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AN INFRARED RADIATION SENSITIVE DEVICE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to ^{an} ~~An~~ infrared radiation sensitive ^{device,} and more particularly to an infrared radiation sensitive device comprising a pyroelectric unit, a light receiving face on said pyroelectric unit for receiving infrared light radiated from an object to be detected, and a pair of external electrodes on opposite end surfaces of said pyroelectric unit respectively.

2. Description of the Prior Art

One prior known pyroelectric infrared sensor device 1 is shown in Fig.7A. This prior art device includes a rectangular-plate shaped pyroelectric body 1a having the top and bottom surfaces on which electrodes 2a, 3a are formed respectively with the polarization treatment being applied between the electrodes 2a, 3a as designated by arrows shown. Another prior art pyroelectric infrared sensor device 1 is shown in Fig.7B which includes a pyroelectric body 1b having the both side surfaces on which electrodes 2b, 3b are formed with the polarization treatment being carried out between the electrodes 2b, 3b as indicated by arrows. With these pyroelectric infrared sensor devices 1, the electrodes 2a, 3a and those 2b, 3b are each formed in the direction perpendicular to the polarization direction as designated by the arrows.

In these prior art pyroelectric infrared sensor devices 1, when infrared light rays 4 radiated from an object to be detected are incident on the light receiving

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plane of each pyroelectric infrared sensor device 1, a slight temperature change can take place in pyroelectric body 1a, 1b. Such temperature change would result in that a packet of surface charge carriers of the pyroelectric body 1a, 1b which carriers have been in the equilibrium condition are forced to move causing a voltage to arise accordingly. This voltage is for use in detecting or sensing the object being detected in such a way that the voltage is electrically amplified by an associated impedance conversion circuit employing field effect transistors (FETs) and is then converted into a corresponding electrical signal.

In order for such prior art pyroelectric infrared sensor devices 1 to improve the relative detection rate or "detectivity" indicative of the pyroelectric device characteristics, it has been required that the thermal insulation be attained by decreasing the thickness of the pyroelectric body per se while simultaneously causing the light receiving section which are expected to receive incoming infrared light rays to be formed in a hollow shape. This would allow the thermal or heat capacitance to decrease with the thermal time constant being decreased as low as possible thus improving resultant relative detectivity.

Unfortunately, the aforesaid prior art pyroelectric infrared sensor devices 1 are encountered with several difficulties which follow. Since it has been strictly required that the thermal insulation be accomplished while decreasing the thickness of the pyroelectric body, the mechanical strength of such pyroelectric body itself might be weakened with the durability against application of thermal shocks being also weakened rendering difficult the handling of such pyroelectric infrared sensor devices. In other words, if the pyroelectric body is decreased in

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thickness then certain risks might arise: mechanical damages including micro-cracks can occur in the pyroelectric infrared sensor devices per se due to significant thermal variations upon application of external vibrations and shocks as well as irradiation of strong infrared light rays thereonto while the performance thereof can decrease due to degradation of heat flow balance. Furthermore, since the pyroelectric body per se becomes brittle making it difficult for the pyroelectric body to be reliably supported by adhesion on a substrate, which in turn renders much difficult both settlement of its support method and attainment of accurate position alignment accuracy thereof. Due to the above difficulties the resulting performance can decrease undesirably.

Another problem faced with the prior art is that since in most cases the thickness of the pyroelectric body itself is designed to fall within the range of from 70 to 100 micrometer, the yield of production remains lowered rendering extremely difficult the manufacture or fabrication of pyroelectric infrared sensor devices per se. This would result in manufacturing costs of the prior art pyroelectric infrared sensor devices 1 being increased unwantedly.

A prior art approach to avoidance of the aforementioned problems has been known which attempts to specifically arrange electrodes of a pyroelectric infrared sensor device so that polarization of a pyroelectric body thereof occurs only near a light incidence plane (a light receiving plane) of the device. One exemplary pyroelectric infrared sensor device employing such scheme is shown in Fig.8 as generally indicated by numeral 5. This structure comes in view of the fact that the contribution of the top surface of the light receiving plane occupies most part of an

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output of pyroelectric infrared sensor devices.

More specifically, the pyroelectric infrared sensor device 5 shown in Fig.8 includes, for example, a rectangular plate-shaped pyroelectric body 6 having a top surface on which two opposed electrodes 7, 8 are formed with certain distance D being defined therebetween. Polarization treatment has been effected between the two electrodes 7, 8 by applying a direct current (DC) voltage therebetween. In this case, polarization is generated mainly at a section positionally close to the light incidence plane of infrared light rays 9 with its polarization direction being rendered parallel to the light incidence plane of infrared light rays 9; in other words, the polarization direction is identical to the x-axis direction of Fig.8.

Accordingly, this pyroelectric infrared sensor device 5 is superior than those of in Figs.7A and 7B in that the polarization of the pyroelectric body 6 may be forced to locally take place only at or near the light incidence plane (light receiving plane) of the pyroelectric infrared sensor device 6 improving the relative detectivity.

However, the above advantage of the prior art pyroelectric infrared sensor device 5 does not come without accompanying a penalty: a reduction in controllability of the relative detectivity. More specifically, in the prior art pyroelectric infrared sensor device 5, it should be required in order to change the relative detectivity that the pyroelectric body 6 for receiving infrared light rays be changed in light receiving area, which would result in increasing complexity and time. For this reason, the prior art device is not adaptable for use in stable mass production while at the same time rendering it difficult to manufacture the same at low costs.

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SUMMARY OF THE INVENTION

It is therefore an object of the invention to provide a pyroelectric infrared sensor device capable of increasing the relative detection rate and simply rendering the relative detection rate variable while at the same time rendering mass production thereof easier and cheaper.

One aspect of the invention provides the above described pyroelectric infrared sensor device which is characterized in that said pyroelectric unit comprises a plurality of pyroelectric layers, internal electrodes are respectively laid between adjacent ones of said plurality of pyroelectric layers, edges of said internal electrodes are alternatively exposed and connected to each said external electrodes at each opposite end surface of said pyroelectric unit, said pyroelectric unit is electrically polarized among said internal electrodes, and side end edges of said internal electrodes are exposed on said light receiving face.

In the above pyroelectric infrared sensor device, while the internal electrodes are alternately disposed and laminated in the pyroelectric unit, a respective one of the pyroelectric layers is reduced in thickness allowing resultant lamination of such plurality of layers to increase the opposing internal electrodes in electrode area within the pyroelectric unit. Accordingly, any desired electrical capacitance (electrostatic capacitance) may be attainable as required to obtain a pyroelectric voltage.

This may be reworded in a way as follows: With the invention, since it employs a lamination structure of the pyroelectric layers and internal electrodes, it

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becomes possible to render variable the magnitude of the electrical capacitance without having to change the light receiving area thereof by, for example, increasing or decreasing the lamination number of the internal electrodes or alternatively by changing the area of the opposed internal electrodes. Consequently, the relative detection rate or "detectivity" of the pyroelectric infrared sensor device becomes variable.

In the above pyroelectric infrared sensor device, a relative detection ratio may be variable by changing the area of said internal electrodes.

With such an arrangement, the area of internal electrodes may be variable by changing the thickness of the pyroelectric unit in particular. In this case, only the internal electrode area is rendered variable without having to change the area of the light receiving plane of the pyroelectric unit. Whereby, the electrical capacitance between the opposed internal electrodes is varied inside the pyroelectric unit causing the relative detectivity of the pyroelectric infrared sensor device to be variable.

In the above pyroelectric infrared sensor device, a relative detection ratio may be variable by changing the number of said internal electrodes.

In this case, only the number of the internal electrode area is rendered variable without having to change the area of the light receiving plane of the pyroelectric unit.

Another aspect of the invention provides a manufacturing method of a pyroelectric infrared radiation sensor device, said method comprising the steps of:

1)preparing a plurality of pyroelectric sheets made of a pyroelectric material,



- 2)forming a pyroelectric unit with internal electrodes being exposed alternately at each opposite end surface thereof by alternately laminating said pyroelectric sheets and said internal electrodes,
- 3)backing said pyroelectric unit,
- 4)forming external electrodes on each opposite end surfaces of said pyroelectric unit so as to said external electrodes are connected to said internal electrodes on each said opposite end surface of said pyroelectric unit,
- 5)polarizing said pyroelectric unit electrically among said internal electrodes via said external electrodes, and
- 6)cutting said pyroelectric unit and said external electrodes in a direction perpendicular to said internal electrodes in such a way that said internal electrodes are exposed at terminate ends thereof on the cut plane, wherein said cut plane acts as a light receiving face for receiving infrared light radiated from an object to be detected.

With such a method, the laminated pyroelectric unit is constituted by alternately disposing the plurality of pyroelectric sheets and internal electrodes. Also, the terminate ends of the internal electrodes which are externally exposed at the both end surfaces of the pyroelectric unit are connected to the external electrodes. The pyroelectric unit is polarized between the external electrodes. Further, the pyroelectric unit is cut away in the direction perpendicular to the internal electrode planes between the external electrodes. At this time, the terminate edges of the internal electrodes are exposed on the cutout planes. The cutout plans on which these internal electrodes are exposed are formed as the light

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receiving plane onto which infrared light rays are incident, thereby obtaining the pyroelectric infrared sensor device.

In the above manufacturing method, the step of cutting said pyroelectric unit may further include a step of rendering said internal electrodes variable in area by changing a thickness of said pyroelectric unit being cut.

Advantageously, at the step of cutting the pyroelectric unit, the area of internal electrodes is rendered variable by changing the cutting thickness. Whereby, the electrical capacitance (electrostatic capacitance) of opposed internal electrodes may be varied permitting suitable variation of the magnitude of the relative detectivity of the pyroelectric infrared sensor device.

In accordance with the principles of the invention, it is possible to provide a pyroelectric infrared sensor device capable of improving the relative detectivity, simply rendering the relative detectivity variable, and being stably manufactured at low cost without having to degrade the electrical characteristics.

These and other objects, features and advantages of the invention will be apparent from the following more particular description of preferred embodiments of the invention, as illustrated in the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig.1 is a perspective view of one embodiment of the present invention.

Figs.2A to 2F illustrate, in perspective view, some of the major steps in the manufacture of the pyroelectric infrared sensor device shown in Fig.1.

Fig.3 is an explosive perspective view of one exemplary sensor structure

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employing the pyroelectric infrared sensor device of Figs.1 and 2.

Fig.4 depicts electrical equivalent circuitry of the pyroelectric infrared sensor device shown in Fig.3.

Fig.5 is a circuit diagram showing another example of the pyroelectric infrared sensor employing therein the pyroelectric infrared sensor device of Figs.1 and 2.

Fig.6 is an explosive perspective view of a further exemplary sensor structure employing the pyroelectric infrared sensor device of Figs.1 and 2.

Figs.7A-7B are perspective views illustrating prior art pyroelectric infrared sensor devices.

Fig.8 is a perspective view of a further prior art pyroelectric infrared sensor device.

DETAILED DESCRIPTION OF THE INVENTION

Referring now to Fig.1, a pyroelectric infrared sensor device 10 includes a pyroelectric unit 12 which is of the planar rectangular shape and has a predefined thickness t . The pyroelectric unit 12 contains a plurality of pyroelectric layers 14, wherein rectangular plate-like internal electrodes 16 are formed between the pyroelectric layers 14, by way of example. In other words, the internal electrodes 16 are disposed within the pyroelectric unit 12 in such a manner that these are spaced apart at specified distances in the width direction thereof.

In this case, the internal electrodes 16 involve those extending from one end side of the pyroelectric unit 12 to the other end side thereof perpendicular to

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the length direction thereof, and the remaining ones extending from the other end side to the one end side in a way such that the former and the latter are alternately formed. These internal electrodes 16 are formed such that certain terminate edges thereof are alternately exposed on the both end surfaces - i.e. the one end surface and the other end surface - perpendicular to the length of the pyroelectric unit 12.

Furthermore, external electrodes 18, 18 are formed respectively on the one end surface and the other end surface of the pyroelectric unit 12 perpendicular to the length direction thereof such that these are connected to the internal electrodes 16. In addition, the side end edges of internal electrodes 16 are exposed on the top and bottom surfaces of the pyroelectric unit 12 in the illustrative state. More specifically, the pyroelectric unit 12 is such that certain side end edges of the internal electrodes 16 perpendicular to the thickness direction are exposed on the top surface of pyroelectric unit 12 whereas the opposite side end edges of the internal electrodes 16 perpendicular to the thickness direction are exposed on the bottom surface of it.

In the pyroelectric infrared sensor device 10 in accordance with this embodiment, the top surface of the pyroelectric unit 12 on which the certain side end edges of the internal electrodes 16 are exposed is formed as what is called the "infrared light receiving plane" for incidence of infrared light rays. In this pyroelectric infrared sensor device 10, polarization treatment has been effected among the internal electrodes 16 by application of a DC voltage via the opposite external electrodes 18. In other words, in this pyroelectric infrared sensor device

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10, the polarization treatment has been done in the horizontal direction with respect to its infrared light receiving plane.

An explanation will now be given of one exemplary manufacturing method of the pyroelectric infrared sensor device 10 of Fig.1 with reference to Figs.2A to 2F.

To fabricate the pyroelectric infrared sensor device 10 shown in Fig.1, first of all, a pyroelectric ceramics measuring 50 to 100 mm in thickness, for example, is prepared, which is then subject to lapping treatment to have a predetermined shape. When this is done, as shown in Fig.2A, a pyroelectric ceramics sheet 14a constituting the pyroelectric layer 14 is manufactured which is of a planar rectangular shape and has a predefined size. Similarly, a plurality of pyroelectric ceramics sheets 14a are prepared. Tetragonal-system lead titanate ceramics may be preferably employed as the material thereof.

Then, a conductive pattern 16a which is made of an electrode material acting as the internal electrode 16 is formed by printing techniques such as the screen print method on a respective one of the plurality of pyroelectric ceramics sheets 14a. In this embodiment, as shown in Fig.2B, electrode patterns 16a are respectively formed on the pyroelectric ceramics sheets 14a corresponding to intermediate layers except the uppermost and lowermost ones of the pyroelectric layers 14. These electrode patterns 16a are formed in such a manner that the edges of them are alternately exposed on the both terminate edges of the pyroelectric ceramics sheets 14a perpendicular to the length direction thereof. Typically, gold (Au), silver (Ag), aluminum (Al) or the like is preferably employed as

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the electrode material for use as the internal electrodes 16; however, alloys made of nickel (Ni), chromium (Cr) or the like may alternatively be used for formation of the same.

Next, these pyroelectric ceramics 14a are laminated and adhered to be hardened together by use of an adhesive forming a multilayer lamination structure 20 of pyroelectric ceramics as shown in Fig.2C. Note that the pyroelectric ceramics lamination structure 20 may alternatively be formed by a method including the steps of laminating the pyroelectric ceramics sheets 14a and adhering them together by a baking process.

Furthermore, metal paste (not shown) are deposited on the opposite terminate surfaces of this pyroelectric ceramics lamination structure 20 perpendicular to the length direction thereof, which pastes are made of a chosen electrode materials to constitute the external electrodes 18. Thereafter, this lamination structure 20 is backed for hardening. Whereby, as shown in Fig.2D, external electrodes 18a are formed on the both terminate surfaces of the pyroelectric ceramics lamination structure 20 perpendicular to the length direction thereof.

The pyroelectric ceramics lamination structure 20 is then subject to polarization treatment among the internal electrodes 16a via the opposite external electrodes 18a. In this case, a DC voltage of for example from 2.0 to 4.0 kilovolts per millimeter (KV/mm) is applied between the external electrodes 18a for sixty (60) minutes at temperatures of 100 to 150°C.

Thereafter, as shown by dash-and-two-dot lines in Fig. 2E, the pyroelectric

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ceramics lamination structure 20 is cut away at a pitch of a predetermined thickness t perpendicular to the plane of internal electrodes 16, thus forming a plurality of pieces of pyroelectric units 12 each of which may be identical to that shown in Fig.1 and Fig.2F.

Note that the manufacturing method of the pyroelectric infrared sensor device 10 should not be exclusively limited to the above embodiment only; the pyroelectric infrared sensor device 10 may alternatively be formed by use of a manufacturing method as will be set forth below. First, a base material sheet is prepared which is made of a pyroelectric ceramics green sheet. This base material sheet is formed to a thin-film sheet member (thin plate shape) measuring, for example, 30 to 80 micrometer in thickness by pyroelectric material slurring. The base-material sheet is suitably cut into a specified shape thus forming a plurality of pyroelectric sheets.

Next, electrode patterns made of a chosen electrode material are formed by print techniques for example on the pyroelectric sheets in the same fabrication method as that discussed previously. These pyroelectric sheets are laminated by solderless contact bonding on one another in a disposal arrangement similar to that of the aforesaid fabrication method; then, resultant structure is backed providing one integral pyroelectric sheet lamination structure. Further, external electrodes made of an electrode material is formed on the both terminate surfaces of the pyroelectric sheet lamination structure; next, polarization treatment is carried out between the external electrodes in a way similar to that of the fabrication method stated supra. Thereafter, the pyroelectric sheet lamination structure is cut

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at a specified thickness in the direction perpendicular to the principal plane of internal electrodes, thereby fabricating a pyroelectric unit 12.

The pyroelectric unit 12 thus fabricated by the foregoing manufacturing methods is such that the terminate edges of the internal electrodes 16 as laminated and disposed at certain intervals therebetween are exposed on the opposite terminate surfaces of pyroelectric unit 12 perpendicular the length thereof while causing the external electrodes 18 to be connected to the internal electrodes 16. Moreover, the both side terminate edges of such internal electrodes 16 perpendicular to the width thereof are exposed on the top and bottom surfaces of the pyroelectric unit 12 in the illustrative state; in this embodiment, the top surface serves as the infrared light receiving plane. The pyroelectric unit 12 as fabricated in this way is adaptable for use with infrared light sensor modules.

Turning now to Fig.3, a pyroelectric infrared sensor module 30 in accordance with one possible example employing the pyroelectric infrared sensor devices shown in Figs.1 and 2 includes a stem 32. The pyroelectric infrared sensor device 10 discussed supra is disposed on the stem 32. Also disposed on the stem 32 is a field effect transistor (FET) 34 which is spaced apart from the pyroelectric infrared sensor device 10 with certain distance being defined therebetween. Further disposed on the stem 32 are terminal pins 36a, 36b and 36c for electrical interconnection.

The gate terminal of FET 34 is connected to one external electrode 18 through an electrode pattern 38, by way of example. The drain terminal of FET 34 is connected via a conductive wire 40 to the terminal pin 36a. The source

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terminal of FET 34 is connected via a conductive wire 42 to the terminal pin 36b. The terminal pin 36c is used as the Earth terminal, which is connected via a conductive wire 44 to the other external electrode 18 of the pyroelectric infrared sensor device 10.

As may be readily seen by those skilled in the art from viewing Fig.4, a resistor 46 for conversion of a pyroelectric current into a corresponding voltage is connected in parallel to the pyroelectric infrared sensor device 10. Note here that a chip component may be employed as this resistor 46, or alternatively, such resistor 46 may be formed of a resistive pattern as printed on the stem 32.

An associated can casing 50 is of a square bracket (J) shape in cross-section. The can casing 50 has a top plate or "ceiling" with a through-going hole 50a of almost the rectangular shape being defined at the center thereof. An optical filter 48 is rigidly attached to the inner surface of ceiling plate of casing 50 to ensure that filter 48 overlies the pyroelectric infrared sensor device 10 as mounted on the substrate thus enabling sensor device 10 to receive incoming rays of infrared light radiated from a target object being detected through filter 48. The can casing 50 is adhered to the stem 32. The interior space as defined by the optical filter 48, can casing 50 and stem 32 assembled may be environmentally sealed.

The pyroelectric infrared sensor 30 of Fig.3 has electrical equivalent circuitry shown in Fig.4. In this pyroelectric infrared sensor module 30, when thermal energy is given upon incidence of infrared light rays onto the top surface (light receiving plane) of the pyroelectric infrared sensor device 10, some



pyroelectric current occurs in the pyroelectric infrared sensor device 10. This pyroelectric current may be obtained as a voltage by use of the synthetic resistance of the resistor 46 and inherent electrical resistance of the sensor device 10 per se. This voltage is input to the gate terminal of FET 34. At this time, a bias voltage is applied to the drain terminal of FET 34 while causing the source terminal of FET 34 to be coupled to ground.

Accordingly, resultant pyroelectric current in the pyroelectric infrared sensor device 10 is impedance-converted by a combination of the pyroelectric infrared sensor device 10, resistor 46 and FET 34 into an output voltage which is derived from the terminal pin 36b.

With this pyroelectric infrared sensor 30, since the pyroelectric infrared sensor device 10 is formed using the manufacturing method shown in Fig.2, the internal electrodes 16 are disposed so as to oppose each other perpendicular to the width direction of the pyroelectric unit 12 and the pyroelectric unit 12 is polarized in the horizontal direction with respect to the infrared light receiving plane thereof. For this reason, there can be obtained the pyroelectric infrared sensor device 10 which does no longer depend upon the thickness direction of the pyroelectric body unlike the prior art including those shown in Figs.7 and 8.

Further, the pyroelectric infrared sensor device 10 is specifically arranged to have the alternate lamination structure of pyroelectric layers 14 and internal electrodes 16. In this case, the pyroelectric layers 14 are decreased in thickness per layer while allowing opposed internal electrodes 16 in the pyroelectric unit 12 to increase in electrode area as a result of the lamination of multiple layers.

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Consequently, there can be obtained the electrical capacitance (electrostatic capacitance) as required for attainment of an intended pyroelectric voltage. Furthermore, due to the lamination structure of pyroelectric layers 14 and internal electrodes 16, this pyroelectric infrared sensor 30 may be enhanced in polarizability of itself also, which in turn leads to an improvement of sensitivity.

Yet further, with this pyroelectric infrared sensor device 10, it becomes possible to render variable the magnitude of the electrical capacitance by increasing/decreasing the lamination number of the internal electrodes 16 and/or by changing the area of opposed internal electrodes 16. Accordingly, it is possible to render variable the relative detectivity of the pyroelectric infrared sensor device 10.

In this embodiment, the area of internal electrodes 16 may be changed by, during the manufacturing process of the pyroelectric infrared sensor device 10, changing the thickness of the pyroelectric unit 12 - namely, by increasing or decreasing the length of the cut width t at the cutting step shown in Fig.2E.

In this embodiment it is possible, by causing the electrode area of the internal electrodes 16 to increase proportionally to the cut width t , to change only the area of internal electrodes 16 without having to change the area of the light receiving plane of the pyroelectric infrared sensor device 10. Therefore, the electrical capacitance can be changed likewise. In this case, a packet of charge carriers as produced from the top surface (light receiving plane) of the pyroelectric infrared sensor device 10 is proportional to the light receiving area thereof while causing its output voltage to be inversely proportional to the electrical capacitance.

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It is thus possible to suitably adjust an output voltage of this pyroelectric infrared sensor device 10 by rendering variable the magnitude of the electrical capacitance.

In this case, white noise components will vary with certain frequency as determined by the electrical capacitance of the internal electrodes 16 laminated to oppose each other in the pyroelectric unit 12 and the output impedance of the pyroelectric infrared sensor device 10. Therefore, it is possible to render variable the relative detectivity of pyroelectric infrared sensor device 10 also by changing this electrical capacitance.

Furthermore, since this pyroelectric infrared sensor device 10 is fabricated by the manufacturing method as discussed supra in connection with Fig.2, it is no longer required to render thinner the pyroelectric body unlike the prior art sensor devices 1, 5 shown in Figs.7 and 8. For this reason, the embodiment sensor device 10 shown in Figs.1 and 2 is such that the resulting mechanical and thermal strength increases enabling elimination of a decrease in electrical characteristic otherwise occurring due to them. It is also possible for this device 10 to form a leakage resistance using the pyroelectric body by itself.

A further advantage of this pyroelectric infrared sensor device 10 is that any kinds of support methods or heat insulation schemes as employed in the conventional devices 1, 5 of Figs.7 and 8 are no longer required, which may in turn enable simple formation of the infrared light receiving plane. Therefore, use of this pyroelectric infrared sensor device 10 may increase the production yield while simultaneously reducing complexity and cost of the manufacture thereof.

It may be appreciated by those skilled in the art from the foregoing



description that with the pyroelectric infrared sensor device 10 in accordance with this embodiment, it becomes possible to improve the relative detectivity while easily enabling the relative detectivity to be variable. In addition, it is also possible to render the manufacture of the same stable while reducing manufacturing costs without having to degrade the electrical characteristics thereof.

Furthermore, with the pyroelectric infrared sensor device 10, since the plurality of internal electrodes 16 which are disposed or "sandwiched" between the plurality of pyroelectric layers 14 within the pyroelectric unit 12 are electrically connected in parallel, it becomes possible to further decrease the entire dielectric resistance of the pyroelectric infrared sensor device 10. In this case, the dielectric resistance may typically measure 10^{11} ohms; this dielectric resistance value may be dropped down at or near 10^9 ohms when one hundred (100) layers are laminated.

As a consequence, use of the impedance converter circuit employing FET 34 is no longer required like the pyroelectric infrared sensor 30 shown in Fig.3. It can thus be directly connected to an amplifier circuit 60 including therein an operational amplifier 62 as shown in Fig.5. In this case, the non-inverting input terminal of operational amplifier 62 is connected to one external electrode 18 of the pyroelectric infrared sensor device 10 allowing an electrical signal to be sent forth from the pyroelectric infrared sensor device 10 at a low resistance, which signal is then amplified by the amplifier circuit 60 to be output from an output terminal of the operational amplifier 62.

It should be noted that while the pyroelectric infrared sensor device 10 in accordance with the above embodiment is arranged so that it is applied to the

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pyroelectric infrared sensor 30 with its structure of the hermetic seal type as exemplarily shown in Fig.3, the same may also be applicable to a pyroelectric infrared sensor 70 with its structure of the surface mount component type shown in Fig.6.

More specifically, in the pyroelectric infrared sensor 70 shown in Fig.6, as compared with the pyroelectric infrared sensor 30 of Fig.3, the pyroelectric infrared sensor device 10 is in particular supported on a dielectric substrate 72 made of alumina, for example, while causing spaced-apart electrode patterns 74a and 74b to be formed at certain distance on one side end surface of the dielectric substrate 72 perpendicular to the width direction thereof. In addition, an electrode pattern 74c is formed as the Earth terminal on the remaining side end surface of the dielectric substrate 72. The drain terminal of FET 34 is connected via a conductive wire 40 to the electrode pattern 74a. Also, the source terminal of FET 34 is connected via conductive wire 42 to the electrode pattern 74b. Further, the other external electrode 18 of the pyroelectric infrared sensor device 10 is connected via a conductive pattern 76 to the electrode pattern 74c. Note in Fig.6 that the same parts or components as those of the embodiment of Fig.3 designated by the same reference characters are identical or similar in structure thereto.

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What is claimed is:

1. An infrared radiation sensitive device (10), comprising
a pyroelectric unit (12),
a light receiving face on said pyroelectric unit (12) for receiving infrared light
radiated from an object to be detected, and
a pair of external electrodes (18) on opposite end surfaces of said pyroelectric unit
(12) respectively,
characterized in that
said pyroelectric unit (12) comprises a plurality of pyroelectric layers (14),
internal electrodes (16) are respectively laid between adjacent ones of said
plurality of pyroelectric layers (14),
edges of said internal electrodes (16) are alternatively exposed and connected to
each said external electrodes (18) at each opposite end surface of said
pyroelectric unit (12),
said pyroelectric unit (12) is electrically polarized among said internal electrodes
(14), and
side end edges of said internal electrodes (16) are exposed on said light receiving
face.

2. An infrared radiation sensitive device (10) according to Claim 1,
characterized in that
a relative detection ratio is variable by changing the area of said internal electrodes



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(16).

3. An infrared radiation sensitive device (10) according to Claim 1 or 2, characterized in that a relative detection ratio is variable by changing the number of said internal electrodes (16).

4. A manufacturing method of a pyroelectric infrared radiation sensor device, said method comprising the steps of:

1) preparing a plurality of pyroelectric sheets (14a) made of a pyroelectric material,
2) forming a pyroelectric unit (20) with internal electrodes (16a) being exposed alternately at each opposite end surface thereof by alternately laminating said pyroelectric sheets (14a) and said internal electrodes (16a),

3) backing said pyroelectric unit (20),

4) forming external electrodes (18a) on each opposite end surface of said pyroelectric unit (20) so as to said external electrodes (20), internal electrodes (16a) on each said opposite end surface of said pyroelectric unit (20),

Terminologies of Claim 4 might be incorrect, because (14a), (16a) (20) etc. are "intermediate" products.

5) polarizing said pyroelectric unit (20) electrically among said external electrodes (16a) via said external electrodes (18a), and

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6) cutting said pyroelectric unit (20) and said external electrodes (18a) perpendicular to said internal electrodes (14a) in such a manner that said internal electrodes (16a) are exposed at terminate ends thereof on the cut plane, wherein

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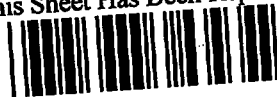


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said cut plane acts as a light receiving face for receiving infrared light radiated from an object to be detected.

5. A manufacturing method of a pyroelectric infrared radiation sensor device according to Claim 4, characterized in that the step of cutting said pyroelectric unit (20) further includes a step of rendering said internal electrodes (16a) variable in area by changing a thickness of said pyroelectric unit (12) being cut.

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ABSTRACT

A pyroelectric infrared sensor device (10) capable of improving the relative detectivity while rendering it easier to change the relative detectivity and also reducing manufacturing cost thereof. This sensor device (10) includes a pyroelectric unit (12) having an alternate lamination of pyroelectric layers (14) and internal electrodes (16) with a predetermined thickness t . The end edges of the opposite internal electrodes (16) perpendicular to the the length direction thereof are alternately exposed on the both terminate surfaces of the pyroelectric unit (12) while allowing the external electrodes (18) to be connected to the end edges of those internal electrodes (16), respectively. The pyroelectric infrared sensor device (10) is horizontally polarized among the internal electrodes (16) via the external electrodes (18) with respect to the infrared light receiving plane thereof. The end edges of the internal electrodes (16) perpendicular to the width direction thereof are exposed on the top and bottom surfaces of the pyroelectric unit (12) in a manner such that its top surface side will act as the light receiving plane of the pyroelectric infrared sensor device (10).

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【書類名】 図 面

【図1】 Fig.1

10

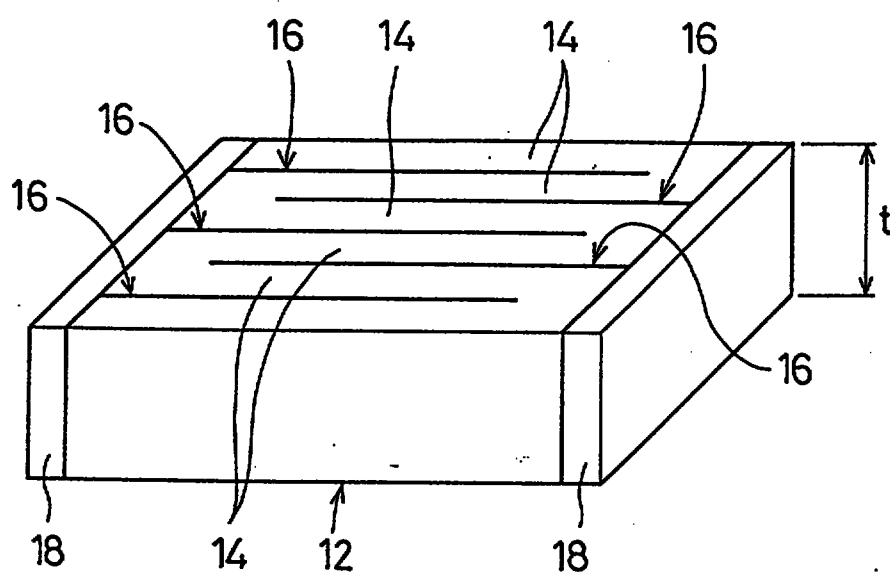


FIG. 1

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【図2】

FIG. 2A

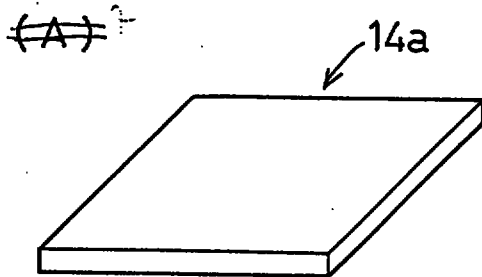


FIG. 2B

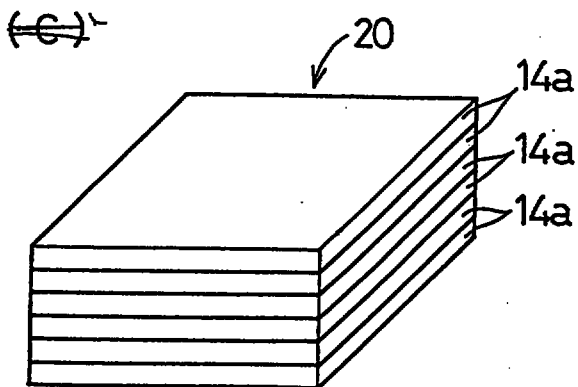
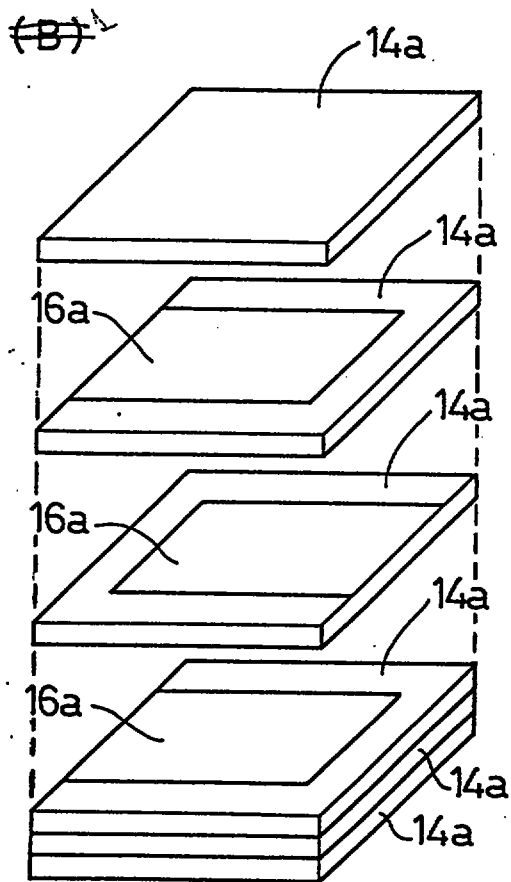
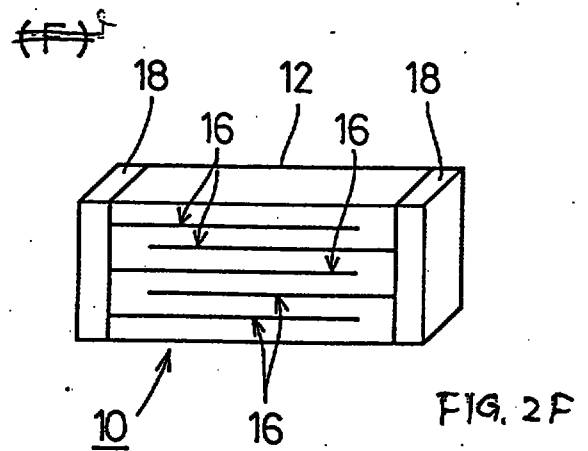
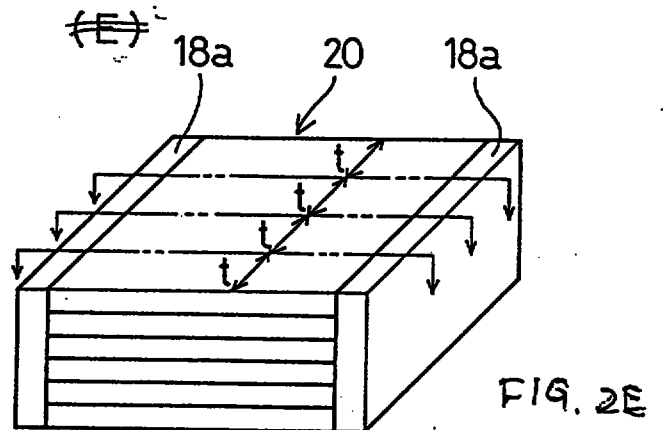
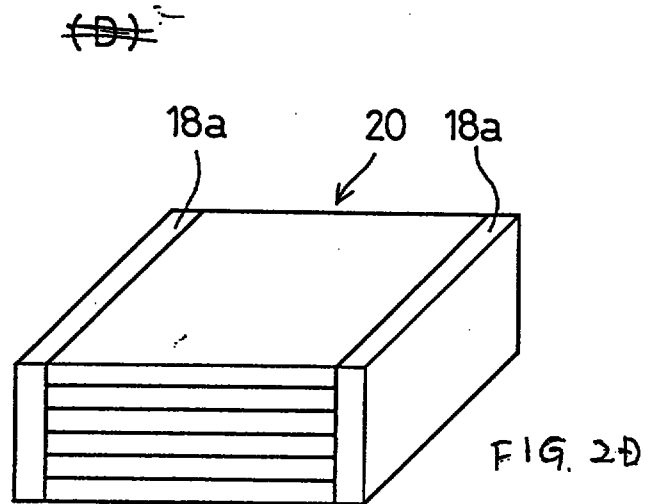


FIG. 2C



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【図 3】 Fig.3

30

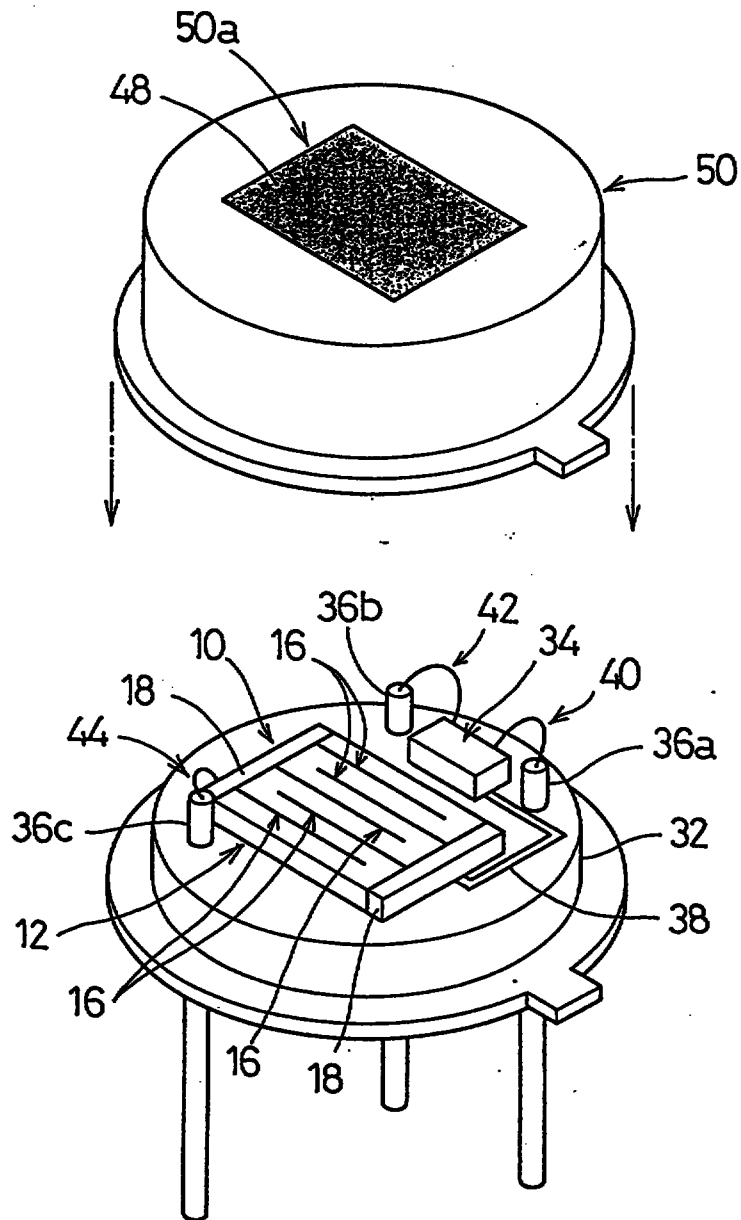


FIG. 3

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Fig.4
【図4】

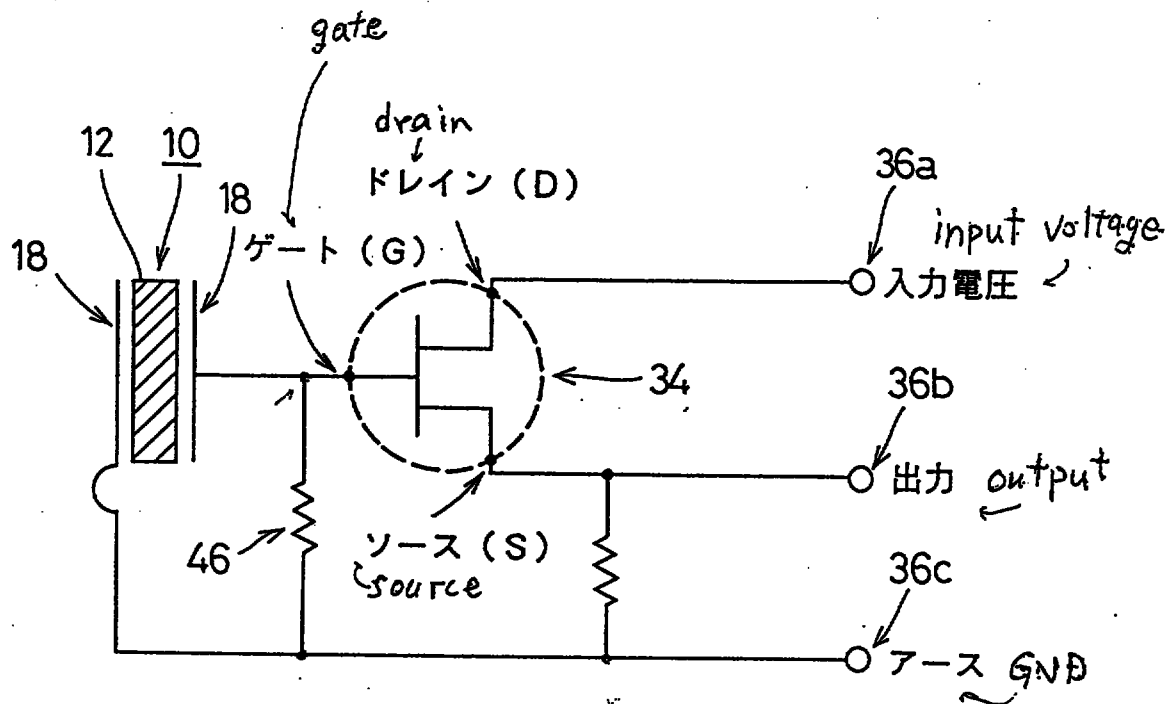


FIG. 4

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Fig. 5
【図5】

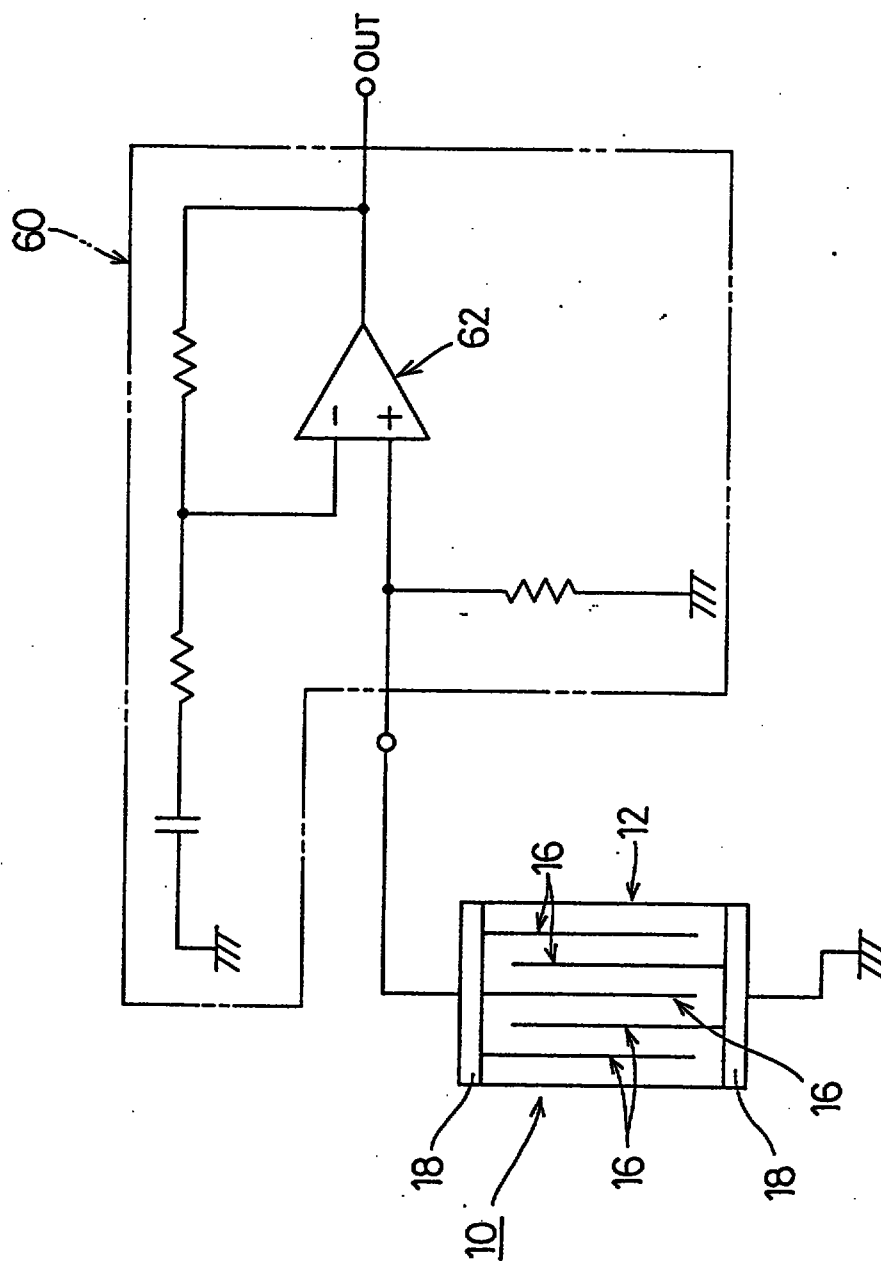


FIG. 5

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Fig. 6
【図 6】

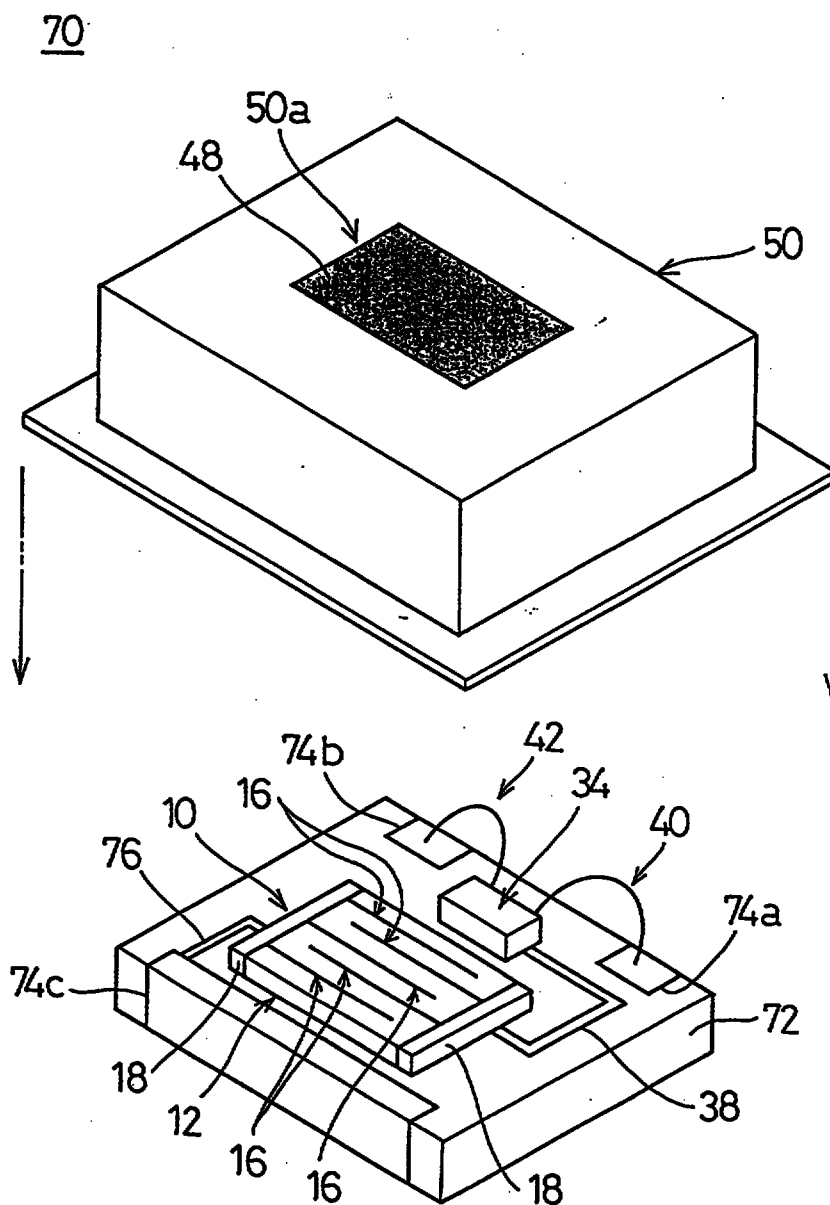


FIG. 6

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【図7】

(A)

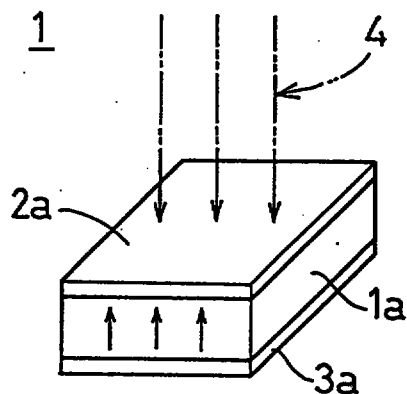


FIG. 7A
PRIOR ART

(B)

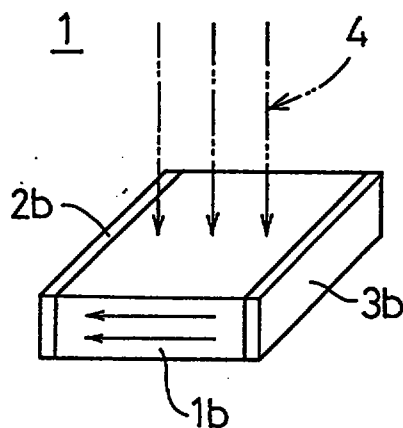


FIG. 7B
PRIOR ART

【図8】

5

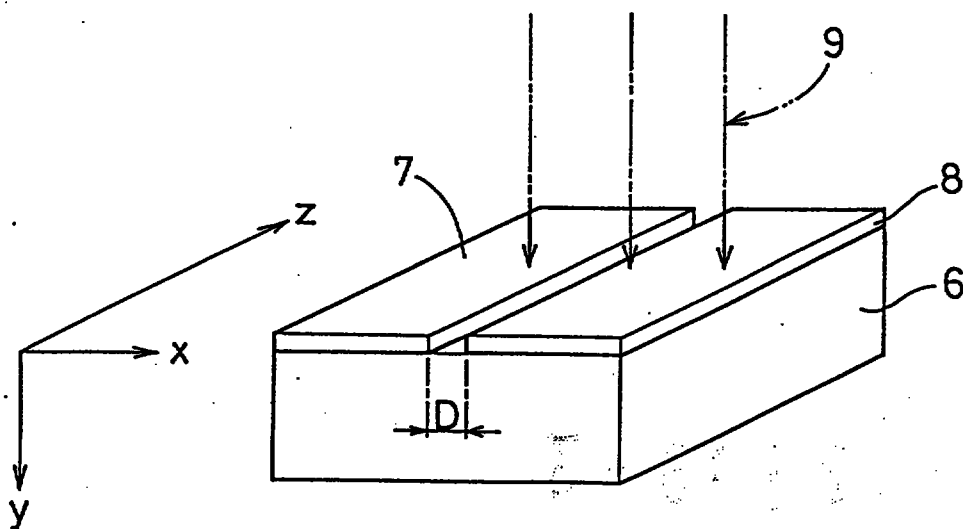


FIG. 8 PRIOR ART



REPLACEMENT SHEETS		SG
☒	Description	: paged 01 to paged 20
☒	Claim(s)	: paged 21 to paged 23
☒	Drawing(s)	: paged 17 to paged 77
☒	Abstract	: paged 24 to paged 24
DATE OF RECEIPT		07/08/1997

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AN INFRARED RADIATION SENSITIVE DEVICE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an infrared radiation sensitive device, and more particularly to an infrared radiation sensitive device comprising a pyroelectric unit, a light receiving face on said pyroelectric unit for receiving infrared light radiated from an object to be detected, and a pair of external electrodes on opposite end surfaces of said pyroelectric unit respectively.

2. Description of the Prior Art

One prior known pyroelectric infrared sensor device 1 is shown in Fig.7A. This prior art device includes a rectangular-plate shaped pyroelectric body 1a having the top and bottom surfaces on which electrodes 2a, 3a are formed respectively with the polarization treatment being applied between the electrodes 2a, 3a as designated by arrows shown. Another prior art pyroelectric infrared sensor device 1 is shown in Fig.7B which includes a pyroelectric body 1b having the both side surfaces on which electrodes 2b, 3b are formed with the polarization treatment being carried out between the electrodes 2b, 3b as indicated by arrows. With these pyroelectric infrared sensor devices 1, the electrodes 2a, 3a and those 2b, 3b are each formed in the direction perpendicular to the polarization direction as designated by the arrows.

In these prior art pyroelectric infrared sensor devices 1, when infrared light rays 4 radiated from an object to be detected are incident on the light

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receiving plane of each pyroelectric infrared sensor device 1, a slight temperature change can take place in pyroelectric body 1a, 1b. Such temperature change would result in that a packet of surface charge carriers of the pyroelectric body 1a, 1b which carriers have been in the equilibrium condition are forced to move causing a voltage to arise accordingly. This voltage is for use in detecting or sensing the object being detected in such a way that the voltage is electrically amplified by an associated impedance conversion circuit employing field effect transistors (FETs) and is then converted into a corresponding electrical signal.

In order for such prior art pyroelectric infrared sensor devices 1 to improve the relative detection rate or "detectivity" indicative of the pyroelectric device characteristics, it has been required that the thermal insulation be attained by decreasing the thickness of the pyroelectric body per se while simultaneously causing the light receiving section which are expected to receive incoming infrared light rays to be formed in a hollow shape. This would allow the thermal or heat capacitance to decrease with the thermal time constant being decreased as low as possible thus improving resultant relative detectivity.

Unfortunately, the aforesaid prior art pyroelectric infrared sensor devices 1 are encountered with several difficulties which follow. Since it has been strictly required that the thermal insulation be accomplished while decreasing the thickness of the pyroelectric body, the mechanical strength of such pyroelectric body itself might be weakened with the durability against application of thermal shocks being also weakened rendering difficult the handling of such pyroelectric infrared sensor devices. In other words, if the

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pyroelectric body is decreased in thickness then certain risks might arise: mechanical damages including micro-clacks can occur in the pyroelectric infrared sensor devices per se due to significant thermal variations upon application of external vibrations and shocks as well as irradiation of strong infrared light rays thereonto while the performance thereof can decrease due to degradation of heat flow balance. Furthermore, since the pyroelectric body per se becomes brittle making it difficult for the pyroelectric body to be reliably supported by adhesion on a substrate, which in turn renders much difficult both settlement of its support method and attainment of accurate position alignment accuracy thereof. Due to the above difficulties the resulting performance can decrease undesirably.

Another problem faced with the prior art is that since in most cases the thickness of the pyroelectric body itself is designed to fall within the range of from 70 to 100 micrometer, the yield of production remains lowered rendering extremely difficult the manufacture or fabrication of pyroelectric infrared sensor devices per se. This would result in manufacturing costs of the prior art pyroelectric infrared sensor devices 1 being increased unwantedly.

A prior art approach to avoidance of the aforementioned problems has been known which attempts to specifically arrange electrodes of a pyroelectric infrared sensor device so that polarization of a pyroelectric body thereof occurs only near a light incidence plane (a light receiving plane) of the device. One exemplary pyroelectric infrared sensor device employing such scheme is shown in Fig.8 as generally indicated by numeral 5. This structure comes in view of the fact that the contribution of the top surface of the light receiving plane

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occupies most part of an output of pyroelectric infrared sensor devices.

More specifically, the pyroelectric infrared sensor device 5 shown in Fig.8 includes, for example, a rectangular plate-shaped pyroelectric body 6 having a top surface on which two opposed electrodes 7, 8 are formed with certain distance D being defined therebetween. Polarization treatment has been effected between the two electrodes 7, 8 by applying a direct current (DC) voltage therebetween. In this case, polarization is generated mainly at a section positionally close to the light incidence plane of infrared light rays 9 with its polarization direction being rendered parallel to the light incidence plane of infrared light rays 9; in other words, the polarization direction is identical to the x-axis direction of Fig.8.

Accordingly, this pyroelectric infrared sensor device 5 is superior than those of in Figs.7A and 7B in that the polarization of the pyroelectric body 6 may be forced to locally take place only at or near the light incidence plane (light receiving plane) of the pyroelectric infrared sensor device 6 improving the relative detectivity.

However, the above advantage of the prior art pyroelectric infrared sensor device 5 does not come without accompanying a penalty: a reduction in controllability of the relative detectivity. More specifically, in the prior art pyroelectric infrared sensor device 5, it should be required in order to change the relative detectivity that the pyroelectric body 6 for receiving infrared light rays be changed in light receiving area, which would result in increasing complexity and time. For this reason, the prior art device is not adaptable for use in stable mass production while at the same time rendering it difficult to

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manufacture the same at low costs.

SUMMARY OF THE INVENTION

It is therefore an object of the invention to provide a pyroelectric infrared sensor device capable of increasing the relative detection rate and simply rendering the relative detection rate variable while at the same time rendering mass production thereof easier and cheaper.

One aspect of the invention provides the above described pyroelectric infrared sensor device which is characterized in that said pyroelectric unit comprises a plurality of pyroelectric layers, internal electrodes are respectively laid between adjacent ones of said plurality of pyroelectric layers, edges of said internal electrodes are alternatively exposed and connected to each said external electrodes at each opposite end surface of said pyroelectric unit, said pyroelectric unit is electrically polarized among said internal electrodes, and side end edges of said internal electrodes are exposed on said light receiving face.

In the above pyroelectric infrared sensor device, while the internal electrodes are alternately disposed and laminated in the pyroelectric unit, a respective one of the pyroelectric layers is reduced in thickness allowing resultant lamination of such plurality of layers to increase the opposing internal electrodes in electrode area within the pyroelectric unit. Accordingly, any desired electrical capacitance (electrostatic capacitance) may be attainable as required to obtain a pyroelectric voltage.

This may be reworded in a way as follows: With the invention, since it employs a lamination structure of the pyroelectric layers and internal electrodes,

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it becomes possible to render variable the magnitude of the electrical capacitance without having to change the light receiving area thereof by, for example, increasing or decreasing the lamination number of the internal electrodes or alternatively by changing the area of the opposed internal electrodes. Consequently, the relative detection rate or "detectivity" of the pyroelectric infrared sensor device becomes variable.

In the above pyroelectric infrared sensor device, a relative detection ratio may be variable by changing the area of said internal electrodes.

With such an arrangement, the area of internal electrodes may be variable by changing the thickness of the pyroelectric unit in particular. In this case, only the internal electrode area is rendered variable without having to change the area of the light receiving plane of the pyroelectric unit. Whereby, the electrical capacitance between the opposed internal electrodes is varied inside the pyroelectric unit causing the relative detectivity of the pyroelectric infrared sensor device to be variable.

In the above pyroelectric infrared sensor device, a relative detection ratio may be variable by changing the number of said internal electrodes.

In this case, only the number of the internal electrode area is rendered variable without having to change the area of the light receiving plane of the pyroelectric unit.

Another aspect of the invention provides a manufacturing method of a pyroelectric infrared radiation sensor device, said method comprising the steps of:

1)preparing a plurality of pyroelectric sheets made of a pyroelectric material,

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- 2)forming a pyroelectric unit with internal electrodes being exposed alternately at each opposite end surface thereof by alternately laminating said pyroelectric sheets and said internal electrodes,
- 3)backing said pyroelectric unit,
- 4)forming external electrodes on each opposite end surfaces of said pyroelectric unit so as to said external electrodes are connected to said internal electrodes on each said opposite end surface of said pyroelectric unit,
- 5)polarizing said pyroelectric unit electrically among said internal electrodes via said external electrodes, and
- 6)cutting said pyroelectric unit and said external electrodes in a direction perpendicular to said internal electrodes in such a way that said internal electrodes are exposed at terminate ends thereof on the cut plane, wherein said cut plane acts as a light receiving face for receiving infrared light radiated from an object to be detected.

With such a method, the laminated pyroelectric unit is constituted by alternately disposing the plurality of pyroelectric sheets and internal electrodes. Also, the terminate ends of the internal electrodes which are externally exposed at the both end surfaces of the pyroelectric unit are connected to the external electrodes. The pyroelectric unit is polarized between the external electrodes. Further, the pyroelectric unit is cut away in the direction perpendicular to the internal electrode planes between the external electrodes. At this time, the terminate edges of the internal electrodes are exposed on the cutout planes. The cutout plans on which these internal electrodes are exposed are formed as the light receiving plane onto which infrared light rays are incident, thereby

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obtaining the pyroelectric infrared sensor device.

In the above manufacturing method, the step of cutting said pyroelectric unit may further include a step of rendering said internal electrodes variable in area by changing a thickness of said pyroelectric unit being cut.

Advantageously, at the step of cutting the pyroelectric unit, the area of internal electrodes is rendered variable by changing the cutting thickness. Whereby, the electrical capacitance (electrostatic capacitance) of opposed internal electrodes may be varied permitting suitable variation of the magnitude of the relative detectivity of the pyroelectric infrared sensor device.

In accordance with the principles of the invention, it is possible to provide a pyroelectric infrared sensor device capable of improving the relative detectivity, simply rendering the relative detectivity variable, and being stably manufactured at low cost without having to degrade the electrical characteristics.

These and other objects, features and advantages of the invention will be apparent from the following more particular description of preferred embodiments of the invention, as illustrated in the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig.1 is a perspective view of one embodiment of the present invention.

Figs.2A to 2F illustrate, in perspective view, some of the major steps in the manufacture of the pyroelectric infrared sensor device shown in Fig.1.

Fig.3 is an explosive perspective view of one exemplary sensor structure employing the pyroelectric infrared sensor device of Figs.1 and 2.

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Fig.4 depicts electrical equivalent circuitry of the pyroelectric infrared sensor device shown in Fig.3.

Fig.5 is a circuit diagram showing another example of the pyroelectric infrared sensor employing therein the pyroelectric infrared sensor device of Figs.1 and 2.

Fig.6 is an explosive perspective view of a further exemplary sensor structure employing the pyroelectric infrared sensor device of Figs.1 and 2.

Figs.7A-7B are perspective views illustrating prior art pyroelectric infrared sensor devices.

Fig.8 is a perspective view of a further prior art pyroelectric infrared sensor device.

DETAILED DESCRIPTION OF THE INVENTION

Referring now to Fig.1, a pyroelectric infrared sensor device 10 includes a pyroelectric unit 12 which is of the planar rectangular shape and has a predefined thickness t . The pyroelectric unit 12 contains a plurality of pyroelectric layers 14, wherein rectangular plate-like internal electrodes 16 are formed between the pyroelectric layers 14, by way of example. In other words, the internal electrodes 16 are disposed within the pyroelectric unit 12 in such a manner that these are spaced apart at specified distances in the width direction thereof.

In this case, the internal electrodes 16 involve those extending from one end side of the pyroelectric unit 12 to the other end side thereof perpendicular to the length direction thereof, and the remaining ones extending from the other end side to the one end side in a way such that the former and the latter are

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alternately formed. These internal electrodes 16 are formed such that certain terminate edges thereof are alternately exposed on the both end surfaces - i.e. the one end surface and the other end surface - perpendicular to the length of the pyroelectric unit 12.

Furthermore, external electrodes 18, 18 are formed respectively on the one end surface and the other end surface of the pyroelectric unit 12 perpendicular to the length direction thereof such that these are connected to the internal electrodes 16. In addition, the side end edges of internal electrodes 16 are exposed on the top and bottom surfaces of the pyroelectric unit 12 in the illustrative state. More specifically, the pyroelectric unit 12 is such that certain side end edges of the internal electrodes 16 perpendicular to the thickness direction are exposed on the top surface of pyroelectric unit 12 whereas the opposite side end edges of the internal electrodes 16 perpendicular to the thickness direction are exposed on the bottom surface of it.

In the pyroelectric infrared sensor device 10 in accordance with this embodiment, the top surface of the pyroelectric unit 12 on which the certain side end edges of the internal electrodes 16 are exposed is formed as what is called the "infrared light receiving plane" for incidence of infrared light rays. In this pyroelectric infrared sensor device 10, polarization treatment has been effected among the internal electrodes 16 by application of a DC voltage via the opposite external electrodes 18. In other words, in this pyroelectric infrared sensor device 10, the polarization treatment has been done in the horizontal direction with respect to its infrared light receiving plane.

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An explanation will now be given of one exemplary manufacturing method of the pyroelectric infrared sensor device 10 of Fig.1 with reference to Figs.2A to 2F.

To fabricate the pyroelectric infrared sensor device 10 shown in Fig.1, first of all, a pyroelectric ceramics measuring 50 to 100 mm in thickness, for example, is prepared, which is then subject to lapping treatment to have a predetermined shape. When this is done, as shown in Fig.2A, a pyroelectric ceramics sheet 14a constituting the pyroelectric layer 14 is manufactured which is of a planar rectangular shape and has a predefined size. Similarly, a plurality of pyroelectric ceramics sheets 14a are prepared. Tetragonal-system lead titanate ceramics may be preferably employed as the material thereof.

Then, a conductive pattern 16a which is made of an electrode material acting as the internal electrode 16 is formed by printing techniques such as the screen print method on a respective one of the plurality of pyroelectric ceramics sheets 14a. In this embodiment, as shown in Fig.2B, electrode patterns 16a are respectively formed on the pyroelectric ceramics sheets 14a corresponding to intermediate layers except the uppermost and lowermost ones of the pyroelectric layers 14. These electrode patterns 16a are formed in such a manner that the edges of them are alternately exposed on the both terminate edges of the pyroelectric ceramics sheets 14a perpendicular to the length direction thereof. Typically, gold (Au), silver (Ag), aluminum (Al) or the like is preferably employed as the electrode material for use as the internal electrodes 16; however, alloys made of nickel (Ni), chromium (Cr) or the like may alternatively be used for formation of the same.

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Next, these pyroelectric ceramics 14a are laminated and adhered to be hardened together by use of an adhesive forming a multilayer lamination structure 20 of pyroelectric ceramics as shown in Fig.2C. Note that the pyroelectric ceramics lamination structure 20 may alternatively be formed by a method including the steps of laminating the pyroelectric ceramics sheets 14a and adhering them together by a baking process.

Furthermore, metal paste (not shown) are deposited on the opposite terminate surfaces of this pyroelectric ceramics lamination structure 20 perpendicular to the length direction thereof, which pastes are made of a chosen electrode materials to constitute the external electrodes 18. Thereafter, this lamination structure 20 is backed for hardening. Whereby, as shown in Fig.2D, external electrodes 18a are formed on the both terminate surfaces of the pyroelectric ceramics lamination structure 20 perpendicular to the length direction thereof.

The pyroelectric ceramics lamination structure 20 is then subject to polarization treatment among the internal electrodes 16a via the opposite external electrodes 18a. In this case, a DC voltage of for example from 2.0 to 4.0 kilovolts per millimeter (KV/mm) is applied between the external electrodes 18a for sixty (60) minutes at temperatures of 100 to 150°C.

Thereafter, as shown by dash-and-two-dot lines in Fig. 2E, the pyroelectric ceramics lamination structure 20 is cut away at a pitch of a predetermined thickness t perpendicular to the plane of internal electrodes 16, thus forming a plurality of pieces of pyroelectric units 12 each of which may be identical to that shown in Fig.1 and Fig.2F.

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Note that the manufacturing method of the pyroelectric infrared sensor device 10 should not be exclusively limited to the above embodiment only; the pyroelectric infrared sensor device 10 may alternatively be formed by use of a manufacturing method as will be set forth below. First, a base material sheet is prepared which is made of a pyroelectric ceramics green sheet. This base material sheet is formed to a thin-film sheet member (thin plate shape) measuring, for example, 30 to 80 micrometer in thickness by pyroelectric material slurring. The base-material sheet is suitably cut into a specified shape thus forming a plurality of pyroelectric sheets.

Next, electrode patterns made of a chosen electrode material are formed by print techniques for example on the pyroelectric sheets in the same fabrication method as that discussed previously. These pyroelectric sheets are laminated by solderless contact bonding on one another in a disposal arrangement similar to that of the aforesaid fabrication method; then, resultant structure is backed providing one integral pyroelectric sheet lamination structure. Further, external electrodes made of an electrode material is formed on the both terminate surfaces of the pyroelectric sheet lamination structure; next, polarization treatment is carried out between the external electrodes in a way similar to that of the fabrication method stated supra. Thereafter, the pyroelectric sheet lamination structure is cut at a specified thickness in the direction perpendicular to the principal plane of internal electrodes, thereby fabricating a pyroelectric unit 12.

The pyroelectric unit 12 thus fabricated by the foregoing manufacturing methods is such that the terminate edges of the internal electrodes 16 as

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laminated and disposed at certain intervals therebetween are exposed on the opposite terminate surfaces of pyroelectric unit 12 perpendicular the length thereof while causing the external electrodes 18 to be connected to the internal electrodes 16. Moreover, the both side terminate edges of such internal electrodes 16 perpendicular to the width thereof are exposed on the top and bottom surfaces of the pyroelectric unit 12 in the illustrative state; in this embodiment, the top surface serves as the infrared light receiving plane. The pyroelectric unit 12 as fabricated in this way is adaptable for use with infrared light sensor modules.

Turning now to Fig.3, a pyroelectric infrared sensor module 30 in accordance with one possible example employing the pyroelectric infrared sensor devices shown in Figs.1 and 2 includes a stem 32. The pyroelectric infrared sensor device 10 discussed supra is disposed on the stem 32. Also disposed on the stem 32 is a field effect transistor (FET) 34 which is spaced apart from the pyroelectric infrared sensor device 10 with certain distance being defined therebetween. Further disposed on the stem 32 are terminal pins 36a, 36b and 36c for electrical interconnection.

The gate terminal of FET 34 is connected to one external electrode 18 through an electrode pattern 38, by way of example. The drain terminal of FET 34 is connected via a conductive wire 40 to the terminal pin 36a. The source terminal of FET 34 is connected via a conductive wire 42 to the terminal pin 36b. The terminal pin 36c is used as the Earth terminal, which is connected via a conductive wire 44 to the other external electrode 18 of the pyroelectric infrared sensor device 10.

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As may be readily seen by those skilled in the art from viewing Fig.4, a resistor 46 for conversion of a pyroelectric current into a corresponding voltage is connected in parallel to the pyroelectric infrared sensor device 10. Note here that a chip component may be employed as this resistor 46, or alternatively, such resistor 46 may be formed of a resistive pattern as printed on the stem 32.

An associated can casing 50 is of a square bracket (J) shape in cross-section. The can casing 50 has a top plate or "ceiling" with a through-going hole 50a of almost the rectangular shape being defined at the center thereof. An optical filter 48 is rigidly attached to the inner surface of ceiling plate of casing 50 to ensure that filter 48 overlies the pyroelectric infrared sensor device 10 as mounted on the substrate thus enabling sensor device 10 to receive incoming rays of infrared light radiated from a target object being detected through filter 48. The can casing 50 is adhered to the stem 32. The interior space as defined by the optical filter 48, can casing 50 and stem 32 assembled may be environmentally sealed.

The pyroelectric infrared sensor 30 of Fig.3 has electrical equivalent circuitry shown in Fig.4. In this pyroelectric infrared sensor module 30, when thermal energy is given upon incidence of infrared light rays onto the top surface (light receiving plane) of the pyroelectric infrared sensor device 10, some pyroelectric current occurs in the pyroelectric infrared sensor device 10. This pyroelectric current may be obtained as a voltage by use of the synthetic resistance of the resistor 46 and inherent electrical resistance of the sensor device 10 per se. This voltage is input to the gate terminal of FET 34. At this

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time, a bias voltage is applied to the drain terminal of FET 34 while causing the source terminal of FET 34 to be coupled to ground.

Accordingly, resultant pyroelectric current in the pyroelectric infrared sensor device 10 is impedance-converted by a combination of the pyroelectric infrared sensor device 10, resistor 46 and FET 34 into an output voltage which is derived from the terminal pin 36b.

With this pyroelectric infrared sensor 30, since the pyroelectric infrared sensor device 10 is formed using the manufacturing method shown in Fig.2, the internal electrodes 16 are disposed so as to oppose each other perpendicular to the width direction of the pyroelectric unit 12 and the pyroelectric unit 12 is polarized in the horizontal direction with respect to the infrared light receiving plane thereof. For this reason, there can be obtained the pyroelectric infrared sensor device 10 which does no longer depend upon the thickness direction of the pyroelectric body unlike the prior art including those shown in Figs.7 and 8.

Further, the pyroelectric infrared sensor device 10 is specifically arranged to have the alternate lamination structure of pyroelectric layers 14 and internal electrodes 16. In this case, the pyroelectric layers 14 are decreased in thickness per layer while allowing opposed internal electrodes 16 in the pyroelectric unit 12 to increase in electrode area as a result of the lamination of multiple layers. Consequently, there can be obtained the electrical capacitance (electrostatic capacitance) as required for attainment of an intended pyroelectric voltage. Furthermore, due to the lamination structure of pyroelectric layers 14 and internal electrodes 16, this pyroelectric infrared

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sensor 30 may be enhanced in polarizability of itself also, which in turn leads to an improvement of sensitivity.

Yet further, with this pyroelectric infrared sensor device 10, it becomes possible to render variable the magnitude of the electrical capacitance by increasing/decreasing the lamination number of the internal electrodes 16 and/or by changing the area of opposed internal electrodes 16. Accordingly, it is possible to render variable the relative detectivity of the pyroelectric infrared sensor device 10.

In this embodiment, the area of internal electrodes 16 may be changed by, during the manufacturing process of the pyroelectric infrared sensor device 10, changing the thickness of the pyroelectric unit 12 - namely, by increasing or decreasing the length of the cut width t at the cutting step shown in Fig.2E.

In this embodiment it is possible, by causing the electrode area of the internal electrodes 16 to increase proportionally to the cut width t , to change only the area of internal electrodes 16 without having to change the area of the light receiving plane of the pyroelectric infrared sensor device 10. Therefore, the electrical capacitance can be changed likewise. In this case, a packet of charge carriers as produced from the top surface (light receiving plane) of the pyroelectric infrared sensor device 10 is proportional to the light receiving area thereof while causing its output voltage to be inversely proportional to the electrical capacitance. It is thus possible to suitably adjust an output voltage of this pyroelectric infrared sensor device 10 by rendering variable the magnitude of the electrical capacitance.

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In this case, white noise components will vary with certain frequency as determined by the electrical capacitance of the internal electrodes 16 laminated to oppose each other in the pyroelectric unit 12 and the output impedance of the pyroelectric infrared sensor device 10. Therefore, it is possible to render variable the relative detectivity of pyroelectric infrared sensor device 10 also by changing this electrical capacitance.

Furthermore, since this pyroelectric infrared sensor device 10 is fabricated by the manufacturing method as discussed supra in connection with Fig.2, it is no longer required to render thinner the pyroelectric body unlike the prior art sensor devices 1, 5 shown in Figs.7 and 8. For this reason, the embodiment sensor device 10 shown in Figs.1 and 2 is such that the resulting mechanical and thermal strength increases enabling elimination of a decrease in electrical characteristic otherwise occurring due to them. It is also possible for this device 10 to form a leakage resistance using the pyroelectric body by itself.

A further advantage of this pyroelectric infrared sensor device 10 is that any kinds of support methods or heat insulation schemes as employed in the conventional devices 1, 5 of Figs.7 and 8 are no longer required, which may in turn enable simple formation of the infrared light receiving plane. Therefore, use of this pyroelectric infrared sensor device 10 may increase the production yield while simultaneously reducing complexity and cost of the manufacture thereof.

It may be appreciated by those skilled in the art from the foregoing

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description that with the pyroelectric infrared sensor device 10 in accordance with this embodiment, it becomes possible to improve the relative detectivity while easily enabling the relative detectivity to be variable. In addition, it is also possible to render the manufacture of the same stable while reducing manufacturing costs without having to degrade the electrical characteristics thereof.

Furthermore, with the pyroelectric infrared sensor device 10, since the plurality of internal electrodes 16 which are disposed or "sandwiched" between the plurality of pyroelectric layers 14 within the pyroelectric unit 12 are electrically connected in parallel, it becomes possible to further decrease the entire dielectric resistance of the pyroelectric infrared sensor device 10. In this case, the dielectric resistance may typically measure 10^{11} ohms; this dielectric resistance value may be dropped down at or near 10^9 ohms when one hundred (100) layers are laminated.

As a consequence, use of the impedance converter circuit employing FET 34 is no longer required like the pyroelectric infrared sensor 30 shown in Fig.3. It can thus be directly connected to an amplifier circuit 60 including therein an operational amplifier 62 as shown in Fig.5. In this case, the non-inverting input terminal of operational amplifier 62 is connected to one external electrode 18 of the pyroelectric infrared sensor device 10 allowing an electrical signal to be sent forth from the pyroelectric infrared sensor device 10 at a low resistance, which signal is then amplified by the amplifier circuit 60 to be output from an output terminal of the operational amplifier 62.

It should be noted that while the pyroelectric infrared sensor device 10

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in accordance with the above embodiment is arranged so that it is applied to the pyroelectric infrared sensor 30 with its structure of the hermetic seal type as exemplarily shown in Fig.3, the same may also be applicable to a pyroelectric infrared sensor 70 with its structure of the surface mount component type shown in Fig.6.

More specifically, in the pyroelectric infrared sensor 70 shown in Fig.6, as compared with the pyroelectric infrared sensor 30 of Fig.3, the pyroelectric infrared sensor device 10 is in particular supported on a dielectric substrate 72 made of alumina, for example, while causing spaced-apart electrode patterns 74a and 74b to be formed at certain distance on one side end surface of the dielectric substrate 72 perpendicular to the width direction thereof. In addition, an electrode pattern 74c is formed as the Earth terminal on the remaining side end surface of the dielectric substrate 72. The drain terminal of FET 34 is connected via a conductive wire 40 to the electrode pattern 74a. Also, the source terminal of FET 34 is connected via conductive wire 42 to the electrode pattern 74b. Further, the other external electrode 18 of the pyroelectric infrared sensor device 10 is connected via a conductive pattern 76 to the electrode pattern 74c. Note in Fig.6 that the same parts or components as those of the embodiment of Fig.3 designated by the same reference characters are identical or similar in structure thereto.

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What is claimed is:

1. An infrared radiation sensitive device (10), comprising
a pyroelectric unit (12),
a light receiving face on said pyroelectric unit (12) for receiving infrared light
radiated from an object to be detected, and
a pair of external electrodes (18) on opposite end surfaces of said pyroelectric
unit (12) respectively,
characterized in that
said pyroelectric unit (12) comprises a plurality of pyroelectric layers (14),
internal electrodes (16) are respectively laid between adjacent ones of said
plurality of pyroelectric layers (14),
edges of said internal electrodes (16) are alternatively exposed and connected
to each said external electrodes (18) at each opposite end surface of said
pyroelectric unit (12),
said pyroelectric unit (12) is electrically polarized among said internal
electrodes (14), and
side end edges of said internal electrodes (16) are exposed on said light
receiving face.
2. An infrared radiation sensitive device (10) according to Claim 1,
characterized in that
a relative detection ratio is variable by changing the area of said internal
electrodes (16).

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REPLACED

3. An infrared radiation sensitive device (10) according to Claim 1 or 2, characterized in that

a relative detection ratio is variable by changing the number of said internal electrodes (16).

4. A manufacturing method of a pyroelectric infrared radiation sensor device, said method comprising the steps of:

1)preparing a plurality of pyroelectric sheets (14a) made of a pyroelectric material,

2)forming a pyroelectric unit (20) with internal electrodes (16a) being exposed alternately at each opposite end surface thereof by alternately laminating said pyroelectric sheets (14a) and said internal electrodes (16a),

3)backing said pyroelectric unit (20),

4)forming external electrodes (18a) on each opposite end surfaces of said pyroelectric unit (20) so as to said external electrodes (20) are connected to said internal electrodes (16a) on each said opposite end surface of said pyroelectric unit (20),

5)polarizing said pyroelectric unit (20) electrically among said internal electrodes (16a) via said external electrodes (18a), and

6)cutting said pyroelectric unit (20) and said external electrodes (18a) in a direction perpendicular to said internal electrodes (14a) in such a way that said internal electrodes (16a) are exposed at terminate ends thereof on the cut plane, wherein said cut plane acts as a light receiving face for receiving infrared light radiated from an object to be detected.

5. A manufacturing method of a pyroelectric infrared radiation sensor

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device according to Claim 4, characterized in that
the step of cutting said pyroelectric unit (20) further includes a step of rendering
said internal electrodes (16a) variable in area by changing a thickness of said
pyroelectric unit (12) being cut.



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ABSTRACT

AN INFRARED RADIATION SENSITIVE DEVICE

A pyroelectric infrared sensor device (10) capable of improving the relative detectivity while rendering it easier to change the relative detectivity and also reducing manufacturing cost thereof. This sensor device (10) includes a pyroelectric unit (12) having an alternate lamination of pyroelectric layers (14) and internal electrodes (16) with a predetermined thickness t . The end edges of the opposite internal electrodes (16) perpendicular to the the length direction thereof are alternately exposed on the both terminate surfaces of the pyroelectric unit (12) while allowing the external electrodes (18) to be connected to the end edges of those internal electrodes (16), respectively. The pyroelectric infrared sensor device (10) is horizontally polarized among the internal electrodes (16) via the external electrodes (18) with respect to the infrared light receiving plane thereof. The end edges of the internal electrodes (16) perpendicular to the width direction thereof are exposed on the top and bottom surfaces of the pyroelectric unit (12) in a manner such that its top surface side will act as the light receiving plane of the pyroelectric infrared sensor device (10).

FIG. 1

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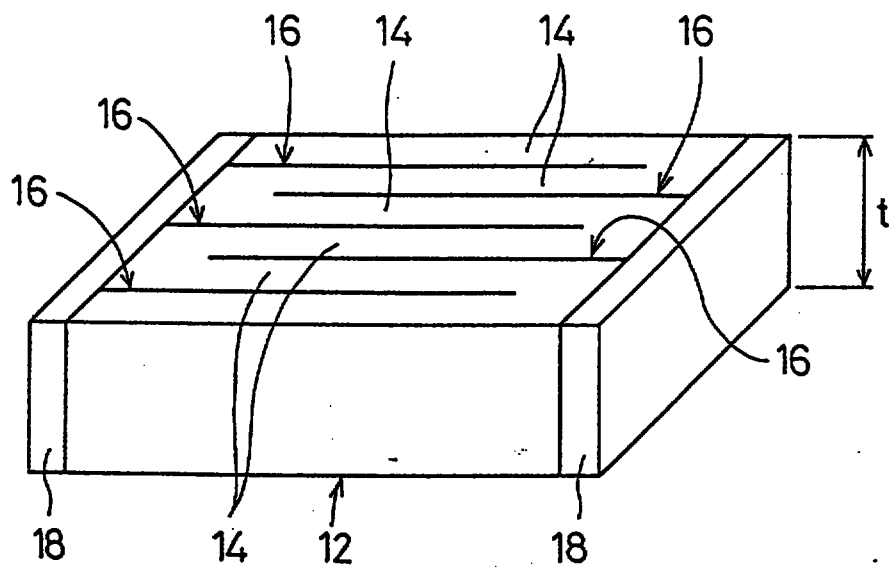


FIG. 1

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FIG. 2A

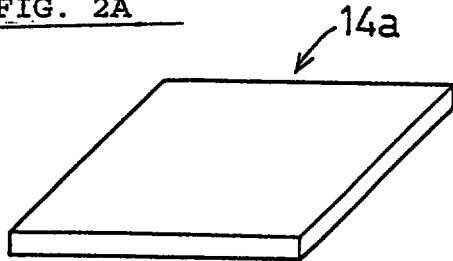


FIG. 2B

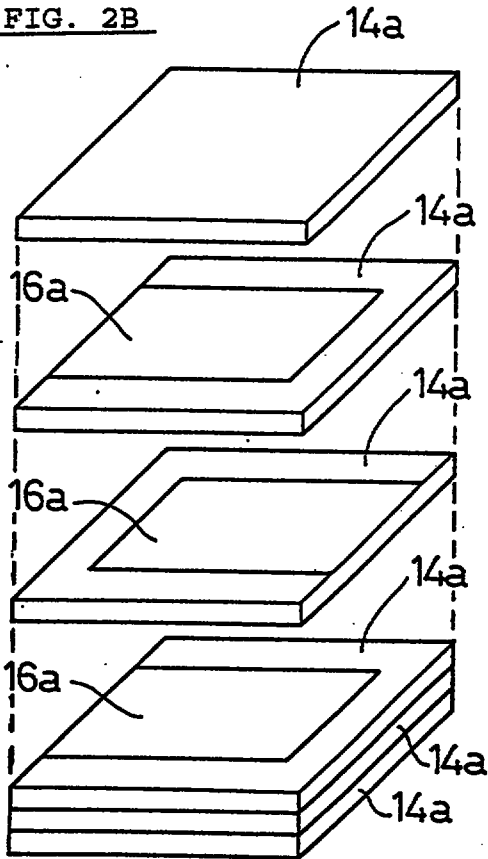


FIG. 2C

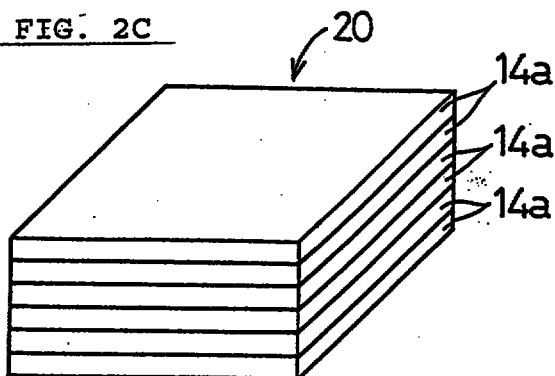


FIG. 2D

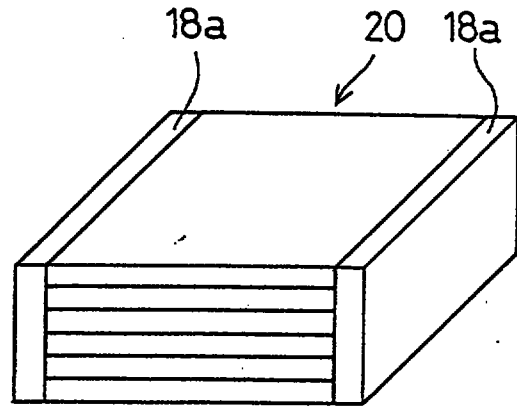


FIG. 2E

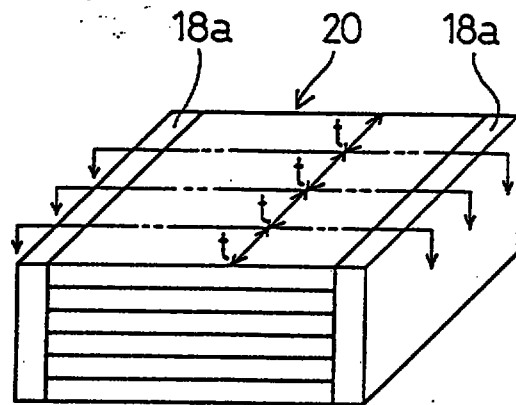
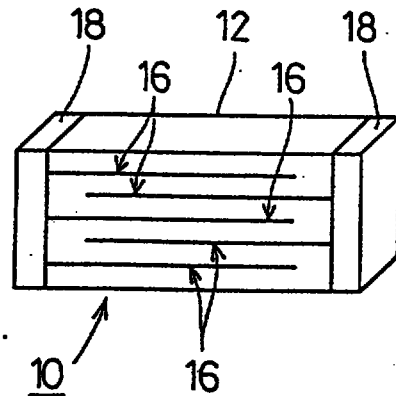


FIG. 2F



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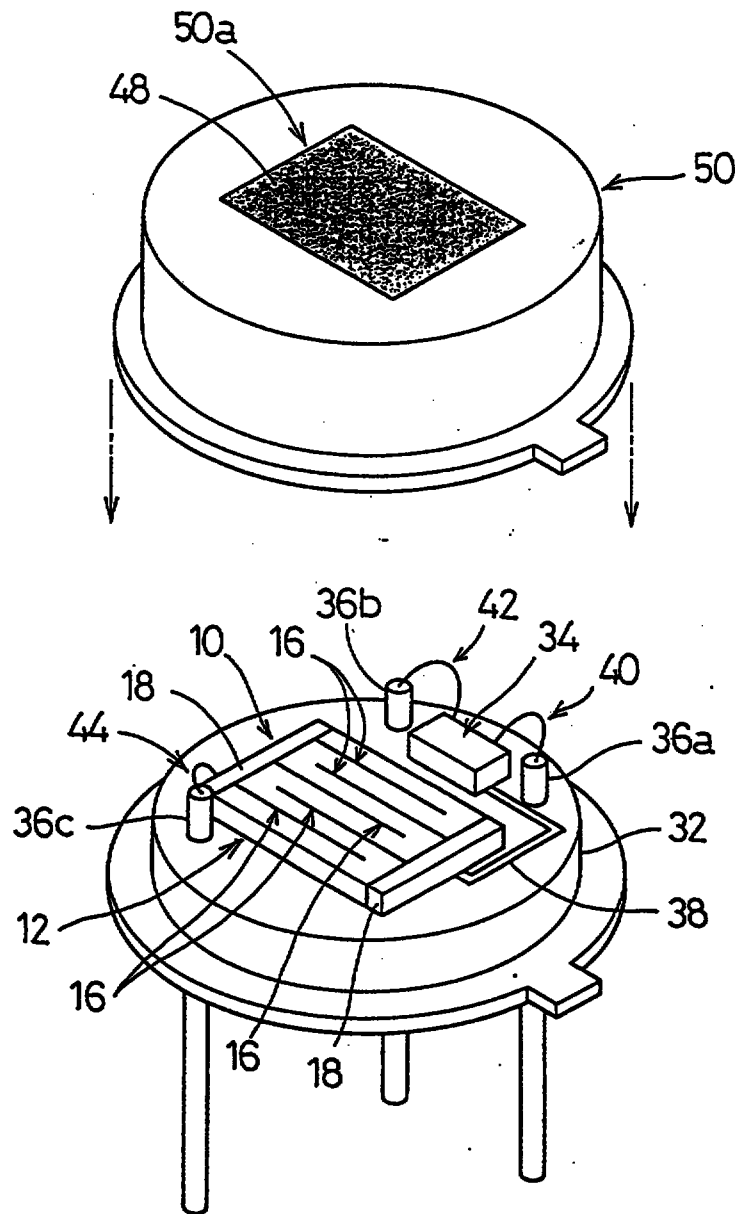


FIG. 3

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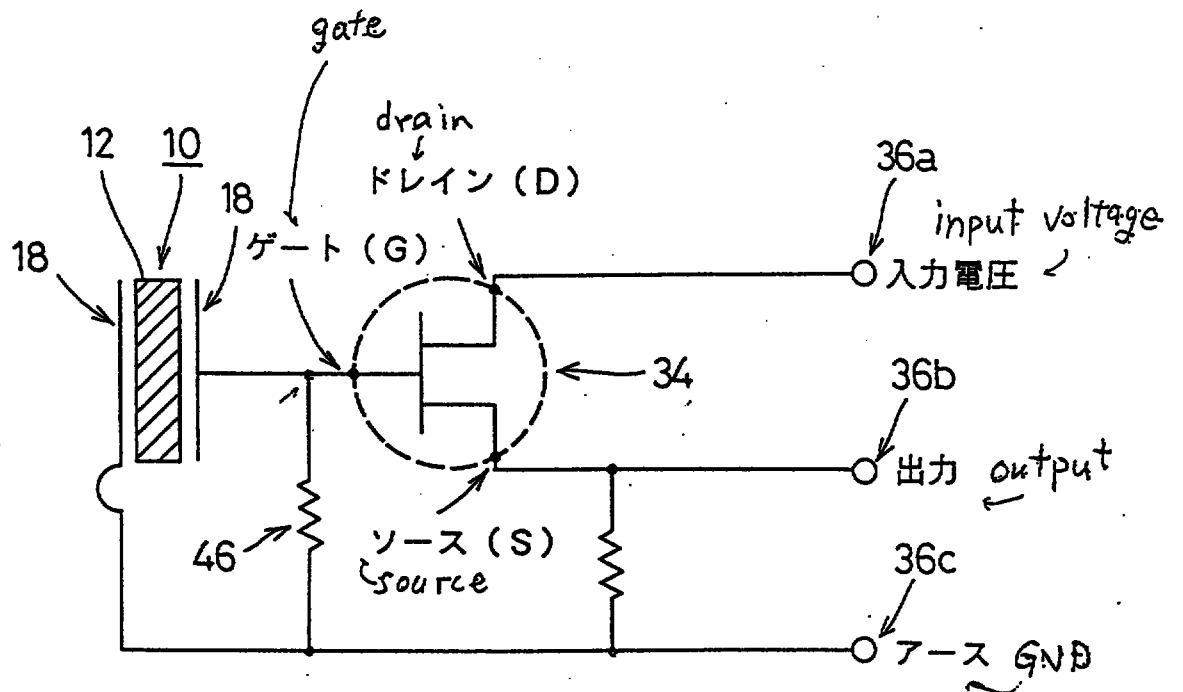


FIG. 4

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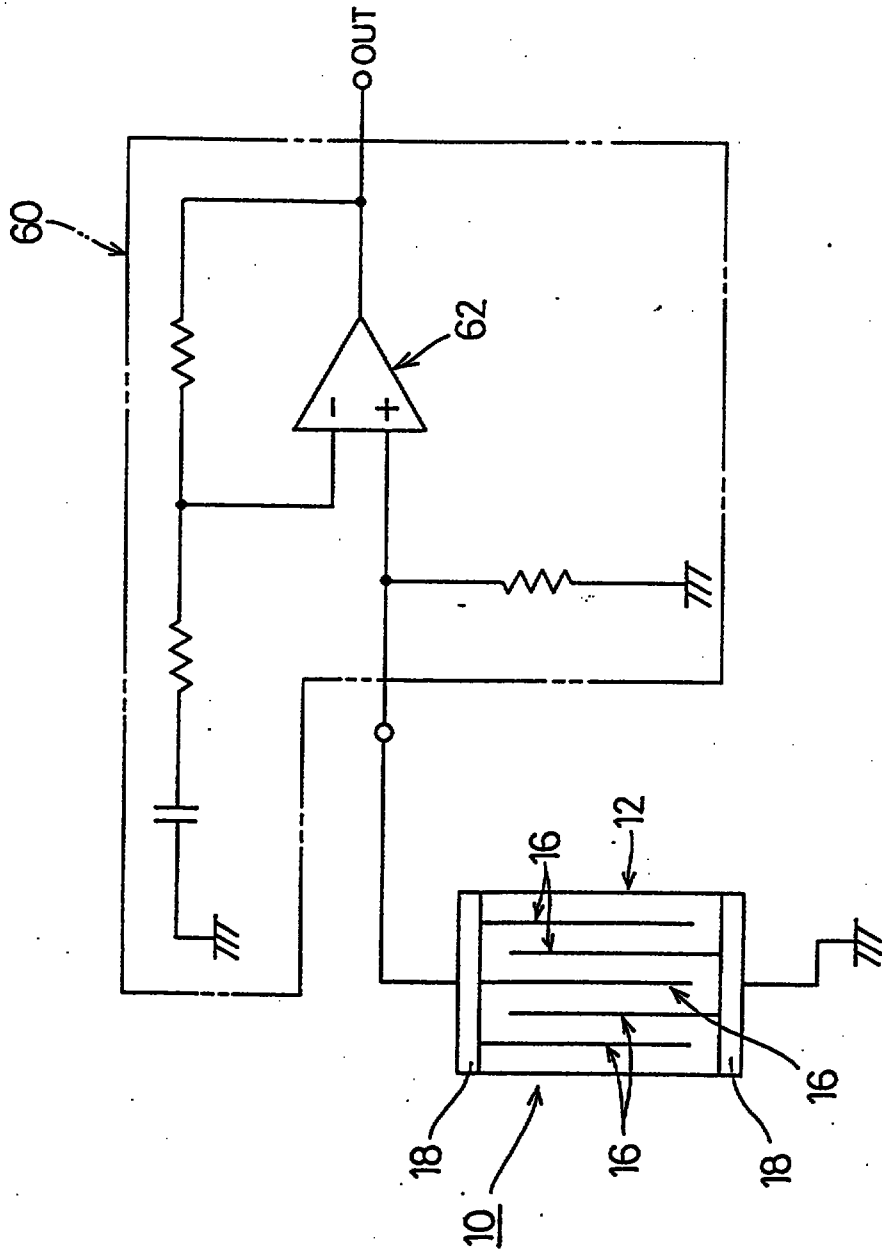


FIG. 5

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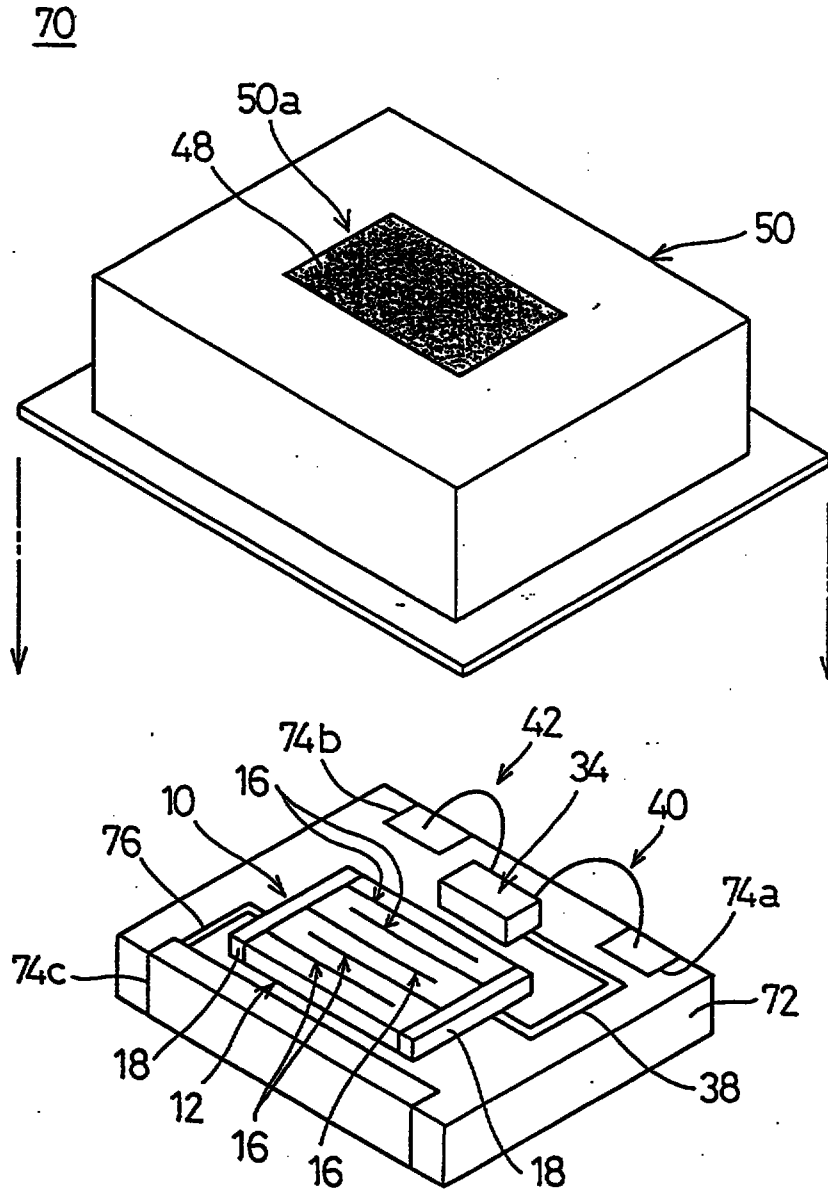


FIG. 6

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(A)

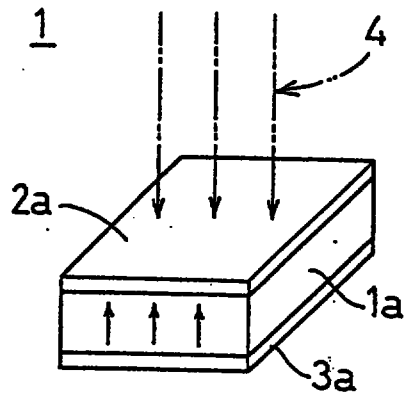


FIG. 7A
PRIOR ART

(B)

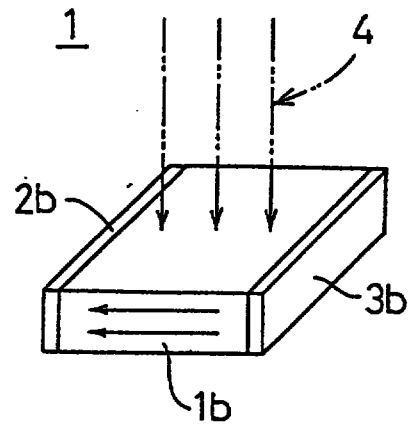


FIG. 7B
PRIOR ART

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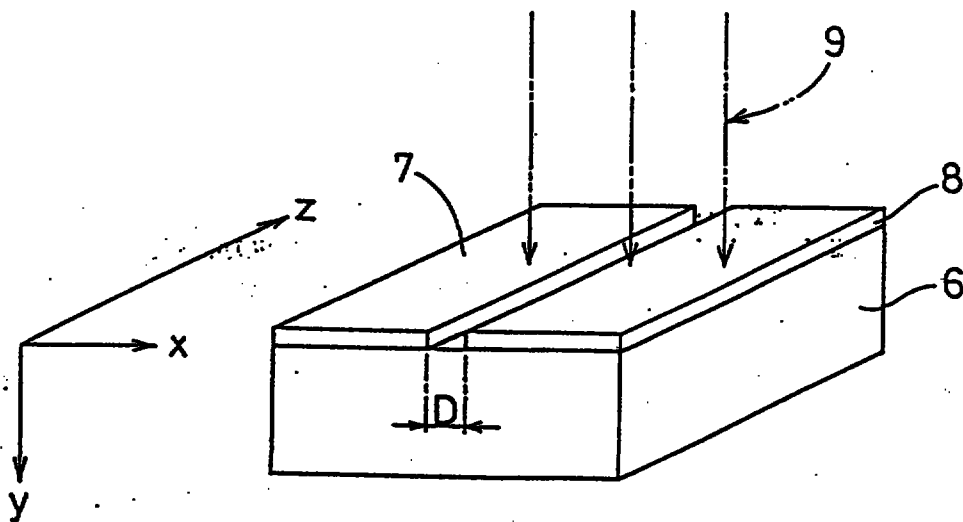


FIG. 8 PRIOR ART

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What is claimed is:

1. An infrared radiation sensitive device (10), comprising
a pyroelectric unit (12),
a light receiving face on said pyroelectric unit (12) for receiving infrared light
radiated from an object to be detected, and
a pair of external electrodes (18) on opposite end surfaces of said pyroelectric
unit (12) respectively,
characterized in that
said pyroelectric unit (12) comprises a plurality of pyroelectric layers (14),
internal electrodes (16) are respectively laid between adjacent ones of said
plurality of pyroelectric layers (14),
edges of said internal electrodes (16) are alternately exposed and connected
to each said external electrodes (18) at each opposite end surface of said
pyroelectric unit (12),
said pyroelectric unit (12) is electrically polarized among said internal
electrodes (14), and
side end edges of said internal electrodes (16) are exposed on said light
receiving face.
2. An infrared radiation sensitive device (10) according to Claim 1,
characterized in that
a relative detection ratio is variable by changing the area of said internal
electrodes (16).

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