).

11. Infrared detector (1) according to claim 10, characterized in that the tuning means (25) comprises one or more integrated piezoelectric elements (30), wherein the integrated piezoelectric elements (30) are integrated with the membrane (6).

12. Infrared detector (1) according to one of claims 1 to 11, characterized in that the membrane (6) is intrinsically electrically conductive and/or comprises one or more conductive elements, wherein the tuning means (25) comprises one or more electrodes spaced apart from the membrane (6) and configured to create an electrostatic potential difference between said one or more electrodes and the membrane (6) and/or the one or more conductive elements.

13. Infrared detector (1) according to one of claims 1 to 12, characterized in that the membrane comprises two or more tethers (31) and is supported by the frame (5) via said tethers (31).

14. Infrared detector (1) according to claim 13, characterized in that the tuning means (25) is for adjusting the tensile stress on one or more of the tethers (31).

15. Infrared detector (1) according to claim 14, characterized in that the tuning means (25) comprises a piezoelectric element integrated in one or more of the tethers (31).

16. Infrared detector (1) according to claim 14, characterized in that the tuning means (25) comprises a microelectromechanical thermomechanical actuator integrated in the frame (2).

17. Infrared detector (1) according to claim 14, characterized in that the tuning means (25) comprises a microelectromechanical capacitive element integrated in the frame (2).

18. Method for controlling an infrared detector according to 1 of claims 1 to 17, the method comprising:

evaluating a signal obtained from the readout means of the infrared detector; and

controlling an input for the tuning means based on the evaluated signal.

19. Method according to claim 18, characterised in that evaluating the signal obtained from the readout means of the infrared detector comprises determining a peak signal or an average signal of the signal over a predetermined time span, and in controlling the tuning means to increase the tensile stress of the membrane if the peak signal or the average signal exceeds a predetermined upper threshold, and in controlling the tuning means to decrease the tensile stress of the membrane if the peak signal or the average signal drops below a predetermined lower threshold.

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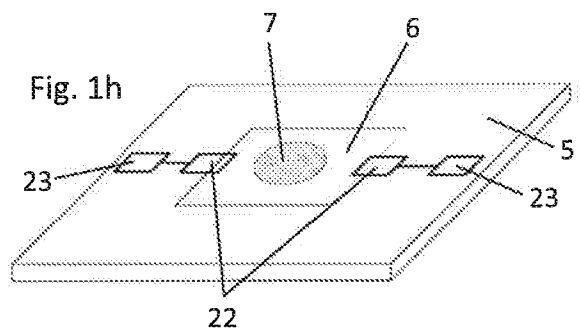
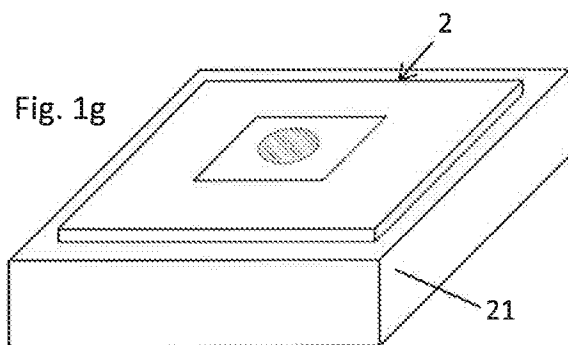
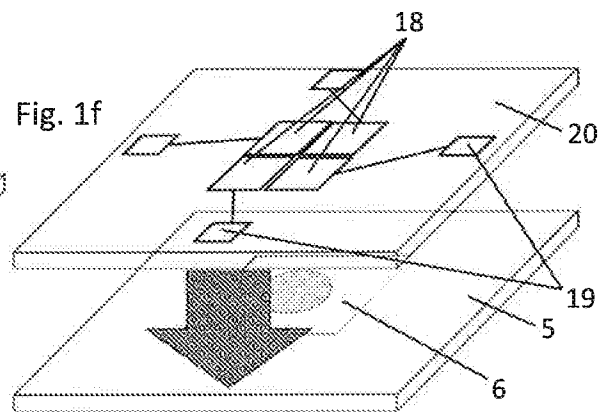
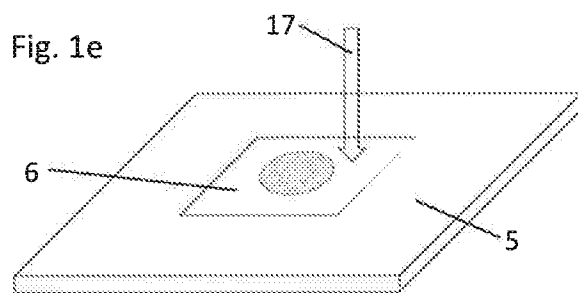
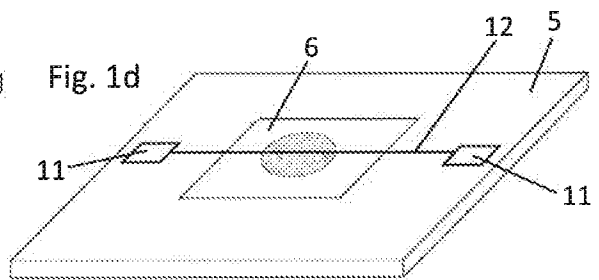
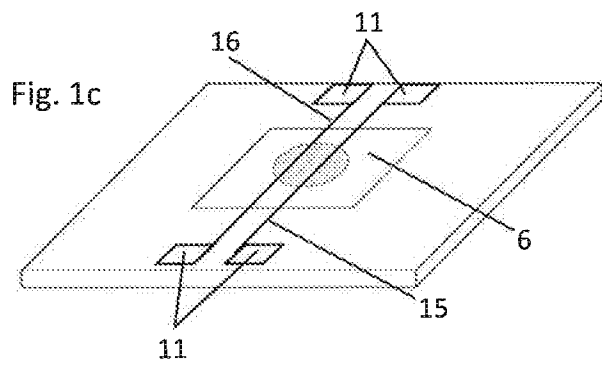
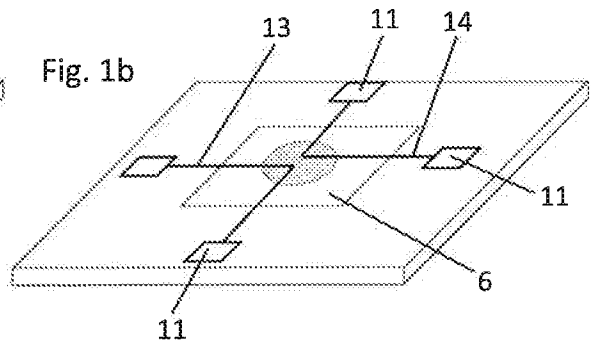
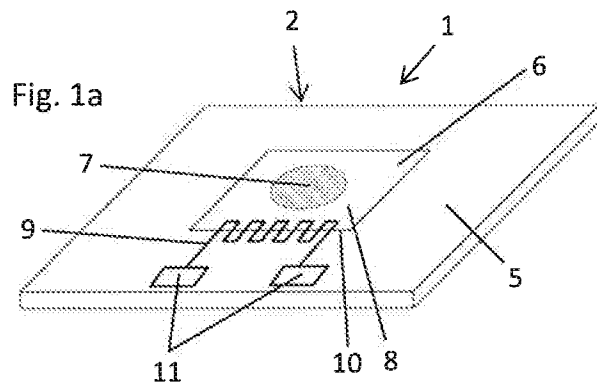


Fig. 2a

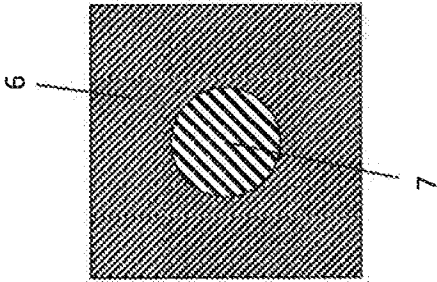


Fig. 2b

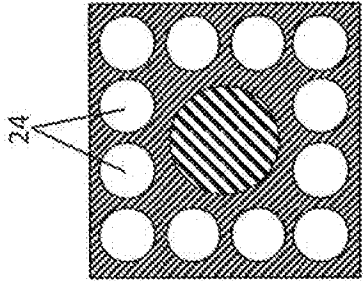


Fig. 2c

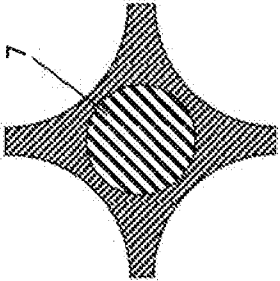


Fig. 2d

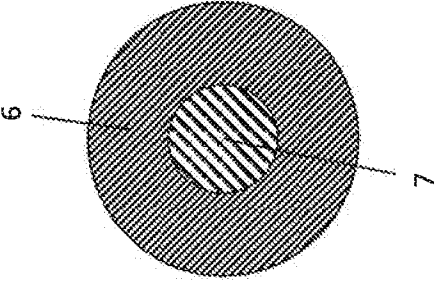
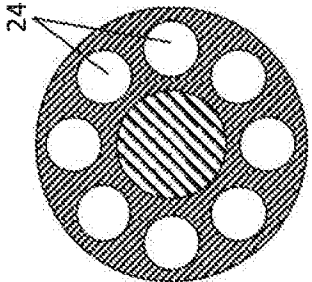


Fig. 2e



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Fig. 3a

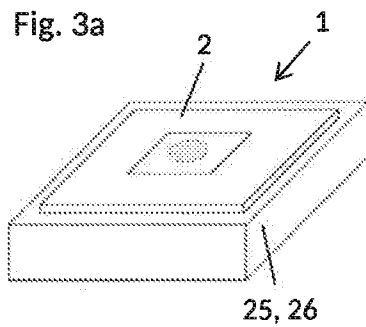


Fig. 3b

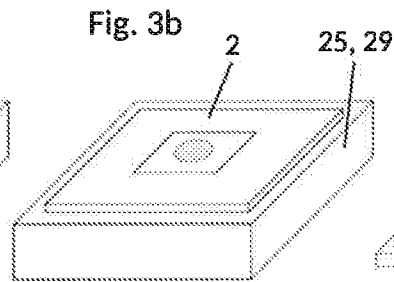


Fig. 3c

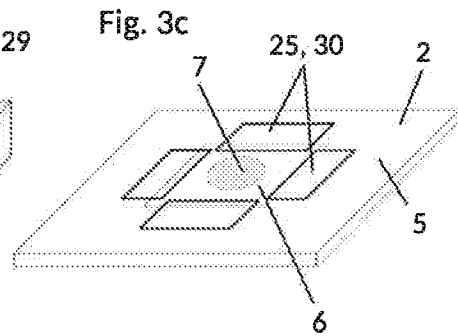


Fig. 3d

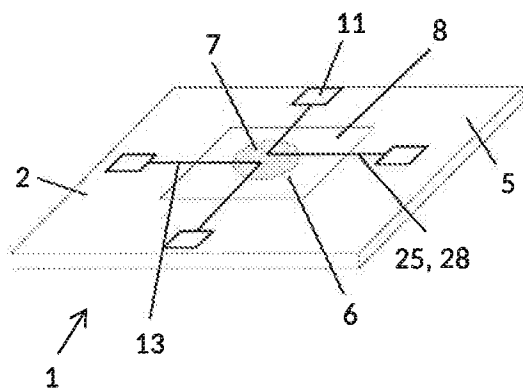


Fig. 3e

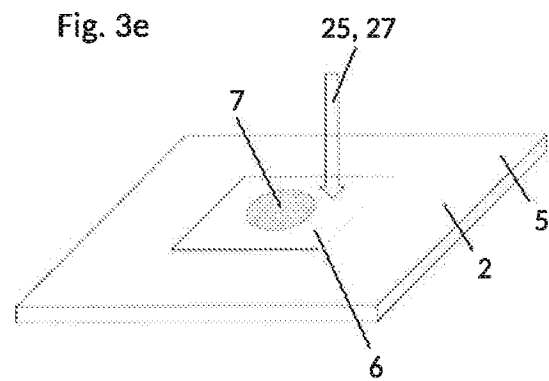
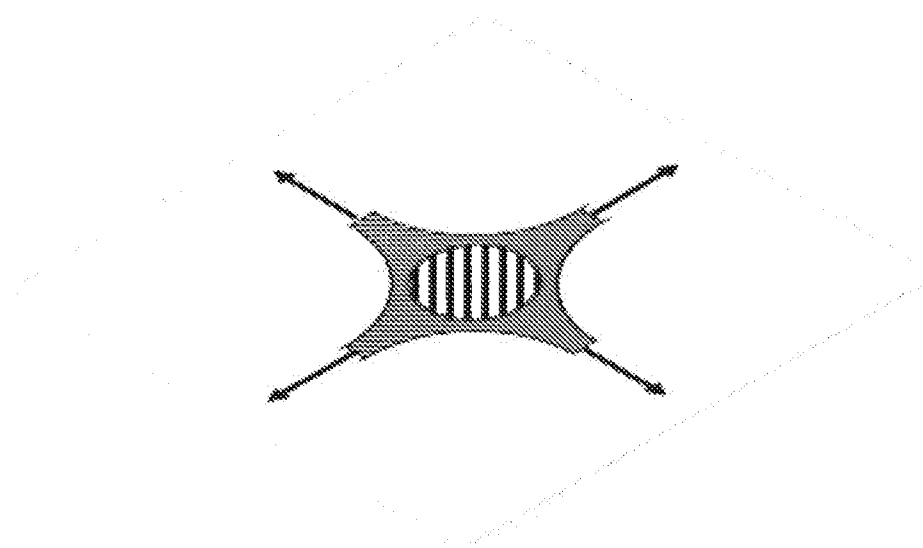


Fig. 3f



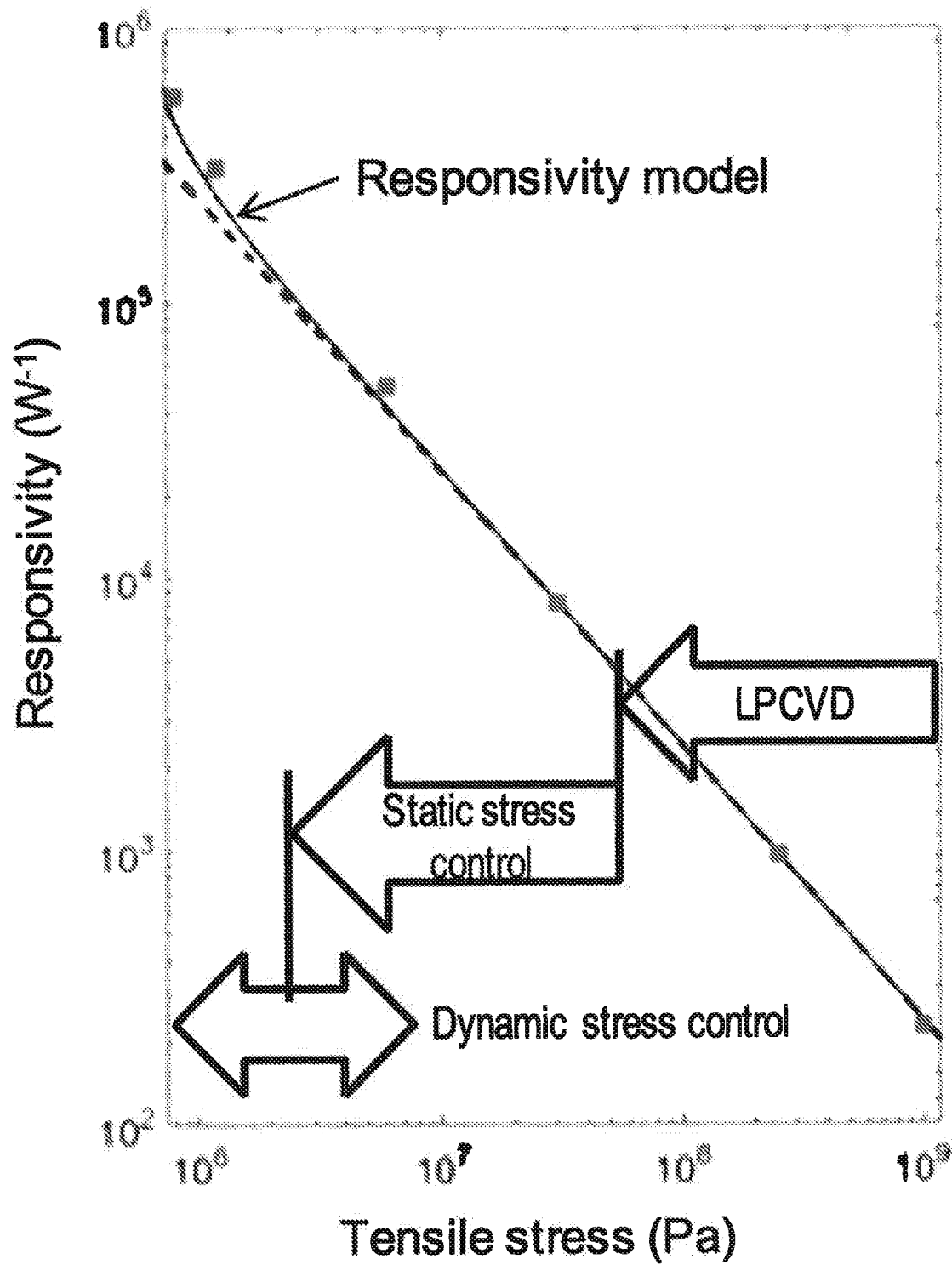


Fig. 4

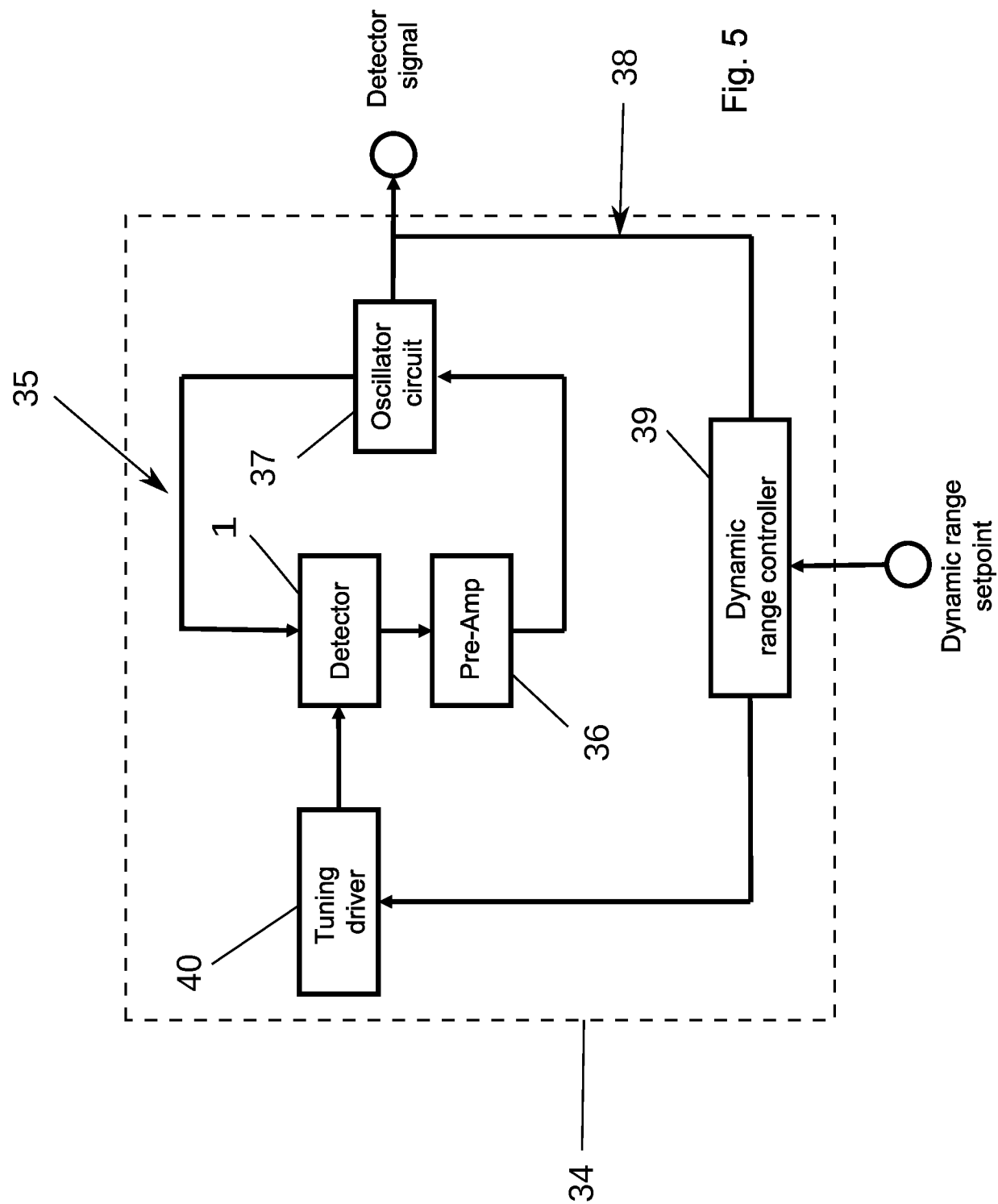


Fig. 5