



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
18.05.2011 Bulletin 2011/20

(51) Int Cl.:
F25D 21/02 (2006.01)

(21) Application number: **10188725.5**

(22) Date of filing: **25.10.2010**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME

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(30) Priority: **12.11.2009 KR 20090109312**

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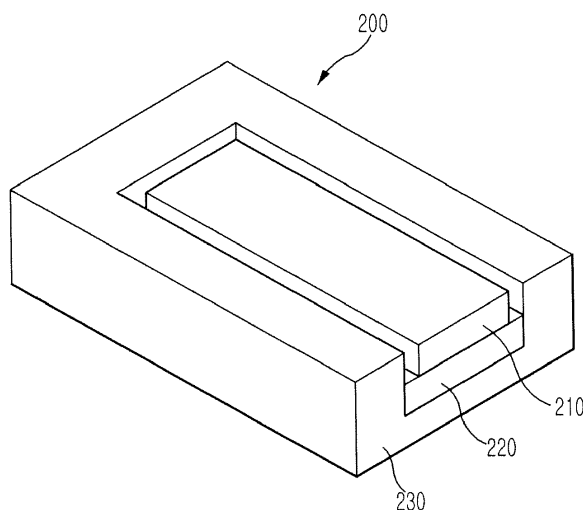
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(54) **Frost detecting apparatus, and cooling system and refrigerator having the same**

(57) A frost detecting apparatus (200) including a first electrode (210) to generate an electric field in a frost detection region, a second electrode (230) to prevent the electric field from leaking into a frost non-detection region, an insulator (220) arranged between the first electrode and the second electrode, to insulate the first electrode, and a shield arranged around an exposed portion of the insulator, to prevent the electric field from leaking

into the frost non-detection region through the exposed portion of the insulator. As the same potential is established at the first and second electrodes, it is possible to prevent electric field from leaking into a frost non-detection region through side surfaces of the first electrode. Accordingly, the electric field is varied only by frost formed in a frost detection region, so that it is possible to more accurately detect formation of frost and the amount of the formed frost.

FIG. 7A



Description

BACKGROUND

1. Field

[0001] Embodiments relate to a frost detecting apparatus, and a cooling system and a refrigerator, which have the frost detecting apparatus, and, more particularly, to a frost detecting apparatus to detect frost formed on an evaporator due to heat exchange, and a cooling system and a refrigerator, which have the frost detecting apparatus.

2. Description of the Related Art

[0002] A cooling system is adapted to cool a confined space by circulating a refrigerant through a refrigeration cycle. As such a cooling system, there are a refrigerator, a Kimchi refrigerator, an air conditioner, etc.

[0003] Here, the refrigeration cycle includes four stages to change the phase of the refrigerant, namely, compression, condensation, expansion, and vaporization stages. To this end, the cooling system should include a compressor, a condenser, an expansion valve, and an evaporator. When a gaseous refrigerant is supplied to the condenser after being compressed in accordance with operation of a compressor, the refrigerant, which is in a compressed state, is cooled as it exchanges heat with air around the condenser. As a result, the refrigerant is condensed into a liquid phase. The liquid refrigerant is then injected into the evaporator while being adjusted in flow rate by the expansion valve. As a result, the refrigerant is abruptly expanded, so that it is vaporized. As the refrigerant is vaporized, it absorbs heat from air around the evaporator, thereby generating cold air. The cold air is supplied to a confined space such as a storage chamber or a room, thereby cooling the confined space. The refrigerant, which has been changed into the gaseous phase in the evaporator, is again introduced into the compressor, and is then compressed into the liquid phase. Thus, the above stages of the refrigeration cycle are repeated for the refrigerant.

[0004] The surface temperature of the evaporator, which functions to cool a confined space by absorbing heat from the confined space through the refrigeration cycle, is relatively lower than the temperature of air present in the confined space. As a result, moisture condensed from the air in the confined space, which is in a moisture-rich state, is attached to the surface of the evaporator, so that frost is formed on the surface of the evaporator. The frost formed on the surface of the evaporator is accumulated with passage of time, so that the thickness of the front is increased. As a result, the heat exchange efficiency of the cold air flowing around the evaporator is degraded, thereby causing degradation in cooling efficiency and excessive power consumption.

[0005] In order to solve such problems, in conventional

cases, an operating time of the compressor is accumulated, and a defrosting operation is carried out when the accumulated operating time exceeds a predetermined time. In the defrosting operation, a heater arranged around the evaporator operates to remove the frost formed on the evaporator. However, this method is inefficient to remove the frost formed on the evaporator because the defrosting operation is carried out based on the operating time of the compressor, irrespective of the actual amount of the frost formed on the evaporator.

[0006] To this end, in order to efficiently control operation of a defrosting heater, there is a conventional frost detecting apparatus to directly detect the amount of frost formed on an evaporator. An example of such a conventional frost detecting apparatus, in particular, a conventional frost detecting apparatus using an electric field, is disclosed in U.S. Patent No. 7,466,146. The configuration of the disclosed frost detecting apparatus is shown in FIG. 1.

[0007] As shown in FIG. 1, the frost detecting apparatus, which uses an electric field, includes a first electrode 11 to detect frost formed between the first electrode 11 and a first cooling fin 21 of an evaporator 20, a first insulator 12 arranged adjacent to the first electrode 11, a second electrode 13 arranged adjacent to the first insulator 12, a second cooling fin 22 arranged opposite the first cooling fin 21, and a second insulator 14 arranged between the second cooling fin 22 and the second electrode 13, to insulate the second cooling fin 22 and second electrode 13 from each other. The first electrode 11 is connected to a sensor terminal A, whereas the second electrode 13 is connected to a shield terminal B.

[0008] In the frost detecting apparatus, an electric field is generated between the first electrode 11 and the first cooling fin 21. When frost is formed between the first cooling fin 21 and the first electrode 11, the electric field is varied due to the formed frost. As a result, the dielectric constants of the first cooling fin 21 and first electrode 11 are varied, so that a variation in capacitance occurs. The varied capacitance is output in the form of a voltage through the sensor terminal A. In this case, whether or not frost has been formed and the amount of the formed frost are detected based on the voltage output through the sensor terminal A.

[0009] Upon detecting formation of frost, the same voltage is supplied to the first electrode 11 and second electrode 13 of the frost detecting apparatus 10, in order to prevent an electric field from being generated in a region beneath the first electrode 11 (namely, a frost non-detection region).

[0010] However, an electric field is inevitably formed between the first electrode 11 and the second electrode 13. This electric field is partially applied to the second cooling fin 22 via corners of the first electrode 11. That is, the distance between the first electrode 11 and the second cooling fin 22 is shorter than the distance between the first electrode 11 and the first cooling fin 21 because the thickness of the frost detecting apparatus

10 is small, so that a great portion of the electric field is applied from the corners of the first electrode 11 to the second cooling fin 22. Since the region arranged toward the second cooling fin 22 with respect to the first electrode 11 is not the frost detection region, the electric field established at the side of the second cooling fin 22 functions as a signal other than a frost detection signal, namely, noise.

[0011] The temperature of the evaporator may be abruptly varied in accordance with the operating time of the compressor. In this case, the dielectric constant of the first insulator 12 may be varied, so that the electric field, which is applied from the first electrode 11 to the second cooling fin 22 via the first insulator 12, may be varied. As a result, the electric field, which is applied from the first electrode 11 to the second cooling fin 22, may be also varied. To this end, it is necessary to take into consideration a variation in the electric field of the first electrode 11 depending on the temperature variation of the first insulator 12, upon detecting formation of frost using the frost detecting apparatus. This will be described with reference to FIGS. 2 and 3.

[0012] FIG. 2 is a graph depicting a variation in dielectric constant according to a variation in the temperature of the first insulator 12 in association with various composition ratios (content ratios of epoxy (a) and silicon (b)) of the first insulator 12. Referring to FIG. 2, it may be seen that, in association with silicon (b), a dielectric constant variation of 0.5 or more is exhibited when the ambient temperature of the frost detecting apparatus ranges between 70 to -30°C.

[0013] FIG. 3A is a graph depicting a variation in noise value exhibited according to a decrease in temperature from room temperature to -23°C under the condition that there is no artificial humidification after installation of the frost detecting apparatus at a cooling fin of an evaporator in a refrigerator. In detail, FIG. 3A is a graph depicting temperature variations of the evaporator and frost detecting apparatus depending on the driving time of a compressor. FIG. 3B is a graph depicting a variation in output voltage according to a variation in the dielectric constant of the first insulator 12 depending on the driving time of the compressor.

[0014] As shown in FIG. 3A, the output voltage of the frost detecting apparatus 10, which initially has a value of 2.491V, is increased to 2.499V due to an abrupt temperature variation for about 60 seconds. Referring to FIG. 3A, it may be seen that, due to the temperature variation for about 60 seconds, the output voltage is varied by 0.008V (Namely, the output voltage becomes noise.). As the temperature is stabilized, the output voltage becomes constant.

[0015] That is, when it is assumed that the output voltage variation caused by formation of frost is 0.025V, there may be an error of about 30% unless the noise value of 0.008V generated due to the temperature variation is compensated for.

[0016] To this end, it may be necessary to attach a

separate temperature sensor to the evaporator, in order to achieve temperature compensation according to variation in ambient temperature of the frost detecting apparatus.

[0017] As frost is formed on the evaporator, the capacitance established between the frost detecting apparatus and the cooling fin is increase. In this case, the output voltage must be decreased. However, an increase in output voltage occurs due to output noise caused by a decrease in temperature. In order to accurately compensate for this error, it may be necessary to accurately detect the dielectric constant of the insulator varied in accordance with a variation in temperature. It may also be necessary to take into consideration a deviation occurring during manufacture of the frost detecting apparatus.

SUMMARY

[0018] In accordance with one aspect, a frost detecting apparatus includes a first electrode to generate an electric field in a frost detection region, a second electrode to prevent the electric field from leaking into a frost non-detection region, an insulator arranged between the first electrode and the second electrode, to insulate the first electrode, and a shield arranged around an exposed portion of the insulator, to prevent the electric field from leaking into the frost non-detection region through the exposed portion of the insulator.

[0019] The shield may be electrically connected to the second electrode.

[0020] The shield may surround side surfaces of the insulator.

[0021] The shield may extend around side surfaces of the first electrode.

[0022] The shield may be spaced apart from the first electrode such that an insulating gap is defined between the shield and the first electrode, to insulate the first electrode.

[0023] The shield may be formed integrally with the second electrode.

[0024] The second electrode may be bent toward the insulator such that at least one outer portion of the second electrode surrounds the insulator.

[0025] The same potential may be established at the first and second electrodes.

[0026] The same potential may be established at the shield and the first electrode.

[0027] The frost detecting apparatus may further include a second insulator formed on an outer surface of the second electrode.

[0028] An object, for which detection of frost formation will be performed, may be in contact with an outer surface of the second insulator.

[0029] The shield may prevent the electric field generated in the frost detection region from varying in spite of a variation in dielectric constant caused by a variation in ambient temperature around the insulator.

[0030] In accordance with another aspect, a frost de-

tecting apparatus includes a first electrode to generate an electric field in a frost detection region, a shield laterally arranged around the first electrode such that the shield surrounds the first electrode while being insulated from the first electrode, to prevent the electric field from leaking into a frost non-detection region through a side surface of the first electrode, an insulator arranged in contact with a back surface of the first electrode and a back surface of the shield, and a second electrode arranged in contact with a back surface of the insulator, to prevent the electric field from leaking into the frost non-detection region through the back surface of the first insulator.

[0031] The frost detecting apparatus may further include a conductor to electrically connect the shield and the second electrode.

[0032] The conductor may extend from the second electrode around the insulator, to laterally surround the insulator.

[0033] The frost detecting apparatus may further include at least one hole extending through the insulator, and a conductor formed in the hole. The conductor may prevent the electric field from leaking into the frost non-detection region through at least one of the side surface of the first electrode and a side surface of the insulator.

[0034] The at least one hole may include at least four holes formed along the side surface of the insulator, and connected to the second electrode.

[0035] The same potential may be established at the second electrode, the first electrode, and the shield.

[0036] The shield may be spaced apart from the first electrode, to define an insulating gap between the shield and the first electrode. The first electrode may be connected to a sensor terminal. The second electrode and the shield may be connected to a shield terminal.

[0037] The frost detecting apparatus may further include a second insulator formed on a back surface of the second electrode, and the second insulator insulates the first electrode, to prevent the first electrode from being eroded by moisture.

[0038] The conductor may extend from the second electrode such that the conductor laterally surrounds the insulator.

[0039] The frost non-detection region may be a region where an electric field generated by the first electrode in an opposite direction to an electric field generated in the frost detecting region by the first electrode is established.

[0040] In accordance with another aspect, a frost detecting apparatus includes a plate-shaped first electrode to generate an electric field in a frost detection region, a plate-shaped first insulator arranged in contact with a back surface of the first electrode, a plate-shaped second electrode arranged in contact with the first insulator, to prevent the electric field from leaking through the back surface of the first electrode, a plate-shaped second insulator arranged in contact with a back surface of the second electrode, and a shield to prevent the electric field from leaking through a side surface of the first insu-

lator, wherein the shield is formed to laterally surround the first insulator.

[0041] The shield may extend along side surfaces of the first electrode.

5 **[0042]** The shield may be electrically connected to the second electrode. The shield may have a plate structure bent to surround the first insulator and the first electrode.

[0043] The same potential may be established at the shield and the first electrode.

10 **[0044]** In accordance with another aspect, a cooling system, which includes an evaporator mounted with a first cooling fin and a second cooling fin, further includes a frost detecting apparatus including a first electrode arranged to face the first cooling fin, the first electrode generating an electric field in a region between the first electrode and the first cooling fin, to detect formation of frost, a first insulator arranged at a back surface of the first electrode, a second electrode arranged at a back surface of the first insulator, to prevent the electric field from leaking toward the second cooling fin, a second insulator arranged in contact with the second cooling fin, to insulate the second cooling fin from the second electrode, and a shield arranged around an exposed portion of the first insulator, to prevent the electric field from leaking toward the second cooling fin through the exposed portion of the first insulator.

25 **[0045]** The shield may extend along side surfaces of the first insulator. The shield may extend to a lower level than upper ends of the side surfaces of the first insulator.

30 **[0046]** The cooling system may further include a detector to detect a voltage corresponding to a variation in the electric field generated between the first electrode of the frost detecting apparatus and the first cooling fin, and a controller to control a defrosting operation, based on the voltage detected by the detector.

35 **[0047]** The shield may extend to a region surrounding the first electrode above the exposed portion of the first insulator.

40 **[0048]** The cooling system may further include a voltage supplier to supply the same voltage to the first and second electrodes, thereby establishing the same potential at the first and second electrodes. The first electrode may be connected to a sensor terminal, and the second electrode is connected to a shield terminal.

45 **[0049]** The frost detecting apparatus may have a U-shaped structure having bent portions, so as to be attached to the second cooling fin facing the first cooling fin.

[0050] The frost detecting apparatus may have a double structure including two frost detecting units each having the same structure as the frost detecting apparatus. The second insulators of the frost detecting units may be in contact with each other.

50 **[0051]** The cooling system may further include a detector to detect a voltage corresponding to a variation in the electric field generated between the first electrode of the frost detecting apparatus and the first cooling fin, and a controller to control a defrosting operation, based on the voltage detected by the detector. The controller may

receives, from the detector, voltages respectively corresponding to capacitances generated in the frost detecting units, may sum the voltages, and may control the defrosting operation, based on the summed voltage.

[0052] The shield may be electrically connected to the second electrode.

[0053] The shield may include a plurality of holes extending through the first insulator, and a conductor formed in each of the holes, so as to electrically connect the shield to the second electrode via the conductor.

[0054] The shield may extend to a level equal to a level of upper ends of side surfaces of the first electrode, and may be spaced apart from the first electrode such that a gap is defined between the shield and the first electrode, to electrically insulate the shield from the first electrode.

[0055] The shield may have at least one outer portion bent toward the first cooling fin to surround at least one side surface of the first insulator.

[0056] The shield may extend to a level equal to a level of upper ends of side surfaces of the first electrode. The first insulator may insulate the shield from the first electrode.

[0057] In accordance with another aspect, a refrigerator, which includes an evaporator mounted with a first cooling fin and a second cooling fin, further includes a frost detecting apparatus including a first electrode arranged to face the first cooling fin, the first electrode generating an electric field, a first insulator arranged at a back surface of the first electrode, a second electrode arranged at a back surface of the first insulator, to prevent the electric field from leaking toward the second cooling fin, a second insulator to insulate the second cooling fin from the second electrode, a shield arranged around an outer peripheral surface of the first insulator, to prevent the electric field from leaking toward the second cooling fin through the outer peripheral surface of the first insulator, and an insulating gap to insulate the shield and the first electrode from each other.

[0058] The shield may be formed integrally with the second electrode.

[0059] The shield may be laterally spaced apart from the first electrode. The shield may include a plurality of holes extending through the first insulator. Each of the holes may electrically connect the shield and the second electrode.

[0060] The shield may further include a conductor formed along side surfaces of the first insulator, to electrically connect the shield to the second electrode.

[0061] The shield may extend to a level equal to a level of upper ends of side surfaces of the first electrode.

[0062] In accordance with one aspect, an electrode is arranged around an electrode functioning to detect formation of frost, and the same potential is established at the electrodes, in order to prevent electric field from leaking into a frost non-detection region through side surfaces of the frost-detecting electrode. Accordingly, the electric field generated by the frost-detecting electrode may be varied only by frost formed in a frost detection region. As

a result, it may be possible to more accurately detect formation of frost on the refrigerant tube and cooling fins of the evaporator, and the amount of the formed frost. It may also be possible to accurately determine a defrosting operation start point and a defrosting operation end point. Thus, an enhancement in defrosting performance may be achieved.

[0063] In accordance with another aspect, an electrode is arranged around an electrode functioning to detect formation of frost such that an insulator is interposed between the electrodes, and the same potential is established at the electrodes, in order to prevent electric field from leaking into a frost non-detection region through side surface edges of the frost-detecting electrode.

[0064] It may also be possible to prevent the electric field leaking into the frost non-detection region from varying in spite of a variation in dielectric constant of an insulator caused by a variation in ambient temperature around the evaporator. That is, it may be possible to prevent the electric field established in the frost detection region from leaking into other regions. Accordingly, it may be possible to more accurately detect formation of frost on the refrigerant tube and cooling fins of the evaporator, and the amount of the formed frost, without temperature compensation required due to a variation in ambient temperature around the frost detecting apparatus. Thus, an enhancement in defrosting performance may be achieved.

[0065] In this regard, it may be possible to simplify the configuration of the frost detecting apparatus because it may be unnecessary to mount a temperature sensor to the evaporator. It may also be possible to easily control the defrosting operation without errors caused by temperature compensation because it may be unnecessary to perform temperature compensation based on a temperature sensed by the temperature sensor during the defrosting operation control. Thus, it may be possible to more accurately detect formation of frost and the amount of the formed frost.

[0066] In this regard, it may be possible to start or stop driving of a heater for a defrosting operation at an appropriate point of time in accordance with the accurately-detected frost amount and the accurately-determined defrosting operation ending time, and thus to optimize the defrosting operation. Accordingly, an enhancement in heat exchange performance of the evaporator may be achieved. Also, an enhancement in energy efficiency may be achieved through a reduction in consumption of energy caused by the defrosting operation.

[0067] Where the cooling system is a refrigerator, it may be possible to control the defrosting operation at an appropriate point of time, based on the accurately-detected frost amount and the accurately-determined defrosting operation ending time. Accordingly, it is possible to prevent degradation in the cooling efficiency of the evaporator caused by degradation in heat exchange and air flow occurring due to formation of frost. It is also possible to efficiently drive a heater used to remove frost. In

this case, accordingly, it may be possible to minimize temperature variation occurring in the interior of the refrigerator, and to store food in the refrigerator in a fresh state for a prolonged period of time.

BRIEF DESCRIPTION OF THE DRAWINGS

[0068] These and/or other aspects will become apparent and more readily appreciated from the following description of the embodiments, taken in conjunction with the accompanying drawings of which:

FIG. 1 is a schematic view illustrating a configuration of a conventional frost detecting apparatus provided at a cooling system;

FIG. 2 is a graph depicting a variation in the dielectric constant of an insulator in the conventional frost detecting apparatus in accordance with variation in ambient temperature of the frost detecting apparatus;

FIG. 3A is a graph depicting temperature variations of an evaporator included in the cooling system and the conventional frost detecting apparatus depending on the driving time of a compressor included in the cooling system;

FIG. 3B is a graph depicting a variation in the output voltage of the conventional frost detecting apparatus depending on the driving time of the compressor;

FIG. 4 is a view illustrating an internal configuration of a refrigerator according to an exemplary embodiment;

FIG. 5 is a view illustrating installation of a frost detecting apparatus provided at the refrigerator according to the illustrated exemplary embodiment;

FIG. 6 is a block diagram illustrating a defrosting control configuration of the refrigerator according to the illustrated exemplary embodiment.

FIG. 7A is a perspective view of a frost detecting apparatus configured in accordance with an exemplary embodiment;

FIG. 7B is a sectional view of the frost detecting apparatus according to the exemplary embodiment illustrated in FIG. 7A;

FIGS. 8A and 8B are distribution diagrams of electric fields respectively generated in a conventional frost detecting apparatus and the frost detecting apparatus according to the illustrated exemplary embodiment;

FIG. 9 depicts graphs of surface charge densities at respective first electrodes in the conventional frost detecting apparatus and the frost detecting apparatus according to the illustrated exemplary embodiment;

FIGS. 10A and 10B are graphs depicting variation in output voltage from the frost detecting apparatus depending on variation in ambient temperature of the frost detecting apparatus in accordance with an exemplary embodiment;

FIG. 11A is a perspective view illustrating a frost de-

tecting apparatus according to an exemplary embodiment;

FIG. 11B to 11D are sectional views respectively illustrating different structures of a second insulator included in the frost detecting apparatus shown in FIG. 11A;

FIG. 12 is a view illustrating an installed state of a frost detecting apparatus according to an exemplary embodiment;

FIG. 13 is a graph depicting a voltage corresponding to an amount of frost detected by the frost detecting apparatus in accordance with an exemplary embodiment;

FIG. 14A is a perspective view of a frost detecting apparatus according to another exemplary embodiment;

FIG. 14B is a sectional view of the frost detecting apparatus shown in FIG. 14A;

FIG. 14C is a sectional view of the frost detecting apparatus shown in FIG. 14B, which additionally includes a second insulator;

FIG. 15 is a sectional view of a frost detecting apparatus according to another exemplary embodiment;

FIG. 16A is a sectional view of a frost detecting apparatus according to another exemplary embodiment;

FIG. 16B is a sectional view illustrating the frost detecting apparatus shown in FIG. 16A;

FIG. 17 is a sectional view of a frost detecting apparatus according to another exemplary embodiment;

FIG. 18 is a perspective view of a frost detecting apparatus according to another exemplary embodiment;

FIG. 19 is a perspective view illustrating an installed state of the frost detecting apparatus shown in FIG. 18;

FIG. 20A is a perspective view of a frost detecting apparatus according to another exemplary embodiment;

FIG. 20B is a cross-sectional view taken along the line X-X in FIG. 20A, illustrating the frost detecting apparatus shown in FIG. 20A; and

FIG. 21 is a perspective view illustrating an installed state of the frost detecting apparatus shown in FIGS. 20A and 20B.

DETAILED DESCRIPTION

[0069] Hereinafter, exemplary embodiments will be described by referring to the figures.

[0070] Each exemplary embodiment is adapted to enhance the defrosting efficiency of a cooling system, and thus to reduce power consumption by accurately detecting whether or not frost has been formed on an evaporator of the cooling system and the amount of the formed frost, and controlling driving of a heater based on the results of the detection, thereby controlling a defrosting operation. The exemplary embodiments are described

in conjunction with an example in which the cooling system is applied to a refrigerator.

[0071] FIG. 4 is a view illustrating an internal configuration of a refrigerator according to an exemplary embodiment. FIG. 5 is a view illustrating installation of a frost detecting apparatus provided at the refrigerator according to the illustrated exemplary embodiment. FIG. 6 is a block diagram illustrating a defrosting control configuration of the refrigerator according to the illustrated embodiment.

[0072] A refrigerator is adapted to store food in a fresh state for a prolonged period of time by maintaining a storage chamber in a low-temperature state through repetition of a refrigeration cycle to sequentially compress, condense, expand, and vaporize a refrigerant.

[0073] As shown in FIG. 4, such a refrigerator, which is designated by reference numeral 100, includes a body 110 having an open front side, and a storage chamber 120 defined in the body 110, to store food. The storage chamber 120 is laterally divided into a freezing compartment and a refrigerating compartment by an intermediate barrier wall. Each of the freezing and refrigerating compartments is open at a front side thereof. A door 130 is provided at the open front side of each compartment, to shield the compartment from an outside of the compartment. A duct D, through which air flows, is formed between the body 110 and one wall of the storage chamber 120. A plurality of holes are formed through the wall of the storage chamber 120. Through the holes, air flows between the storage chamber 120 and the duct D.

[0074] Installed in the duct D are an evaporator 140 to cool ambient air present around the evaporator 140 in accordance with a cooling operation of absorbing latent heat from the ambient air while evaporating a refrigerant supplied from a condenser (not shown), a fan 150 to suck air from the storage chamber 120 while supplying air passing around the evaporator 140 to the storage chamber 120, and a heater 160 to remove frost formed on the evaporator 140. In a machinery chamber defined in a lower portion of the body 110, a compressor 170 to supply the refrigerant after compressing the refrigerant is installed. The condenser (not shown) is also installed in the machinery chamber, to discharge heat from the refrigerant, which has been compressed into a high-temperature and high-pressure state, thereby condensing the refrigerant.

[0075] The evaporator 140 includes a refrigerant tube 141, through which the refrigerant flows, and a plurality of cooling fins 142 (142a and 142b) mounted to the refrigerant tube 141, to achieve an enhancement in heat exchange efficiency. The evaporator 140 functions to heat-exchange the refrigerant, which is maintained in a low-temperature and low-pressure state, with air present in the storage chamber at a higher temperature than the refrigerant, and thus to evaporate the refrigerant, thereby lowering the internal temperature of the storage chamber. Due to a temperature difference between the refrigerant and the air in the storage chamber, frost is contin-

uously formed on the refrigerant tube 141 and cooling fins 142.

[0076] In order to remove the frost formed on the evaporator 140, a defrosting operation is carried out. To control the defrosting operation, driving of the heater 160 is controlled under control of the controller 180. In order to control the defrosting operation, it is necessary to know whether or not frost has been formed on the evaporator 140 and the amount of the formed frost.

[0077] As shown in FIGS. 5 and 6, the refrigerator, which is an example of the cooling system, further includes a frost detecting apparatus 200 installed at at least one of the refrigerant tube 141 and plural cooling fins 142 (142a and 142b) of the evaporator 140, to detect whether or not frost has been formed on the evaporator 140 and the amount of the formed frost.

[0078] The cooling system, namely, the refrigerator, further includes a detector 190 electrically connected with the frost detecting apparatus 200, to receive frost data from the frost detecting apparatus, and to transmit the data to the controller 180. The refrigerator further includes a power supply P to supply voltages having the same phase and magnitude to a sensor terminal A and a shield terminal B, which are included in the frost detecting apparatus 200, so as to establish the same potential at first and second electrodes 210 and 230 of the frost detecting apparatus 200.

[0079] The frost data generated from the frost detecting apparatus 200 represents a capacitance C detected between the frost detecting apparatus 200 and the cooling fin 142 where the frost detecting apparatus 200 is installed. As the amount of frost formed between the frost detecting apparatus 200 and the cooling fin 142 increases, an increase in dielectric constant occurs, thereby causing the capacitance C to increase. In accordance with the capacitance increase, a decrease in voltage occurs. That is, the voltage generated between the frost detecting apparatus 200 and the cooling fin 142 is proportional to the impedance Z established between the frost detecting apparatus 200 and the cooling fin 142. On the other hand, the impedance Z is inversely proportional to the capacitance C ($Z = 1/j\omega C$). As a result, the voltage between the frost detecting apparatus 200 and the cooling fin 142 is inversely proportional to the capacitance C between the frost detecting apparatus 200 and the cooling fin 142.

[0080] The detector 190 is connected to the sensor terminal A of the frost detecting apparatus 200, to detect a voltage generated in accordance with the capacitance between the frost detecting apparatus 200 and the cooling fin 142. The detector 190 transmits the detected voltage to the controller 180.

[0081] The controller 180 compares the voltage received from the detector 190 with a first reference voltage, to determine a point of time when a defrosting operation is to be begun. That is, when the voltage received from the detector 190 is lower than the first reference voltage, the controller 180 determines that it is time to

perform a defrosting operation. In this case, the controller 180 controls the fan 150 and compressor 170 to stop. The controller 180 also controls the heater 160 to be driven. In accordance with these control operations, a defrosting operation is carried out.

[0082] During the defrosting operation, the controller 180 compares the voltage received from the detector 190 with a second reference voltage, to determine a point of time when the defrosting operation is to be ended. That is, when the voltage received from the detector 190 is higher than the second reference voltage, the controller 180 determines that it is time to end the defrosting operation in that defrosting operation is no longer required because there is no frost. In this case, the controller 180 controls the heater 160 to stop. The controller 180 also controls the fan 150 and compressor 170 to be driven. In accordance with these operations, a cooling operation is carried out. At this time, the controller 180 controls the compressor 170 and fan 150 to be driven in accordance with an operation mode set by the user, in order to maintain the storage chamber at a predetermined temperature.

[0083] Frost amount data, which is represented by a corresponding voltage, is experimentally acquired. Based on the acquired frost amount data, the first reference voltage associated with the point of time when the defrosting operation is to be begun, and the second reference voltage associated with the point of time when the defrosting operation is to be ended are determined. The determined first and second reference voltages are stored in a memory (not shown) or the like so that they may be subsequently used.

[0084] Alternatively, the frost detecting apparatus 200 may be installed at the cooling fin 142 of the evaporator 140, to experimentally acquire an initial voltage generated between the frost detecting apparatus 200 and the cooling fin 142, and to experimentally acquire a saturated voltage generated in a frost saturation state. In this case, the first reference voltage may be set to a voltage obtained through comparison between the initial voltage and the saturated voltage. Also, the second reference voltage is set to "0". The set first and second voltages may then be stored in the memory (not shown), so as to be subsequently used.

[0085] The reason why the second reference voltage is set to "0" is that the initial voltage is output when the defrosting operation for the evaporator 140 is ended, because frost is no longer present between the frost detecting apparatus 200 and the cooling fin 142.

[0086] Then, the controller 180 compares the current voltage between the frost detecting apparatus 200 and the cooling fin 142 with the initial voltage, and subsequently compares the resulting comparison voltage with the first reference voltage. When the comparison voltage is higher than the first reference voltage, the controller 180 performs a control operation to begin a defrosting operation. During the defrosting operation, the controller 180 compares the current voltage between the frost de-

tecting apparatus 200 and the cooling fin 142 with the initial voltage, and then compares the resulting comparison voltage with the second reference voltage. When the comparison voltage is lower than the second reference voltage, the controller 180 performs a control operation to end the defrosting operation.

[0087] Upon setting the first and second reference voltages, the distance between the cooling fins 142 should be taken into consideration.

[0088] That is, the distance between one of the cooling fins 142 and the frost detecting apparatus 200 is varied in accordance with the distance between the frost detecting apparatus 200 and the other cooling fin 142 where the frost detecting apparatus 200 is installed. For this reason, the capacitance between the one cooling fin 142 and the frost detecting apparatus 200 ($C = k\epsilon_0 A/d$ (A: the area of the first electrode, d: the distance between the cooling fins, k: the dielectric constant between the electrodes, and ϵ_0 : the dielectric constant of free space)) is varied, thereby varying the voltage between the frost detecting apparatus 200 and the cooling fin 142.

[0089] It may also be possible to experimentally acquire amounts of frost respectively corresponding to given different voltages and times respectively taken to remove the amounts of frost corresponding to the given different voltages, and to store the acquired data in the memory (not shown). In this case, the controller 180 may control the defrosting operation by controlling the heater 160 to be driven for the stored time corresponding to a detected voltage.

[0090] Thus, it may be possible to optimize the defrosting operation by starting the defrosting operation at an appropriate point of time, and ending the defrosting operation at an appropriate point of time. Accordingly, power consumption may be minimized.

[0091] Hereinafter, the frost detecting apparatus 200 will be described with reference to FIG. 7.

[0092] FIG. 7A is a perspective view of the frost detecting apparatus 200, which is configured in accordance with an exemplary embodiment. FIG. 7B is a sectional view of the frost detecting apparatus 200 according to the illustrated exemplary embodiment.

[0093] The frost detecting apparatus 200 includes a first electrode 210 to detect formation of frost, a first insulator 220 arranged in contact with the first electrode 210, and a second electrode 230 arranged in contact with the first insulator 220.

[0094] In detail, the second electrode 230 is arranged in contact with the back surface of the first insulator 220. The second electrode 230 extends around an exposed portion of the first insulator 220, so as to surround the exposed portion of the first insulator 220. Thus, the second electrode 230 extends along the surfaces of the first electrode 210, except for the front surface of the first electrode 210, (namely, the side surfaces of the first electrode 210), so as to surround the first electrode 210. In this case, the first electrode 210 is arranged to face the first cooling fin, to detect formation of frost.

[0095] In accordance with this arrangement, the second electrode 230 functions as a shield to cut off an electric field leaking at side surface edges of the first insulator 220 and first electrode 210.

[0096] The second electrode 230 may extend to a higher level than the side surfaces of the first electrode 210. In this case, the second electrode 230 guides an electric field generated from the first electrode 210 such that the electric field of the first electrode 210 defines a frost detection region.

[0097] Of course, the second electrode 230 may extend to a lower level than the side surfaces of the first electrode 210.

[0098] An insulation gap g is formed between the second electrode 230 and the first electrode 210, to insulate the second electrode 230 from the first electrode 210. Of course, an insulator may be inserted between the second electrode 230 and the first electrode 210.

[0099] The first electrode 210 of the frost detecting apparatus 200 is connected to a sensor terminal A, whereas the second electrode 230 is connected to a shield terminal B. Voltages having the same phase and magnitude are applied to the first electrode 210 and second electrode 230, respectively. As a result, the same potential is established at both the electrodes 210 and 230. Thus, the electric field generated from the second electrode 230 prevents the electric field generated from the first electrode 210 from being transmitted to the second cooling fin.

[0100] In the frost detecting apparatus 200, the same potential is established at both the first electrode 210 and the second electrode 230. In particular, the same potential is established at both the side surfaces of the first electrode 210 and the portions of the second electrode 230 arranged around the side surfaces of the first electrode 210. Accordingly, it may be possible to prevent the electric field generated from the first electrode 210 from leaking at the side surface edges of the first electrode 210. It may also be possible to prevent the electric field of the first electrode 210 from leaking through the side surface edges of the first insulator 220. Thus, it may be possible to prevent the electric field of the first electrode 210, which defines the frost detection region, from being varied. That is, the electric field of the first electrode 210 is guided only to the first cooling fin without leaking, by the second electrode 230. Thus, the electric field of the first electrode 210 in the frost detecting apparatus 200 is varied only by frost formed between the first electrode 210 and the first cooling fin.

[0101] Meanwhile, the first insulator 220 of the frost detecting apparatus 200 exhibits a variation in dielectric constant in accordance with a variation in ambient temperature around the first insulator 220. In this case, the surface charge density of the first electrode 210 may be varied, thereby causing a variation in the electric field leaking through the first insulator 220. However, the second electrode 230 may prevent the electric field from leaking at the side surface edges of the first insulator 220

even when the dielectric constant of the first insulator 220 varies, and thus prevent the electric field from being varied. That is, it may be possible to prevent the electric field generated between the first electrode 210 and the second cooling fin from leaking and varying in spite of a variation in the dielectric constant of the first insulator 220. Thus, the electric field generated between the first electrode 210 and the first cooling fin may be varied only by frost formed between the first electrode 210 and the first cooling fin. This will be described with reference to FIGS. 8 and 9.

[0102] FIGS. 8A and 8B depict distribution diagrams of electric fields respectively generated in a conventional frost detecting apparatus and the frost detecting apparatus according to the illustrated exemplary embodiment. FIG. 9 depicts graphs of surface charge densities at respective first electrodes in the conventional frost detecting apparatus and the frost detecting apparatus according to the illustrated exemplary embodiment.

[0103] FIG. 8A is a distribution diagram of an electric field generated from a first electrode 11 where a second electrode 13 in a conventional frost detecting apparatus 10 is formed only beneath a first insulator 12, as in the conventional case shown in FIG. 1. FIG. 8B is a distribution diagram of an electric field generated from the first electrode 210 where the second electrode 230 of the frost detecting apparatus 200 is formed to surround the first insulator 220 and first electrode 210. Referring to FIGS. 8A and 8B, it may be seen that, in the frost detecting apparatus 200, in which the second electrode 230 surrounds the first insulator 220 and first electrode 210, the electric field distribution of the first electrode 210 is denser in the frost detection region.

[0104] FIG. 9 is a graph depicting a variation in the surface charge density of the first electrode 11 or 210 exhibited when the dielectric constant of the first insulator 12 or 220 interposed between the two electrodes 11 and 13 in the conventional frost detecting apparatus or between the two electrodes 210 and 230 in the frost detecting apparatus according to the illustrated embodiment varies between 1 and 5. Where the second electrode 13 is formed only beneath the first insulator 12, as in the conventional case, it may be seen that a relatively-considerable variation in surface charge density occurs in accordance with a variation in the dielectric constant of the first insulator 12. On the other hand, where the second electrode 230 surrounds the first insulator 220, as in the illustrated embodiment, it may be seen that there is no variation in surface charge density in spite of a variation in the dielectric constant of the first insulator 220.

[0105] In the conventional case, the dielectric constant of the first insulator 12 is varied in accordance with variation in ambient temperature of the defrost detecting apparatus 10, so that the surface charge density between the first insulator 12 and the first electrode 11 is varied, thereby causing a variation in the electric field leaking from the first electrode 11 into the frost non-detection region. As a result, the electric field between the first elec-

trode 11 and the first cooling fin 21 is varied, so that the frost detection signal generated due to formation of frost is varied. In the illustrated embodiment, however, it may be seen that the surface charge density is constant in spite of a variation in the dielectric constant of the first insulator 220 according to temperature variation, because the second electrode 230 is formed to surround the first electrode 210 and first insulator 220, and the same potential is established at both the first and second electrodes 210 and 230.

[0106] Thus, the second electrode 230, which has the same potential as the first electrode 210, may prevent the electric field of the first electrode 210, which will be established in the frost detection region, from leaking into a non-detection region, and thus prevent the electric field between the first electrode 210 and the first cooling fin from being varied due to a variation in temperature. This will be described with reference to FIG. 10A and FIG. 10B

[0107] FIG. 10A is a graph depicting variation in output voltage from the frost detecting apparatus 200 depending on variation in ambient temperature of the frost detecting apparatus 200 in accordance with an exemplary embodiment.

[0108] As the compressor 170 operates for a cooling operation, the ambient temperature of the evaporator 140 is decreased. As a result, the ambient temperature of the frost detecting apparatus 200 is lowered from about 15°C to about -25°C, as shown in FIG. 10B. In this case, however, the electric field between the first electrode 210 and the cooling fin is constant in spite of a variation in the dielectric constant of the first insulator 220 caused by the ambient temperature variation of the frost detecting apparatus 200, as shown in FIG. 10A. That is, there is no variation in capacitance. Thus, it may be seen that the voltage output from the sensor terminal A connected to the first electrode 210 of the frost detecting apparatus 200 is constant.

[0109] That is, the frost detection signal from the first electrode 210 is not influenced by the ambient temperature variation of the frost detecting apparatus 200. In other words, the electric field established between the first electrode 210 and the cooling fin is influenced only by formation of frost.

[0110] As a result, it may be unnecessary to perform a temperature compensation procedure upon detecting formation of frost. Accordingly, it may be unnecessary to mount a separate temperature sensor in the vicinity of the frost detecting apparatus 200. Also, it may be possible to use a simple and easy control algorithm in that no temperature compensation algorithm is needed upon detecting formation of frost.

[0111] The first and second electrodes 210 and 230 of the frost detecting apparatus 200 are made of a conductive material such as aluminum or copper. Where the frost detecting apparatus 200 is installed at the cooling fin 142, which is made of metal, a second insulator 240 is formed on the second electrode 230, which comes into contact with the second cooling fin, in order to insulate

the second cooling fin from the second electrode 230. This will be described with reference to FIG. 11.

[0112] FIG. 11A to 11D are a perspective view and sectional views illustrating frost detecting apparatuses according to exemplary embodiments. In each embodiment, the frost detecting apparatus 200 thereof includes a first electrode 210, a first insulator 220, a second electrode 230, and a second insulator 240.

[0113] FIG. 11A is a perspective view of the frost detecting apparatus, and FIG. 11B is a sectional view of the frost detecting apparatus. The second insulator 240 of the frost detecting apparatus 200 is formed on an outer surface of the second electrode 230, to shield the second electrode 230 from being electrically connected to a cooling fin. The second insulator 240 of the frost detecting apparatus 200 is in contact with a cooling fin 142 of an evaporator 140.

[0114] In the case of FIG. 11C, the second insulator 240 of the frost detecting apparatus 200 shields a region around the second electrode 230, in order to prevent the second electrode 230 from being electrically connected with a cooling fin. The second insulator 240 is formed on an outer surface of the first electrode 210, which is made of metal, to prevent the first electrode 210 from being eroded by frost. Thus, the second insulator 240 shields the first electrode 210. The second insulator 240 is also filled in an insulating gap g, so that it shields the insulating gap g from the outside of the frost detecting apparatus 200.

[0115] In the case of FIG. 11D, the second insulator 240 of the frost detecting apparatus 200 is formed on an outer surface of the second electrode 230, in order to prevent the second electrode 230 from being electrically connected with a cooling fin. Thus, the second insulator 240 shields the second electrode 230. The second insulator 240 is also formed on surfaces of the first electrode 210 and surfaces defining an insulating gap g, in order to prevent the first electrode 210, which is made of metal, from being eroded by frost. Thus, the second insulator 240 shields the first electrode 210 and insulating gap g.

[0116] FIG. 12 is a view illustrating an installed state of a frost detecting apparatus 200 according to an exemplary embodiment.

[0117] The frost detecting apparatus 200 is installed at an evaporator 140, which includes a refrigerant tube 141, through which a refrigerant flows, and a plurality of cooling fins 142, for example, a first cooling fin 142a and a second cooling fin 142b. In detail, the frost detecting apparatus 200 is mounted to at least one of the plural cooling fins.

[0118] In more detail, the frost detecting apparatus 200 includes a first electrode 210 arranged to face the first cooling fin 142a while being connected to a sensor terminal A, a first insulator 220 arranged in contact with the first electrode 210, a second electrode 230 arranged in contact with a back surface of the first insulator 220 and connected to a shield terminal B while surrounding the

first insulator 220 and first electrode 210, and a second insulator 240 arranged in contact with the second electrode 230 and formed on an outer surface of the second electrode 230 to surround the second electrode 230 while being in contact with the second cooling fin 142b. An insulating gap g is formed between the second electrode 230 and the first electrode 210, in order to prevent the second electrode 230 from being electrically connected with the first electrode 210.

[0119] In the above-described frost detecting apparatus 200, the second insulator 240 is in contact with the second cooling fin 142b. In this case, the first electrode 210 faces the first cooling fin 142a of the evaporator 140.

[0120] A frost detection region S1 is formed between a front surface of the first electrode 210 and the first cooling fin 142a. A frost non-detection region S2 is formed between a front surface of the first electrode 210 and the second cooling fin 142b. That is, the frost detecting apparatus 200 detects formation of frost in the frost detection region S1 between the first electrode 210 and the first cooling fin 142a.

[0121] The frost non-detection region S2 is a region where an electric field generated by the first electrode 210 in an opposite direction to an electric field generated in the frost detecting region S1 by the first electrode 210 is established.

[0122] In the frost detecting apparatus 200, voltages having the same phase and magnitude are supplied to the first electrode 210 and second electrode 230 via the sensor terminal A and shield terminal B, respectively. As a result, the same potential is established at both the first electrode 210 and second electrode 230.

[0123] Accordingly, it may be possible to prevent the electric field from leaking at the side surface edges of the first electrode 210 and first insulating layer 220. Also, there is no variation in electric field corresponding to a variation in the dielectric constant of the first insulator 220, which may occur when the ambient temperature of the frost detecting apparatus 200 varies. That is, the electric field of the first electrode 210 is guided, by the second electrode 230, to the frost detection region S1 without leakage and variation in spite of a variation in the dielectric constant of the first insulator 220 caused by a variation in temperature. Thus, the electric field is varied only by frost formed in the frost detection region S1 between the first electrode 210 and the first cooling fin 142a.

[0124] Accordingly, it may be possible to achieve an enhancement in frost detection performance. As a result, it may be possible to accurately determine a defrosting operation start point and a defrosting operation end point, and thus to appropriately control the defrosting operation. Thus, it may be possible to prevent degradation in the cooling efficiency of the evaporator caused by degradation in heat exchange and air flow occurring due to formation of frost. It is also possible to efficiently drive a heater used to remove frost where the cooling system is a refrigerator. In this case, accordingly, it may be possible to minimize temperature variation occurring in the interior

of the refrigerator, and to store food in the refrigerator in a fresh state for a prolonged period of time.

[0125] When a voltage is applied to the first electrode 210 in the frost detecting apparatus 200, charges are distributed to both the first electrode 210 and the first cooling fin 142a. As a result, an electric field is generated in a region between the first electrode 210 and the first cooling fin 142a.

[0126] This electric field is reduced in accordance with an increase in dielectric constant caused by formation of frost between the first electrode 210 and the first cooling fin 142a. Such a dielectric constant variation also causes a variation in capacitance, which is, in turn, output in the form of a voltage from the sensor terminal A. That is, a voltage corresponding to the varied capacitance is output from the sensor terminal A connected to the first electrode 210. The output voltage is detected by the detector 190.

[0127] The output voltage of the frost detecting apparatus 200 according to formation of frost on the evaporator 140 will be described with reference to FIG. 13.

[0128] FIG. 13 is a graph depicting a voltage corresponding to an amount of frost detected by the frost detecting apparatus 200 in accordance with an exemplary embodiment.

[0129] When the compressor 170 operates for a cooling operation, heat exchange is carried out at the evaporator 140, so that frost is formed in the frost detection region S1 between the first electrode 210 and the first cooling fin 142a. As the amount of the frost formed in the frost detection region S1 increases, the electric field between the first electrode 210 and the first cooling fin 142a is varied. The electric field variation causes a variation in capacitance. Thus, it may be seen that, as the amount of frost formed in the frost detection region S1, the voltage output from the sensor terminal A is lowered.

[0130] Referring to FIG. 13, it may be seen that the output voltage generated in a state, in which the formation of frost in the frost detection region S1 is saturated, is lower than the output voltage generated in a state, in which no frost is formed, by about 30mV.

[0131] Of course, the output voltage difference of 30mV may be varied in accordance with the distance between the first cooling fin and the frost detecting apparatus, the applied voltage, etc.

[0132] In this case, it may be possible to set the result of the comparison between the output voltage from the frost detecting apparatus 200 in a frost saturation state and the output voltage from the frost detecting apparatus 200 in a frost non-formation state, namely, a voltage difference (about 30mV), to a reference voltage at a defrosting operation start point, namely, a first reference voltage. In this case, a reference voltage at a defrosting operation end point, namely, a second reference voltage, may also be set to 0 because, in the defrosting operation end point, the frost detecting apparatus 200 outputs a voltage equal to the output voltage in the frost non-formation state, in accordance with complete removal of frost from the frost detection region S1.

[0133] Meanwhile, the distance between the frost detecting apparatus 200 and the first cooling fin 142a is varied in accordance with the distance between the two cooling fins 142a and 142b. In accordance with the distance between the frost detecting apparatus 200 and the first cooling fin 142a, the capacitance of the frost detection region S1 between the frost detecting apparatus 200 and the first cooling fin 142a is varied, thereby causing the output voltage from the frost detecting apparatus 200 to be varied. To this end, it may be necessary to take into consideration the distance between the cooling fins 142a and 142b upon setting the first and second reference voltages.

[0134] FIG. 14A is a perspective view of a frost detecting apparatus 200 according to another exemplary embodiment. FIG. 14B is a sectional view of the frost detecting apparatus 200 shown in FIG. 14A.

[0135] The frost detecting apparatus 200 includes a first electrode 210, a first insulator 220 arranged in contact with the first electrode 210, a second electrode 230 arranged in contact with the first insulator 220, and a shield 250 arranged around the first electrode 210 while being spaced apart from the first electrode 210, to define an insulation gap g for insulation from the first electrode 210. The shield 250 is arranged in contact with the first insulator 220.

[0136] The frost detecting apparatus 200 also includes one or more holes h extending through the shield 250, first insulator 220, and second electrode 230. A wire as a conductor 260 may be inserted into each hole h, in order to electrically connect the second electrode 230 and shield 250. Alternatively, the conductor 260 may be formed by plating a conductive material in the hole h.

[0137] In the frost detecting apparatus 200, voltages having the same phase and magnitude are supplied to the first electrode 210 and second electrode 230 via the sensor terminal A and shield terminal B, respectively. As a result, the same potential is established at both the first electrode 210 and second electrode 230.

[0138] When a voltage is applied to the first electrode 210 in the frost detecting apparatus 200, charges are distributed to both the first electrode 210 and the cooling fin. As a result, an electric field is generated in a region between the first electrode 210 and the cooling fin.

[0139] In the frost detecting apparatus 200, the dielectric field, electric field, and capacitance between the first electrode 210 and the cooling fin are varied due to frost formed between the first electrode 210 and the cooling fin. The varied capacitance is output in the form of a voltage from the sensor terminal A. That is, a voltage corresponding to the varied capacitance is output from the sensor terminal A connected to the first electrode 210. The output voltage is detected by the detector 190.

[0140] In the frost detecting apparatus 200, the same potential is established at both the first electrode 210 and the second electrode 230, and the same potential is established at both the shield 250 electrically connected to the second electrode 230 via the holes h and the first

electrode 210. Accordingly, it may be possible to prevent the electric field from leaking into the frost non-detection region at the side surface edges of the first electrode 210. Also, the conductors 260 are formed by inserting wires into respective holes h, which extend through the shield 250, first insulator 220, and second electrode 230 while being arranged around the first electrode 210 or plating a conductive material in the holes h. By the conductors 260, the same potential is established at both the first electrode 210 and the portion of the first insulator 220 arranged around the first electrode 210. Accordingly, it may be possible to prevent the electric field from leaking into the frost non-detection region through the first insulator 220. Since the same potential is established at both the first electrode 210 and the portion of the first insulator 220 arranged around the first electrode 210, there may be no electric field variation corresponding to a variation in the dielectric constant of the first insulator 220 possibly caused by variation in ambient temperature of the frost detecting apparatus 200. That is, the electric field is varied only by frost formed in the frost detection region between the first electrode 210 and the cooling fin.

[0141] FIG. 14C is a sectional view of the frost detecting apparatus 200 shown in FIGS. 14A and 14B. As shown in FIG. 14C, the frost detecting apparatus 200 further includes a second insulator 240.

[0142] The first electrode 210 and second electrode 230 are made of a conductive material such as aluminum or copper. Where the frost detecting apparatus 200 is installed at the cooling fin 142, which is made of metal, the second insulator 240 may be formed over the entire outer surface of the frost detecting apparatus 200, in order to prevent the second electrode 230 and cooling fin 142 from being electrically connected to each other, and to prevent the first electrode 210 from being eroded by moisture.

[0143] The second insulator 240 may be formed on the second electrode 230, which comes into contact with the cooling fin 142, in order to insulate the second electrode 230 from the cooling fin 142. The second insulator 240 may also be formed on the first electrode 210, in order to prevent the first electrode 210 from being eroded by moisture.

[0144] FIG. 15 is a sectional view of a frost detecting apparatus 200 according to another exemplary embodiment.

[0145] As shown in FIG. 15, the frost detecting apparatus 200 includes a first electrode 210, a first insulator 220 arranged in contact with the first electrode 210, a second electrode 230 arranged in contact with the first insulator 220, a shield 250 arranged around the first electrode 210 while being spaced apart from the first electrode 210, to define an insulation gap g for insulation from the first electrode 210, and a conductor 270 arranged in contact with side surfaces of the second electrode 230, first insulator 220, and shield 250. The conductor 270 is a plating layer formed on the side surfaces of the second electrode 230, first insulator 220, and shield 250. The

conductor 270 functions to electrically connect the second electrode 230 and shield 250.

[0146] In this frost detecting apparatus 200, voltages having the same phase and magnitude are applied to the first electrode 210 and second electrode 230 via a sensor terminal A and a shield terminal B, respectively. As a result, the same potential is established among the first electrode 210, second electrode 230, shield 250, and conductor 270.

[0147] When a voltage is applied to the first electrode 210 in the frost detecting apparatus 200, an electric field is generated in a region between the first electrode 210 and the cooling fin. This electric field is varied due to a variation in dielectric constant caused by frost formed between the first electrode 210 and the cooling fin. Due to the varied dielectric constant and electric field, a variation in capacitance occurs. The varied capacitance is output in the form of a voltage from the sensor terminal A. That is, a voltage corresponding to the varied capacitance is output from the sensor terminal A connected to the first electrode 210. The output voltage is detected by the detector 190.

[0148] In the frost detecting apparatus 200, the same potential is established at the first electrode 210, second electrode 230, shield 250, and conductor 270. Accordingly, it may be possible to prevent the electric field from leaking at the side surface edges of the first electrode 210 and the first insulator 220. Also, the potential in a region around the first insulator 220 is equal to the potential at the first electrode 210. Accordingly, there is no electric field variation corresponding to the dielectric constant variation of the first insulator 220, which may occur due to variation in ambient temperature of the frost detecting apparatus 220. Thus, the electric field variation occurs only due to frost formed between the first electrode 210 and the first cooling fin.

[0149] The first and second electrodes 210 and 230 of the frost detecting apparatus 200 are made of a conductive material such as aluminum or copper. Accordingly, a second insulator 240 may be formed on the first electrode 210, second electrode 230, and conductor 270, in order to prevent the second electrode 230 and cooling fin 142 from being electrically connected, and to prevent the first electrode 210, conductor 270, etc. from being eroded by moisture. Alternatively, the second insulator 240 may be formed on the entire outer surface of the frost detecting apparatus 200.

[0150] FIG. 16A is a sectional view of a frost detecting apparatus 200 according to another exemplary embodiment.

[0151] As shown in FIG. 16A, the frost detecting apparatus 200 includes a first electrode 210, a first insulator 220 arranged in contact with the first electrode 210, and a second electrode 230 arranged in contact with the first insulator 220. The second electrode 230 extends around an exposed portion 211 of the first insulator 220, to surround the first insulator 220.

[0152] In this case, the second electrode 230 may ex-

tend to a higher level than the exposed portion 211 of the first insulator 220, or may extend to a lower level than the exposed portion 211 of the first insulator 220.

[0153] When a voltage is applied to the first electrode 210 in the frost detecting apparatus 200, an electric field is generated in a region between the first electrode 210 and the cooling fin. This electric field is varied due to frost formed between the first electrode 210 and the cooling fin. Due to the varied electric field, a variation in capacitance occurs. The varied capacitance is output in the form of a voltage from the sensor terminal A. That is, a voltage corresponding to the varied capacitance is output from the sensor terminal A connected to the first electrode 210. The output voltage is detected by the detector 190.

[0154] In the frost detecting apparatus 200, a voltage equal to the voltage supplied to the first electrode 210 is supplied to the second electrode 230, so that the potential established at the second electrode 230 is equal to the potential at the first electrode 210. As a result, it is possible to prevent the electric field from leaking through the first insulator 220. Also, there is no variation in electric field corresponding to a variation in the dielectric constant of the first insulator 220, which may occur when the ambient temperature of the frost detecting apparatus 200 varies. That is, the electric field is varied only by frost formed in the frost detection region between the first electrode 210 and the cooling fin, irrespective of the dielectric constant variation of the first insulator 220.

[0155] Thus, the second electrode 230 functions as a shield to shield the electric field of the first electrode 210, which may leak into the exposed portion 211 of the first insulator 220.

[0156] FIG. 16B is a sectional view illustrating the frost detecting apparatus 200 shown in FIG. 16A. Referring to FIG. 16B, the frost detecting apparatus 200 further includes a second insulator 240.

[0157] The first and second electrodes 210 and 230 of the frost detecting apparatus 200 are made of a conductive material such as aluminum or copper. Where the frost detecting apparatus 200 is installed at the cooling fin, which is made of metal, the second insulator 240 may be formed on the entire outer surface of the frost detecting apparatus 200, in order to prevent the second electrode 230 and cooling fin from being electrically connected, and to prevent the first electrode 210 from being eroded by moisture.

[0158] The second insulator 240 may be formed on the second electrode 230, which comes into contact with the cooling fin 142, in order to insulate the second electrode 230 from the cooling fin 142. The second insulator 240 may also be formed on the first electrode 210, in order to prevent the first electrode 210 from being eroded by moisture.

[0159] FIG. 17 is a sectional view of a frost detecting apparatus 200 according to another exemplary embodiment.

[0160] As shown in FIG. 17, the frost detecting apparatus 200 includes a first electrode 210, a first insulator

220 arranged in contact with the first electrode 210, a second electrode 230 arranged adjacent to the first insulator 220, and a shield 250 arranged around the first electrode 210 while being spaced apart from the first electrode 210, to define an insulation gap *g* for insulation from the first electrode 210.

[0161] When a voltage is applied to the first electrode 210 in the frost detecting apparatus 200, an electric field is generated in a region between the first electrode 210 and the cooling fin. This electric field is varied by frost formed between the first electrode 210 and the cooling fin. Due to the varied electric field, a variation in capacitance occurs. The varied capacitance is output in the form of a voltage from the sensor terminal A. That is, a voltage corresponding to the varied capacitance is output from the sensor terminal A connected to the first electrode 210. The output voltage is detected by the detector 190.

[0162] In the frost detecting apparatus 200, a voltage equal to the voltage supplied to the first electrode 210 is supplied to the second electrode 230 and shield 250 via the shield terminal B, so that the potential established at the second electrode 230 and shield 250 is equal to the potential at the first electrode 210. As a result, it is possible to prevent the electric field from leaking into the frost non-detection region through the side surface edges of the first electrode 210.

[0163] Also, the first insulator 220 of the frost detecting apparatus 200 has a thickness allowing the first insulator 220 to prevent leakage of the electric field and to minimize a variation in dielectric constant in spite of temperature variation. Accordingly, it may be possible to minimize the amount of electric field leaking through the first insulator 220.

[0164] Thus, the electric field variation of the first electrode 210 occurs only by frost formed in the frost detection region between the first electrode 210 and the cooling fin.

[0165] FIG. 18 is a perspective view of a frost detecting apparatus 200 according to another exemplary embodiment. FIG. 19 is a perspective view illustrating an installed state of the frost detecting apparatus 200 shown in FIG. 18.

[0166] The frost detecting apparatus 200 is installed at an evaporator. The evaporator includes a refrigerant tube 141, through which the refrigerant flows, and a plurality of cooling fins 142 (142a and 142b) mounted to the refrigerant tube 141. The frost detecting apparatus 200 is mounted to at least one of the plural cooling fins.

[0167] The frost detecting apparatus 200 has a U-shaped structure having two bent portions, taking into consideration the structure of the evaporator in which the refrigerant tube 141 extends through the cooling fins 142. As the frost detecting apparatus 200 has the U-shaped structure, the area of a first electrode 210, which is included in the frost detecting apparatus 200, is maximized. Accordingly, the capacitance formed between the first electrode 210 and the cooling fin is increased. Thus, it may be possible to easily detect a voltage output through the sensor terminal A in accordance with the amount of

frost formed on the evaporator.

[0168] In detail, the frost detecting apparatus 200 includes a first electrode 210 arranged to correspond to the second cooling fin 142b, a first insulator 220 arranged in contact with the first electrode 210, a second electrode 230 arranged in contact with the first insulator 220 while being in contact with side surfaces of the first insulator 220 and first electrode 210 to surround the first insulator 220 and first electrode 210, and a second insulator 240 arranged in contact with the first insulator 220 while extending around the second electrode 230 to surround the second electrode 230. The second insulator 240 is arranged in contact with the second cooling fin 142b. An insulating gap *g* is formed between the second electrode 230 and the first electrode 210, in order to prevent the second electrode 230 from being electrically connected with the first electrode 210.

[0169] As shown in FIG. 19, the frost detecting apparatus 200 is installed such that the second insulator 240 is in contact with the second cooling fin 142b, and the refrigerant tube 141 extends through an opening O (FIG. 18). In this case, the first electrode 210 is arranged to face the first cooling fin 142a of the evaporator 210. Thus, the frost detecting apparatus 200 detects formation of frost between the first electrode 210 and the first cooling fin 142a.

[0170] When a voltage is applied to the first electrode 210 in the frost detecting apparatus 200, charges are distributed to both the first electrode 210 and the first cooling fin 142a. As a result, an electric field is generated in a region between the first electrode 210 and the first cooling fin 142a.

[0171] The electric field between the first electrode 210 and the first cooling fin 142a is varied due to frost formed between the first electrode 210 and the first cooling fin 142a. The electric field variation causes a variation in capacitance, which is, in turn, output in the formation of a voltage from the sensor terminal A. That is, a voltage corresponding to the varied capacitance is output from the sensor terminal A connected to the first electrode 210. The output voltage is detected by the detector 190.

[0172] In the frost detecting apparatus 200, voltages having the same phase and magnitude are supplied to the first electrode 210 and second electrode 230 via the sensor terminal A and shield terminal B, respectively. As a result, the same potential is established at both the first electrode 210 and second electrode 230. Accordingly, it may be possible to prevent an electric field from leaking at the side surface edges of the first electrode 210. It may also be possible to prevent the electric field of the first electrode 210 from leaking through the side surface edges of the first insulator 220. Thus, it may be possible to prevent electric field of the first electrode 210, which defines the frost detection region, from being varied.

[0173] Also, there is no variation in electric field corresponding to a variation in the dielectric constant of the first insulator 220, which may occur when the ambient temperature of the frost detecting apparatus 200 varies.

That is, the electric field is varied only by frost formed in the frost detection region S1 between the first electrode 210 and the first cooling fin 142a.

[0174] FIG. 20A is a perspective view of a frost detecting apparatus according to another exemplary embodiment. FIG. 20B is a cross-sectional view taken along the line X-X in FIG. 20A, illustrating the frost detecting apparatus shown in FIG. 20A.

[0175] The frost detection apparatus has a double structure including two frost detecting units 200 and 200' each having a U-shaped structure with two bent portions, taking into consideration the structure of the evaporator in which a refrigerant tube extends through a plurality of cooling fins. In the double structure, second insulators 240 and 240' of the frost detecting units 200 and 200' are in contact with each other. In this case, first electrodes 210 and 210' of the frost detecting units 200 and 200' are connected to a sensor terminal A, whereas second electrodes 230 and 230' of the frost detecting units 200 and 200' are connected to a shield terminal B.

[0176] In this frost detecting apparatus, the areas of the first electrodes 210 and 210' are maximized. Accordingly, the capacitance formed between each of the first electrodes 210 and 210' and the cooling fin is increased. Thus, it may be possible to easily detect a voltage output through the sensor terminal A in accordance with the amount of frost formed on the evaporator.

[0177] In more detail, the frost detecting apparatus includes the first electrode 210, a first insulator 220 arranged in contact with the first electrode 210, the second electrode 230, which is arranged in contact with the first insulator 220 while extending around the first insulator 220 and first electrode 210, to surround the first electrode 210, the second insulator 240, which is arranged in contact with the second electrode 230 while extending around the second electrode 230, to surround the second electrode 230, the second insulator 240' arranged in contact with the second insulator 240, the second electrode 230' surrounded by the second insulator 240', a first insulator 220' surrounded by the second electrode 230', and the first electrode 210' arranged in contact with the first insulator 220' while being laterally adjacent to the second electrode 230', to define an insulating gap g between the first electrode 210' and the second electrode 230'.

[0178] FIG. 21 is a perspective view illustrating an installed state of the frost detecting apparatus shown in FIGS. 20A and 20B.

[0179] The frost detecting apparatus is installed at an evaporator. The evaporator includes a refrigerant tube 141, through which the refrigerant flows, and a plurality of cooling fins 142 (142a, 142a', and 142b) mounted to the refrigerant tube 141. The frost detecting apparatus is mounted to at least one of the plural cooling fins, for example, the second cooling fin 142b. In this case, the U-shaped frost detecting units 200 and 200' are installed on opposite surfaces of the second cooling fin 142b, respectively.

[0180] Alternatively, the frost detecting apparatus may be installed between opposite ends of the cooling fin, using a separate mounting device.

[0181] The frost detecting unit 200 is installed such that the second insulator 240 is in contact with one surface of the second cooling fin 142b, and the refrigerant tube 141 of the evaporator 140 extends through an opening formed at the frost detecting unit 200. In this case, the first electrode 210 faces the first cooling fins 142a and 142a'.

[0182] On the other hand, the frost detecting unit 200' is installed such that the second insulator 240' is in contact with the other surface of the second cooling fin 142b, and the refrigerant tube 141 of the evaporator 140 extends through an opening formed at the frost detecting unit 200'. In this case, the first electrode 210' faces the first cooling fin 142a' of the evaporator 140.

[0183] Accordingly, the frost detecting units 200 and 200' detect formation of frost between the first electrode 210 and the first cooling fin 142a and formation of frost between the first electrode 210' and the first cooling fin 142a', respectively.

[0184] When a voltage is applied to the first electrodes 210 and 210' in the frost detecting units 200 and 200', charges are distributed to both the first electrode 210 and the first cooling fin 142a while being distributed to both the first electrode 210' and the first cooling fin 142a'. As a result, an electric field is generated in a region between the first electrode 210 and the first cooling fin 142a, and an electric field is generated in a region between the first electrode 210' and the first cooling fin 142a'.

[0185] The electric field between the first electrode 210 and the first cooling fin 142a is varied due to frost formed between the first electrode 210 and the first cooling fin 142a. Also, the electric field between the first electrode 210' and the first cooling fin 142a' is varied due to frost formed between the first electrode 210' and the first cooling fin 142a'. The electric field variation causes a variation in capacitance, which is, in turn, output in the form of a voltage from the sensor terminal A. That is, a voltage corresponding to the varied capacitance is output from the sensor terminal A connected to a corresponding one of the first electrodes 210 and 210'. The output voltage is detected by the detector 190.

[0186] The controller 180 sums voltages, namely, data as to frost formed between the frost detecting unit 200 and the first cooling fin 142a and data as to frost formed between the frost detecting unit 200' and the first cooling fin 142a', and controls a defrosting operation based on the summed voltage. First and second reference voltages used to control the defrosting operation are experimentally acquired based on the summed voltage, and stored in the memory so that they may be subsequently used.

[0187] In the frost detecting unit 200, voltages having the same phase and magnitude are supplied to the first electrode 210 and second electrode 230 via the sensor terminal A and shield terminal B, respectively. As a result,

the same potential is established at both the first electrode 210 and second electrode 230. Also, in the frost detecting unit 200', voltages having the same phase and magnitude are supplied to the first electrode 210' and second electrode 230' via the sensor terminal A and shield terminal B, respectively. As a result, the same potential is established at both the first electrode 210' and second electrode 230'.

[0188] Accordingly, it may be possible to prevent an electric field from leaking through the side surface edges of the first electrodes 210 and 210' and the first insulators 220 and 220'. Also, there is no variation in electric field corresponding to a variation in the dielectric constant of the first insulator 220 or 220', which may occur when the ambient temperature of the frost detecting unit 200 or 200' varies. That is, the electric field is varied only by frost formed in the frost detection region between the first electrode 210 and the first cooling fin 142a or by frost formed in the frost detection region between the first electrode 210' and the first cooling fin 142a'.

[0189] Accordingly, it may be possible to more accurately detect whether or not frost has been formed on the refrigerant tube and cooling fins of the evaporator and the amount of the formed frost. As a result, it may be possible to accurately determine a defrosting operation start point and a defrosting operation end point.

[0190] As the amount of frost formed on the evaporator and the defrosting operation completion time may be accurately determined, it may be possible to drive or stop the heater used for the defrosting operation at an appropriate point of time. Accordingly, the defrosting operation may be optimized, so that the heat exchange performance of the evaporator may be enhanced. Also, energy consumption caused by the defrosting operation may be reduced, so that an enhancement in energy efficiency may be achieved.

[0191] Although a few embodiments have been shown and described, it would be appreciated by those skilled in the art that changes may be made in these embodiments without departing from the principles and spirit of the invention, the scope of which is defined in the claims and their equivalents.

Claims

1. A frost detecting apparatus comprising:

a first electrode to generate an electric field in a frost detection region;
a second electrode to prevent the electric field from leaking into a frost non-detection region;
an insulator arranged between the first electrode and the second electrode, to insulate the first electrode; and
a shield arranged around an exposed portion of the insulator, to prevent the electric field from leaking into the frost non-detection region

through the exposed portion of the insulator.

2. The frost detecting apparatus according to claim 1, wherein the shield is electrically connected to the second electrode.
3. The frost detecting apparatus according to claim 2, wherein the shield surrounds side surfaces of the insulator.
4. The frost detecting apparatus according to claim 3, wherein the shield extends around side surfaces of the first electrode.
5. The frost detecting apparatus according to claim 4, wherein the shield extends to a level equal to a level of upper ends of side surfaces of the first electrode.
6. The frost detecting apparatus according to claim 2, wherein the shield is spaced apart from the first electrode such that an insulating gap is defined between the shield and the first electrode, to insulate the first electrode.
7. The frost detecting apparatus according to claim 2, wherein the shield is formed integrally with the second electrode.
8. The frost detecting apparatus according to claim 7, wherein the second electrode is bent toward the insulator such that at least one outer portion of the second electrode surrounds the insulator.
9. The frost detecting apparatus according to claim 1, wherein the same potential is established at the first and second electrodes.
10. The frost detecting apparatus according to claim 9, wherein the same potential is established at the shield and the first electrode.
11. The frost detecting apparatus according to claim 1, further comprising:

a second insulator formed on an outer surface of the second electrode.

12. The frost detecting apparatus according to claim 11, wherein an object, for which detection of frost formation will be performed, is in contact with an outer surface of the second insulator.
13. The frost detecting apparatus according to claim 1, wherein the shield prevents the electric field generated in the frost detection region from varying in spite of a variation in dielectric constant caused by a variation in ambient temperature around the insulator.

14. The frost detecting apparatus according to claim 1, further comprising: a conductor to electrically connect the shield and the second electrode.

15. The frost detecting apparatus according to claim 1, wherein the shield comprises at least one hole extending through the insulator, and a conductor formed in the hole and electrically connected to the second electrode.

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FIG. 1

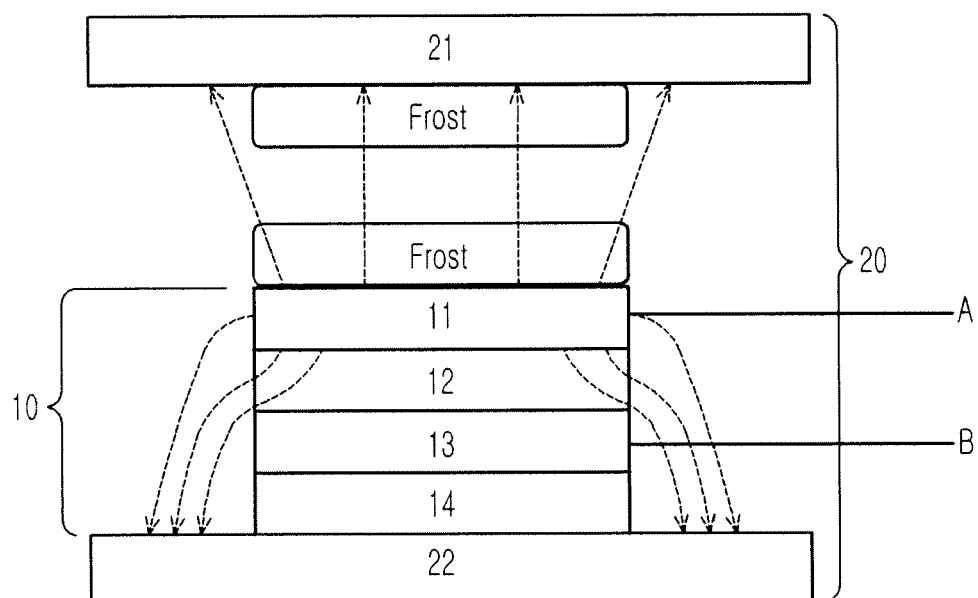


FIG. 2

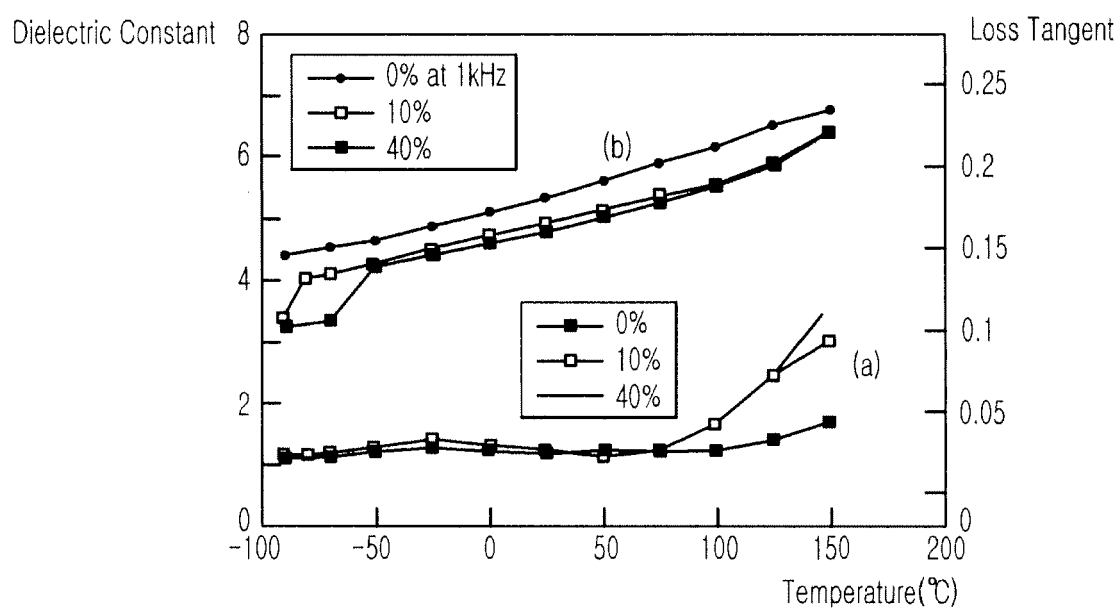


FIG. 3A

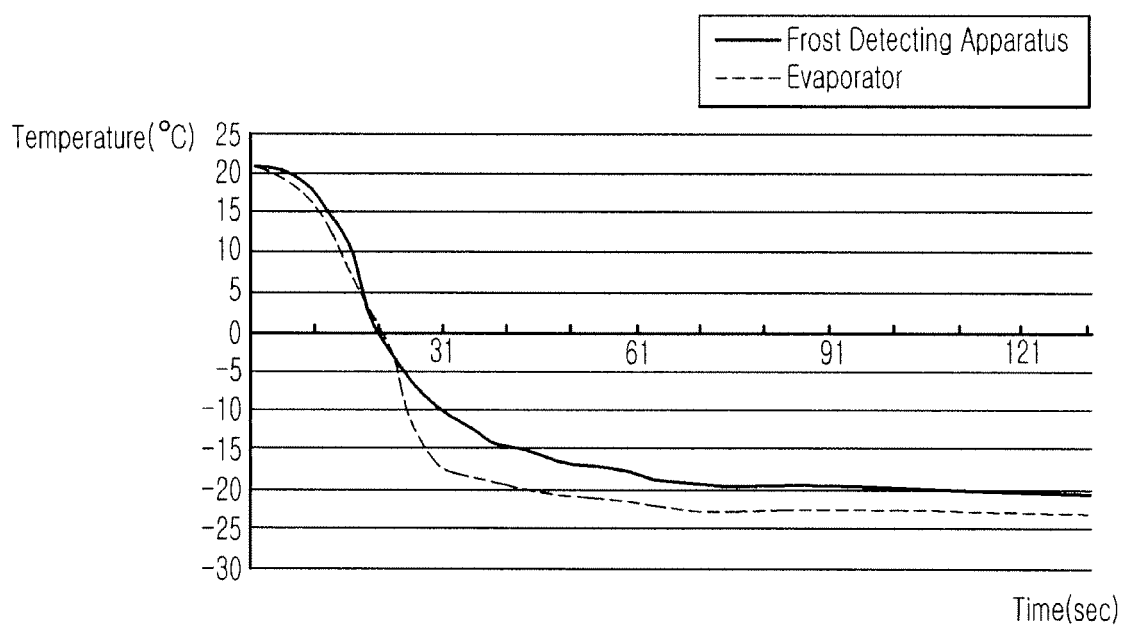


FIG. 3B

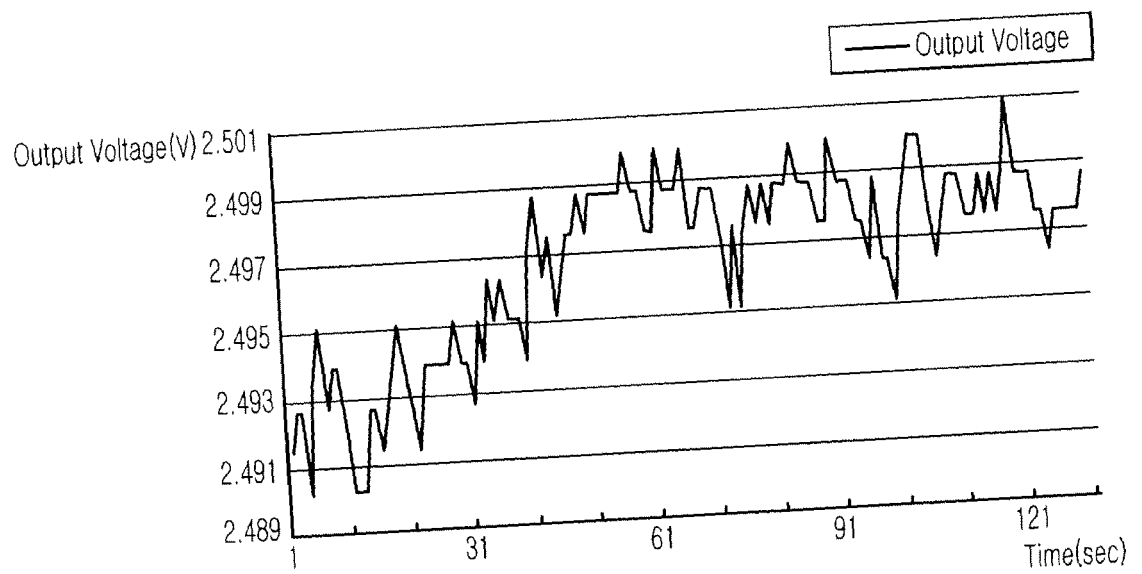


FIG. 4

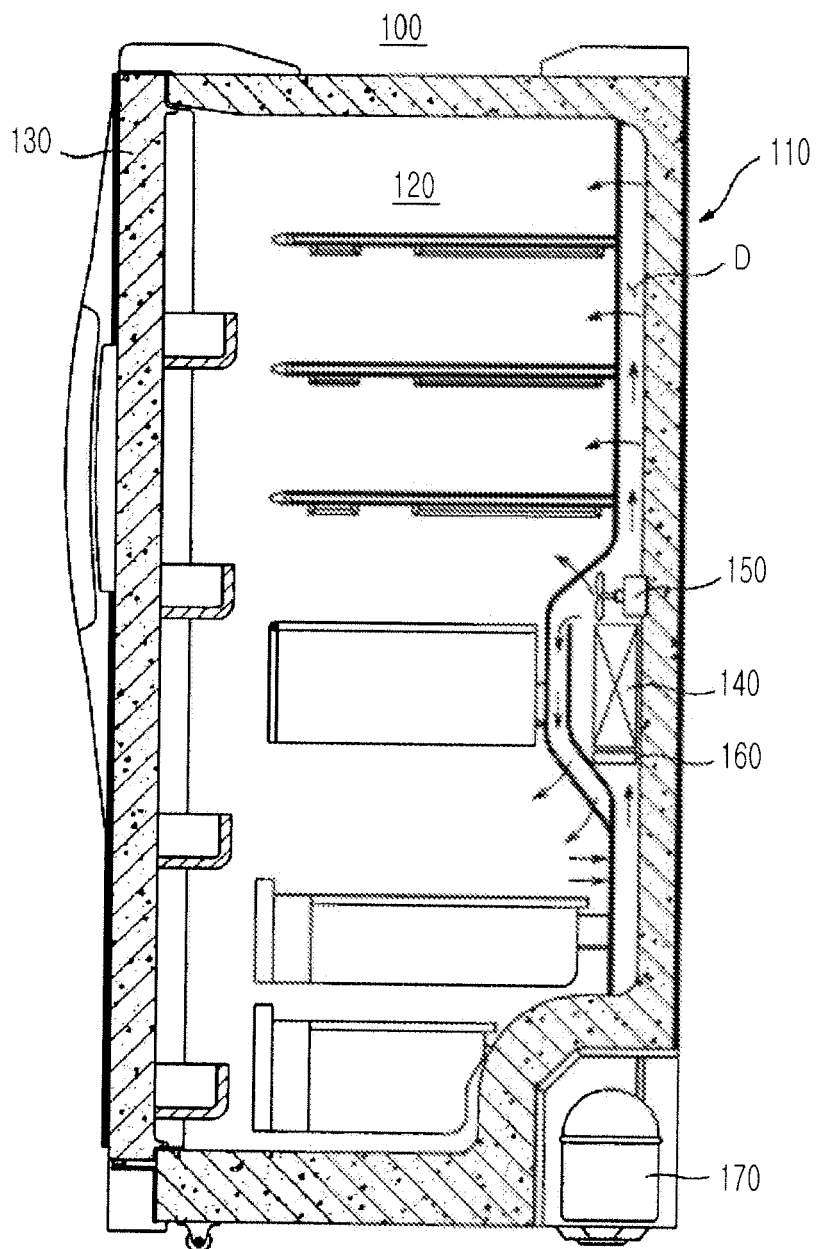


FIG. 5

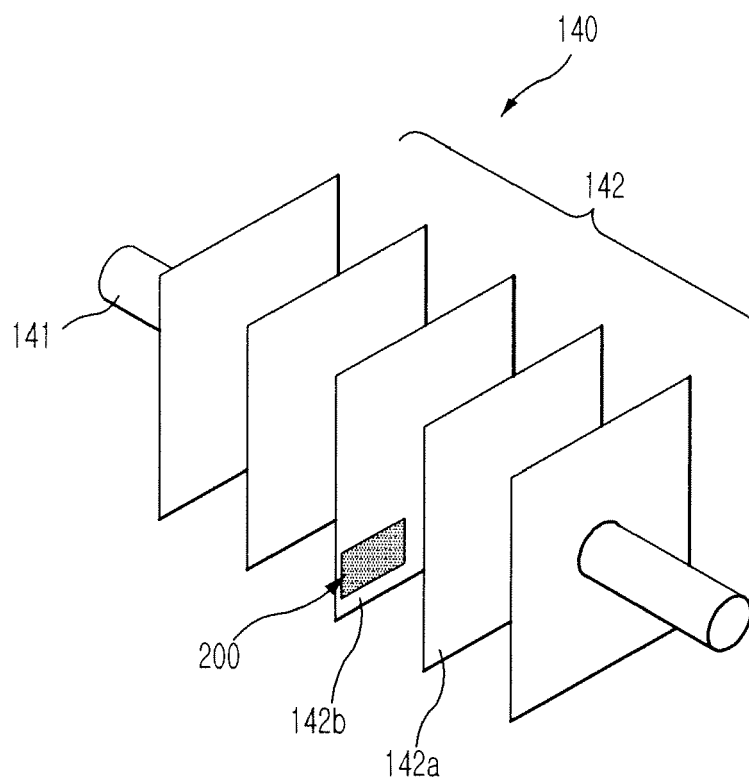


FIG. 6

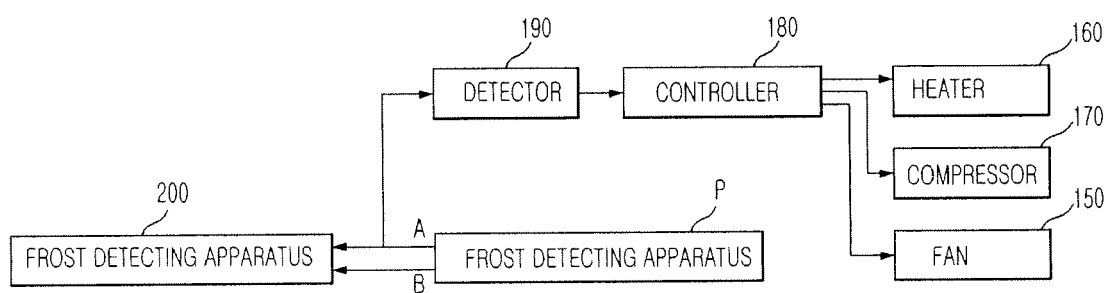


FIG. 7A

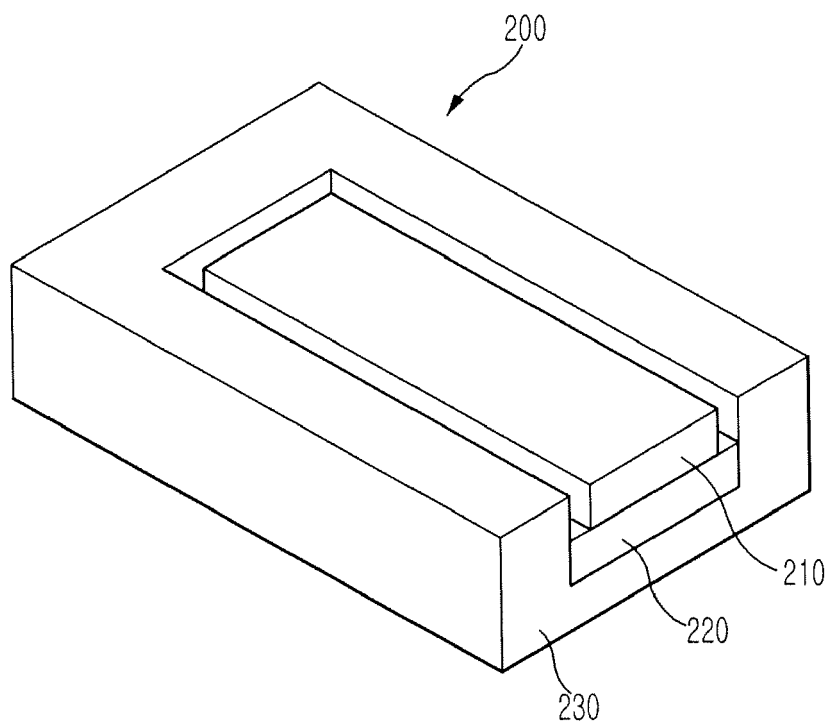


FIG. 7B

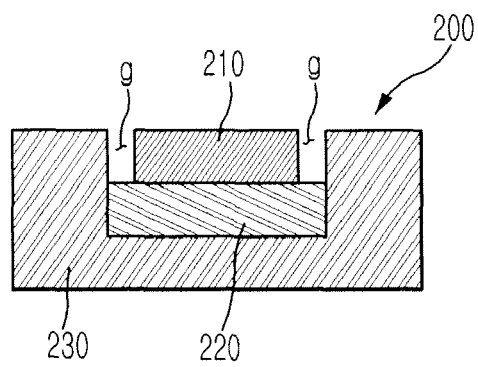


FIG. 8A

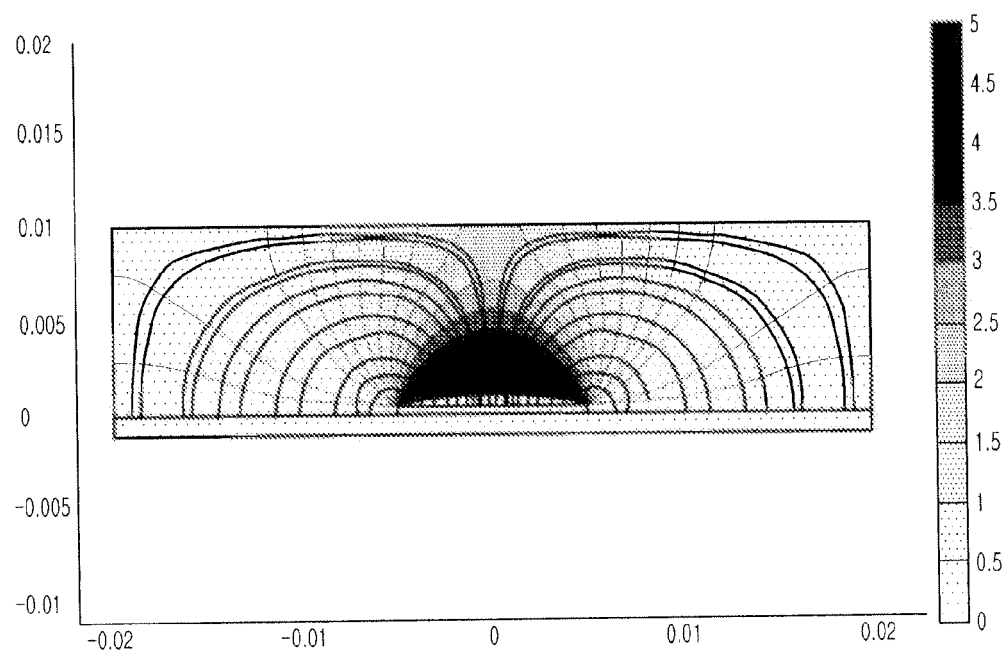


FIG. 8B

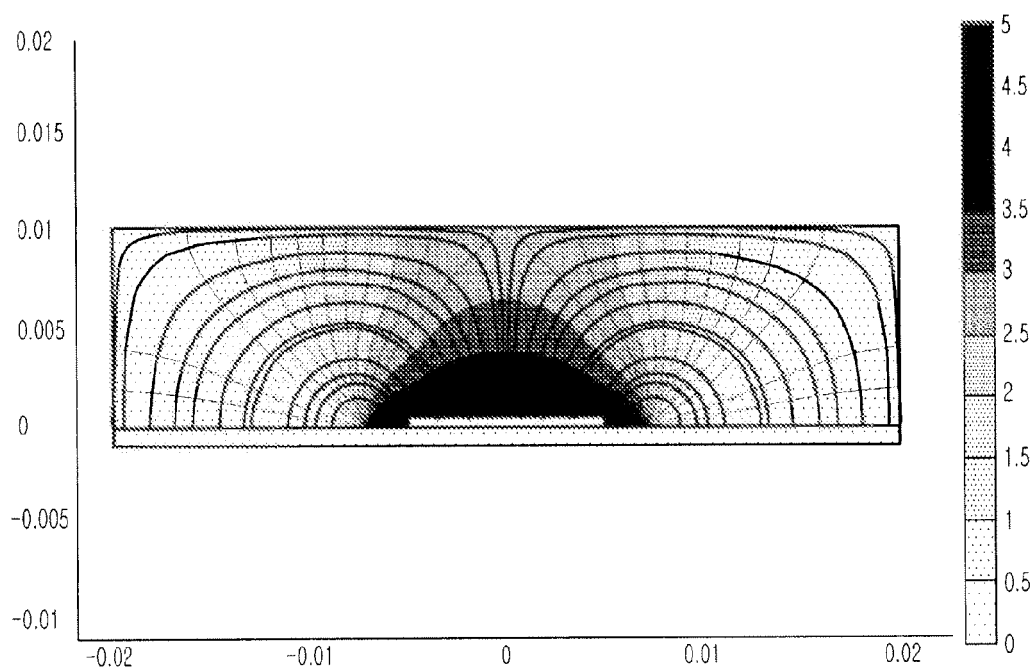


FIG. 9

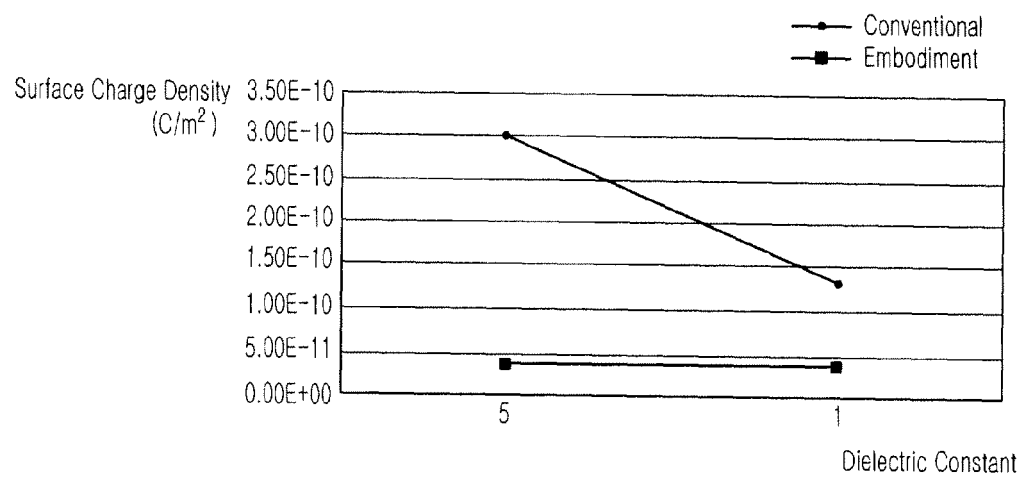


FIG. 10A

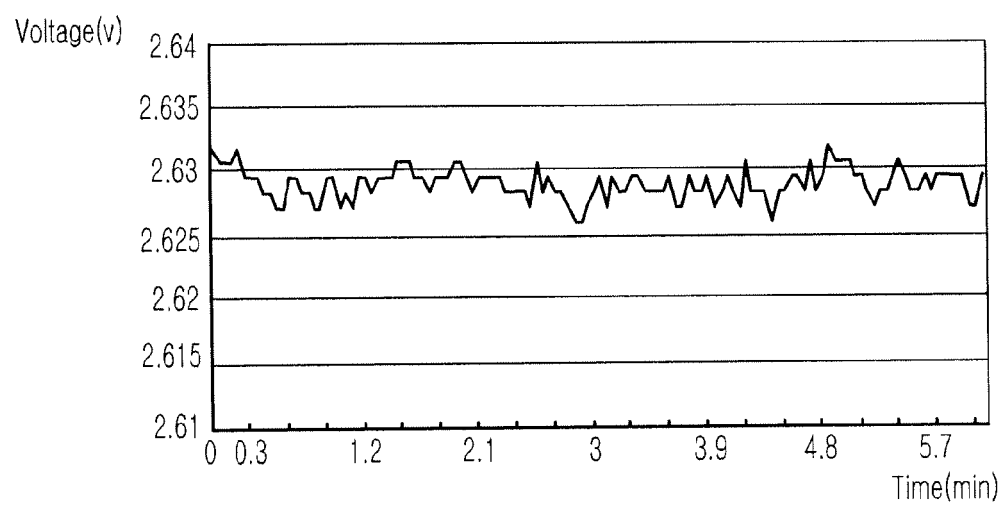


FIG. 10B

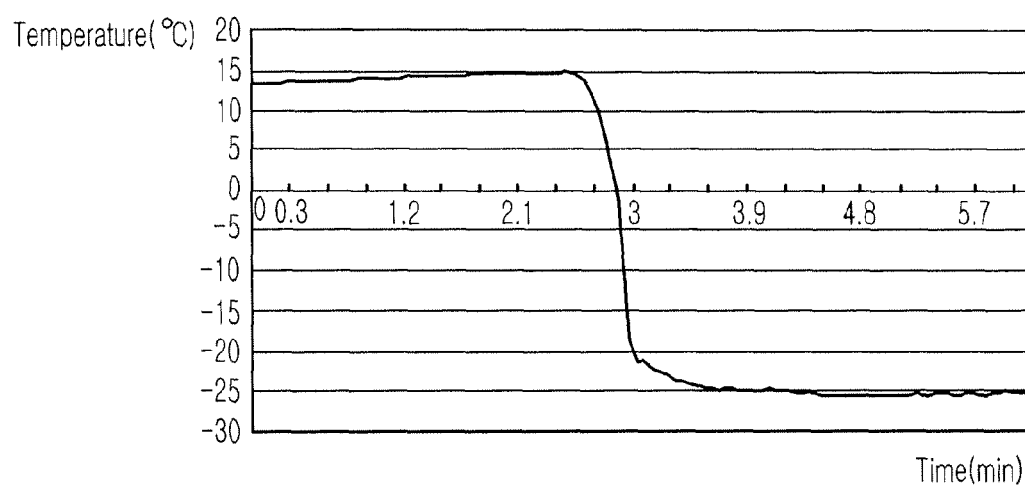


FIG. 11A

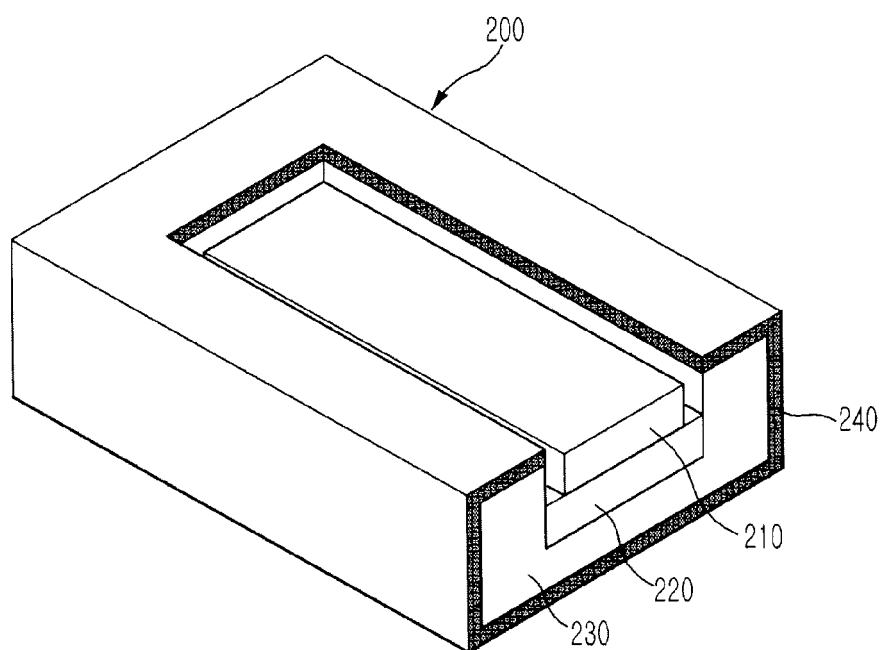


FIG. 11B

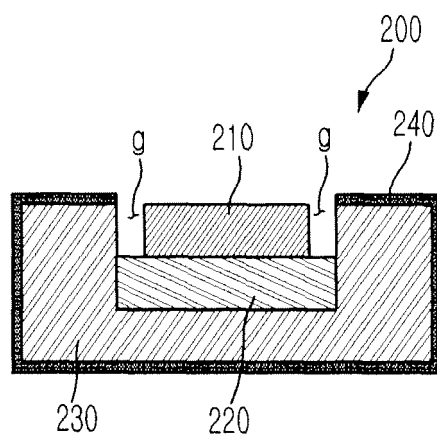


FIG. 11C

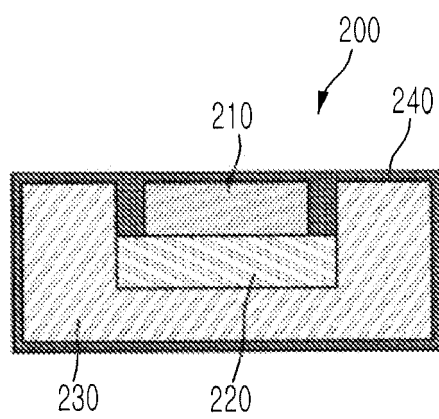


FIG. 11D

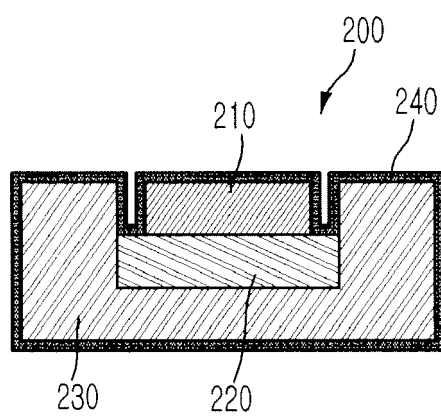


FIG. 12

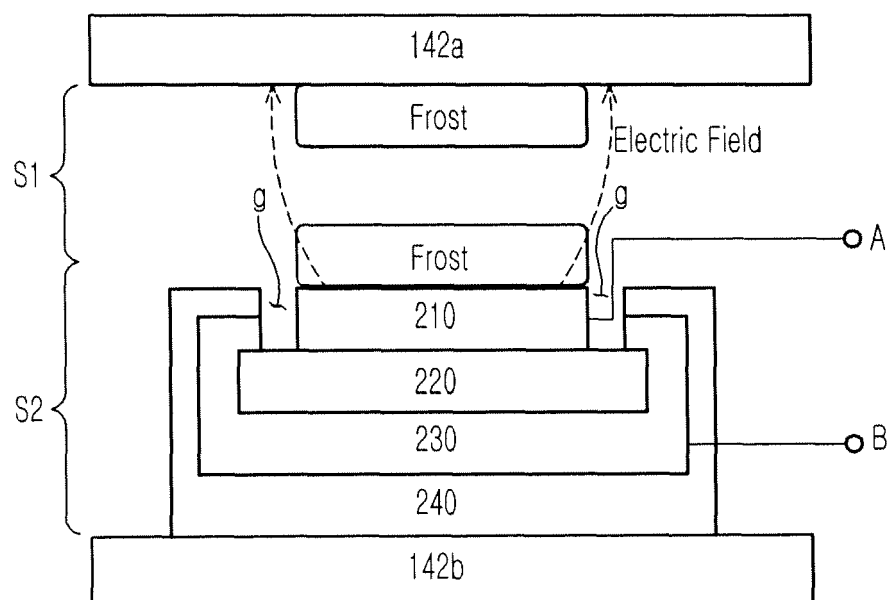


FIG. 13

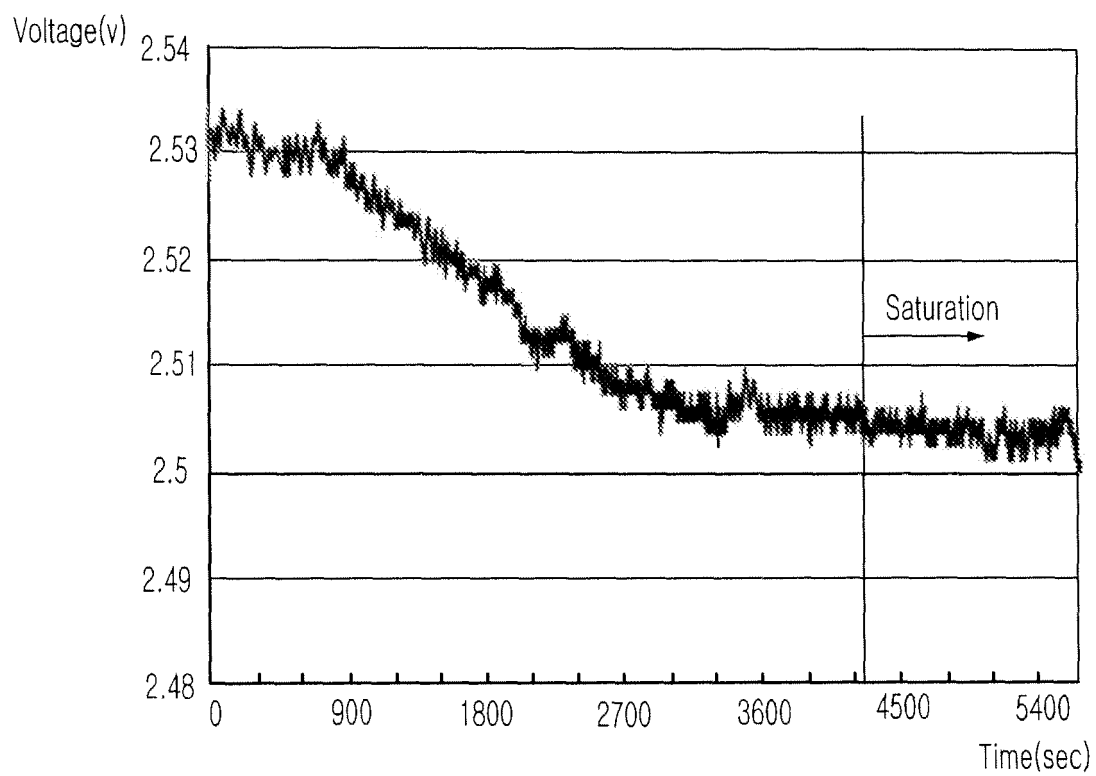


FIG. 14A

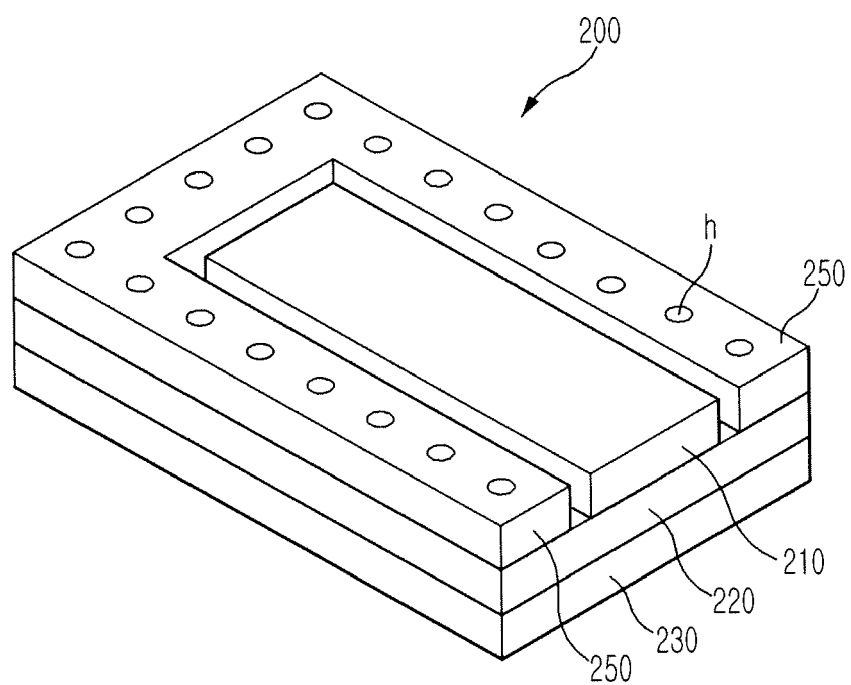


FIG. 14B

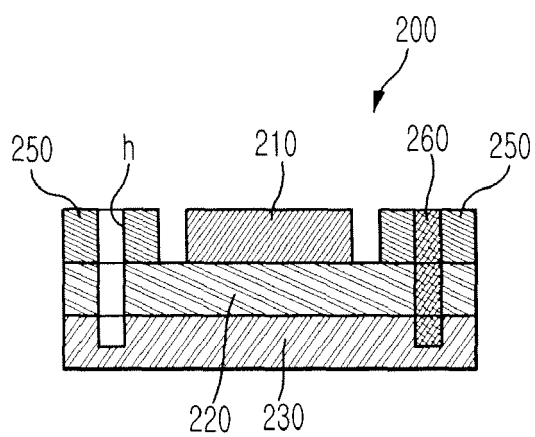


FIG. 14C

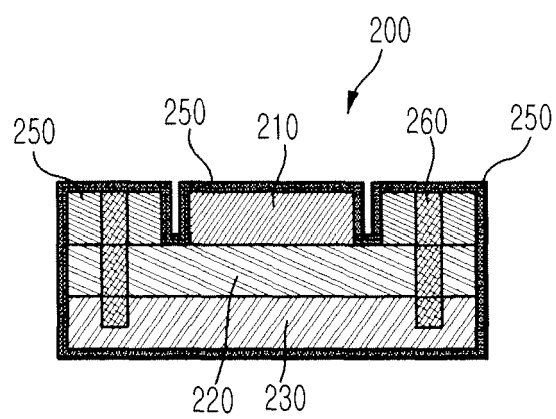


FIG. 15

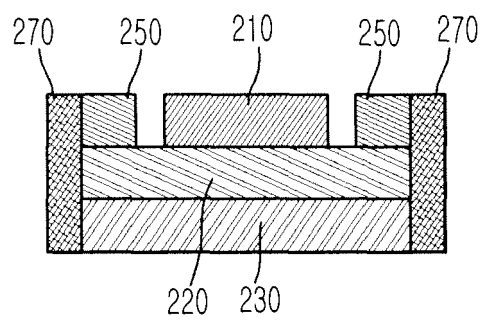


FIG. 16A

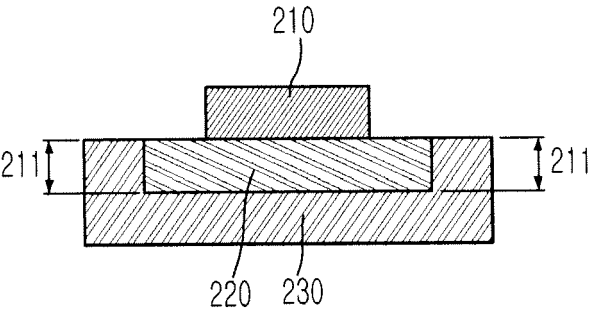


FIG. 16B

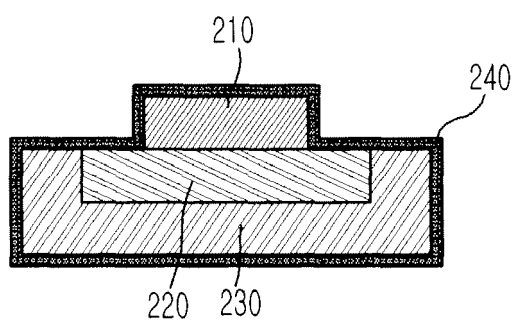


FIG. 17

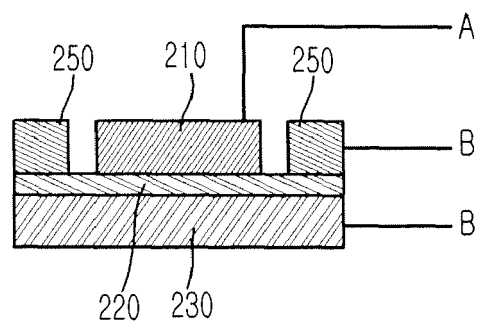


FIG. 18

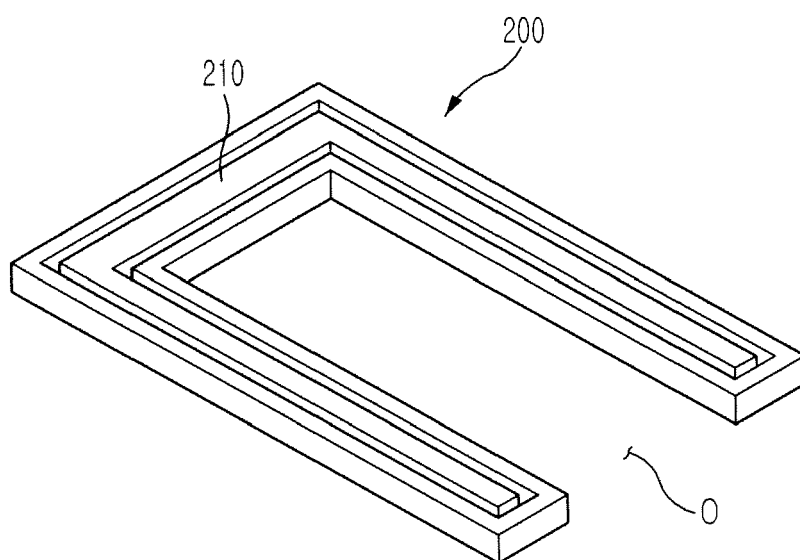


FIG. 19

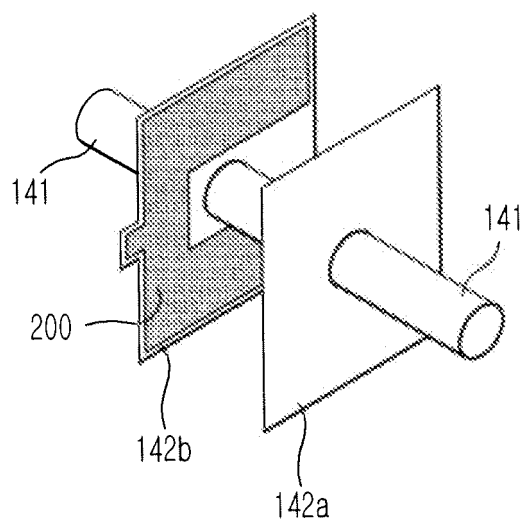


FIG. 20A

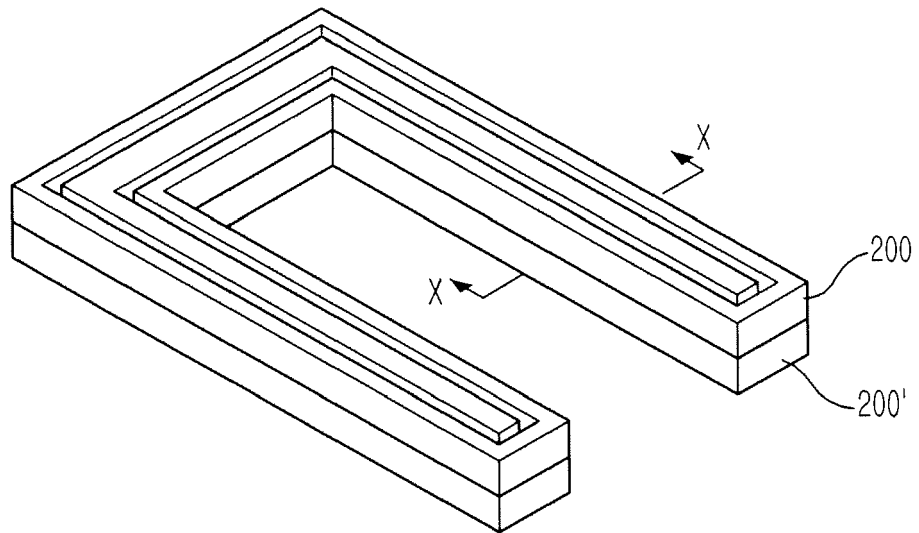


FIG. 20B

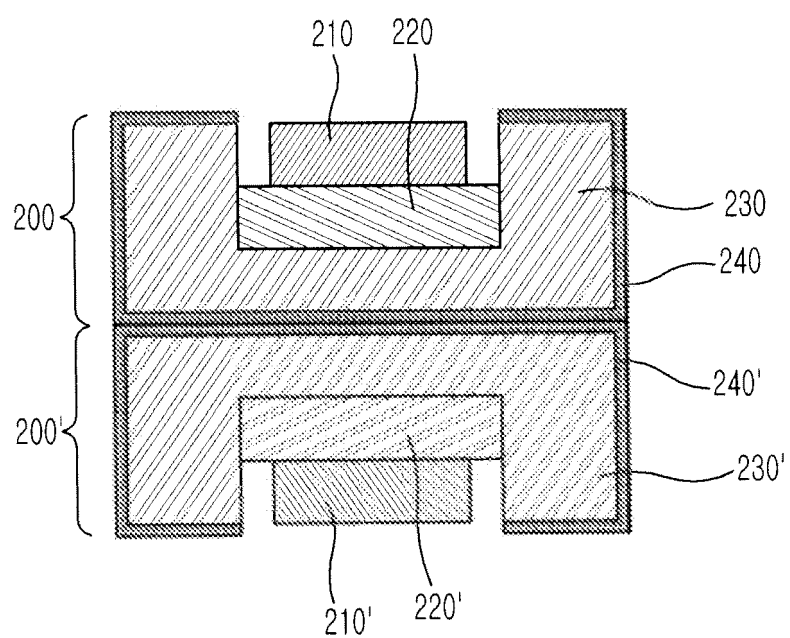
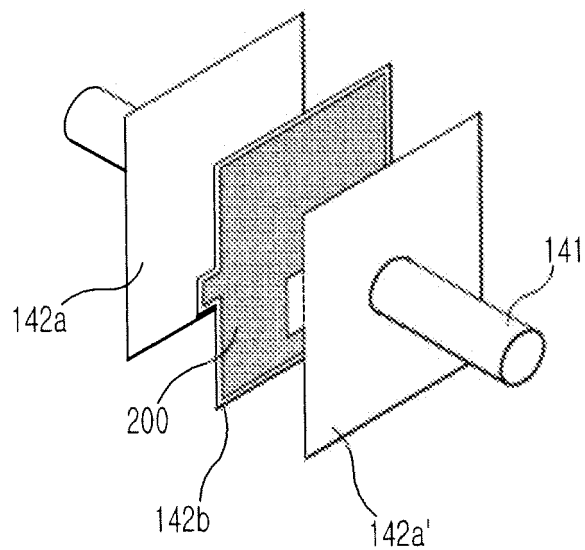


FIG. 21



REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- US 7466146 B [0006]