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Soil sensor

Abstract

A soil sensor includes a base, a first detection unit, a second detection unit, and a circuit unit. A first signal line of the first detection unit has a circular wiring pattern when being projected to an installation surface of the base. A first GND line of the first detection unit is arranged to be spaced from the first signal line and has a wiring pattern, when being projected to the installation surface, located within a region surrounded by the wiring pattern of the first signal line projected on the installation surface. The second detection unit is located within a region surrounded by the wiring pattern of the first GND line projected on the installation surface of the base.

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Background/Summary

CROSS REFERENCE TO RELATED APPLICATION (1) The present application is a continuation application of International Patent Application No. PCT/JP2022/003362 filed on Jan. 28, 2022, which designated the U.S. and claims the benefit of priority from Japanese Patent Application No. 2021-18325 filed on Feb. 8, 2021, Japanese Patent Application No. 2021-18324 filed on Feb. 8, 2021, Japanese Patent Application No. 2021-132203 filed on Aug. 16, 2021, and Japanese Patent Application No. 2021-132202 filed on Aug. 16, 2021. The entire disclosures of all of the above applications are incorporated herein by reference.

TECHNICAL FIELD
(1) The present disclosure relates to a soil sensor.
BACKGROUND ART
(2) A soil sensor that measures a water content of soil includes a folded transmission path and a

circuit unit. The folded transmission path includes a first linear portion and a second linear portion arranged in parallel with each other, a folded portion integrating respective one end sides of the linear portions, and a linear conductor arranged between and in parallel with the linear portions.

SUMMARY

(3) According to an aspect of the present disclosure, a soil sensor includes a base, a first detection unit, a second detection unit, and a circuit unit. The base has an installation surface. The first detection unit includes a first signal line and a first GND line arranged on the base. The second detection unit includes a second signal line, a second GND line and a ceramic body arranged on the installation surface of the base. The second signal line has one end portion that is one electrode with respect to the ceramic body, and the second GND line has one end portion that is another electrode with respect to the ceramic body. The circuit unit inputs a frequency signal between the one end portion of the first signal line and the one end portion of the first GND line. The circuit unit measures a water potential of soil based on capacitance between the one end portion of the second signal line and the one end portion of the second GND line, the capacitance being changed by water contained in the soil entering the ceramic body. The first signal line has a circular wiring pattern when being projected on the installation surface of the base. The first GND line is arranged to be spaced from the first signal line, and has a wiring pattern, when being projected on the installation surface of the base, within a region surrounded by the wiring pattern of the first signal line projected on the installation surface. The second detection unit is located within a region surrounded by the wiring pattern of the first GND line projected on the installation surface of the base.

Description

BRIEF DESCRIPTION OF DRAWINGS

(1) The above and other objects, features, and advantages of the present disclosure will become more apparent from the following detailed description with reference to the accompanying drawings. In the accompanying drawings:

(2) FIG. **1** is a plan view of a soil sensor according to a first embodiment;

(3) FIG. **2** is a cross-sectional view taken along line II-II of FIG. **1**;

(4) FIG. **3** is a view illustrating arrangement of the soil sensor into soil;

(5) FIG. **4** is a view illustrating a state of raindrops when a base and a circuit unit of the soil sensor are arranged in a direction perpendicular to a gravity direction;

(6) FIG. **5** is a view illustrating a state of raindrops when the base and the circuit unit of the soil sensor are arranged in the gravity direction;

(7) FIG. **6** is a view for explaining a method of measuring a water content;

(8) FIG. **7** is a plan view of a soil sensor according to a second embodiment;

(9) FIG. **8** is a cross-sectional view taken along line VIII-VIII of FIG. **7**;

(10) FIG. **9** is a plan view of a soil sensor according to a third embodiment;

(11) FIG. **10** is a schematic diagram illustrating a spreading manner of electric fields when the density of wiring patterns is low;

(12) FIG. **11** is a schematic diagram illustrating a spreading manner of electric fields when the density of wiring patterns is high;

(13) FIG. **12** is a plan view of a soil sensor according to a fourth embodiment;

(14) FIG. **13** is a plan view of a soil sensor according to a fifth embodiment;

(15) FIG. **14** is a plan view of a soil sensor according to a sixth embodiment;

(16) FIG. **15** is a plan view of a soil sensor according to a seventh embodiment;

(17) FIG. **16** is a plan view illustrating a modification of the soil sensor according to the seventh embodiment;

(18) FIG. **17** is a plan view of a soil sensor according to an eighth embodiment;
(19) FIG. **18** is a side view of the soil sensor illustrated in FIG. **17**;
(20) FIG. **19** is a plan view illustrating a modification of the soil sensor according to the eighth embodiment;
(21) FIG. **20** is a side view of the soil sensor illustrated in FIG. **19**;
(22) FIG. **21** is a plan view illustrating another modification of the soil sensor according to the eighth embodiment;
(23) FIG. **22** is a plan view illustrating still another modification of the soil sensor according to the eighth embodiment;
(24) FIG. **23** is a perspective view of a soil sensor according to a ninth embodiment;
(25) FIG. **24** is a cross-sectional view of a soil sensor according to a tenth embodiment;
(26) FIG. **25** is a cross-sectional view of a soil sensor according to an eleventh embodiment;
(27) FIG. **26** is a cross-sectional view of a soil sensor according to a twelfth embodiment;
(28) FIG. **27** is a cross-sectional view of a soil sensor according to a thirteenth embodiment;
(29) FIG. **28** is a cross-sectional view of a soil sensor according to a fourteenth embodiment;
(30) FIG. **29** is a cross-sectional view of a soil sensor according to a fifteenth embodiment;
(31) FIG. **30** is a cross-sectional view of a soil sensor according to a sixteenth embodiment;
(32) FIG. **31** is a cross-sectional view of a soil sensor according to a seventeenth embodiment;
(33) FIG. **32** is a cross-sectional view of a soil sensor according to an eighteenth embodiment;
(34) FIG. **33** is a cross-sectional view of a soil sensor according to a nineteenth embodiment;
(35) FIG. **34** is a plan view of a soil sensor according to a twentieth embodiment; and
(36) FIG. **35** is a cross-sectional view taken along line XXXV-XXXV of FIG. **34**.

DESCRIPTION OF EMBODIMENTS

(37) A conventional device that measures a water content of soil includes a folded transmission path and a circuit unit.
(38) The folded transmission path includes a first linear portion and a second linear portion arranged in parallel with each other, a folded portion integrating respective one end sides of the linear portions, and a linear conductor arranged between and in parallel with the linear portions.
(39) The circuit unit supplies a frequency signal having a predetermined frequency to the folded transmission path and obtains the permittivity of the soil based on a frequency signal from the folded transmission path. The circuit unit obtains the water content of the soil by using the information of the permittivity.
(40) In addition to the above conventional technique, devices are known each of which measures a water potential of soil. Although each device can measure a water content or a water potential, each device has difficulty simultaneously measuring the water content and the water potential.
(41) Consideration may be thus given to integration of a device that measures a water content and a device that measures a water potential. In a case where the integration is made, a detection unit that measures a water content and a detection unit that measures a water potential are arranged close to each other in order to measure the same position in soil. This is because a large difference may be present in the state of the soil if the position to be measured is slightly shifted in the soil.
(42) However, closer arrangement of the detection units may generate unnecessary capacitance. One of the detection units may thus have an influence on the other detection unit. Such a possibility is not limited to the case of integrating the device that measures a water content and the device that measures a water potential, and may be applied to a case of detecting at least two physical quantities. For example, even when a device that measures electric conductivity and the device that measures a water potential are integrated, one of the detection units may have an influence on the other detection unit.
(43) An object of the present disclosure is to provide a soil sensor that can reduce mutual influence between at least two detection units.
(44) According to a first aspect of the present disclosure, a soil sensor includes a base, a first

detection unit, a second detection unit, and a circuit unit.
(45) The base has an installation surface. The first detection unit includes a first signal line and a first GND line arranged on the base. The second detection unit includes a second signal line, a second GND line and a ceramic body arranged on the installation surface of the base. The second signal line has one end portion that is one electrode with respect to the ceramic body, and the second GND line has one end portion that is another electrode with respect to the ceramic body.
(46) The circuit unit inputs a frequency signal between the one end portion of the first signal line and the one end portion of the first GND line, and obtains water content of soil on which the base is arranged, based on a propagation time taken for the frequency signal to reach another end portion of the first signal line. The circuit unit measures a water potential of soil based on capacitance between the one end portion of the second signal line and the one end portion of the second GND line, the capacitance being changed by water contained in the soil entering the ceramic body.
(47) The first signal line has a circular wiring pattern when being projected on the installation surface of the base. The first GND line is arranged to be spaced from the first signal line, and has a wiring pattern, when being projected on the installation surface of the base, within a region surrounded by the wiring pattern of the first signal line projected on the installation surface.
(48) The second detection unit is located within a region surrounded by the wiring pattern of the first GND line projected on the installation surface of the base.
(49) Thus, the second detection unit is arranged while the second detection unit avoids the region of an electric field spread by the first signal line and the first GND line of the first detection unit. Therefore, mutual influence can be reduced between the first detection unit configured to measure the water content of the soil and the second detection unit configured to measure the water potential of the soil.
(50) According to a second aspect of the present disclosure, a soil sensor includes a base, a first detection unit, a second detection unit, and a circuit unit.
(51) The base has an installation surface. The first detection unit includes a first signal line and a first GND line arranged on the base. The second detection unit includes a second signal line, a second GND line and a ceramic body arranged on the installation surface of the base. The second signal line has one end portion that is one electrode with respect to the ceramic body, and the second GND line has one end portion that is another electrode with respect to the ceramic body.
(52) The circuit unit inputs a frequency signal between one end portion of the first signal line and one end portion of the first GND line, and obtains electric conductivity of soil, on which the base is arranged, based on steepness of a slope of a rise of the frequency signal reaching another end portion of the first signal line. The circuit unit measures a water potential of soil based on capacitance between the one end portion of the second signal line and the one end portion of the second GND line, the capacitance being changed by water contained in the soil entering the ceramic body.
(53) The first signal line has a circular wiring pattern when being projected on the installation surface of the base. The first GND line is arranged to be spaced from the first signal line, and has a wiring pattern, when being projected on the installation surface of the base, located within a region surrounded by the wiring pattern of the first signal line projected on the installation surface.
(54) The second detection unit is located within a region surrounded by the wiring pattern of the first GND line projected on the installation surface of the base.
(55) Thus, the second detection unit is arranged while the second detection unit avoids the region of an electric field spread by the first signal line and the first GND line of the first detection unit. Therefore, mutual influence can be reduced between the first detection unit configured to measure the electric conductivity of the soil and the second detection unit configured to measure the water potential of the soil.
(56) Embodiments of the present disclosure will be described hereafter referring to drawings. In the embodiments, a part that corresponds to a matter described in a preceding embodiment may be

assigned with the same reference numeral, and redundant explanation for the part may be omitted. When only a part of a configuration is described in an embodiment, another preceding embodiment may be applied to the other parts of the configuration. The parts may be combined even if it is not explicitly described that the parts can be combined. The embodiments may be partially combined even if it is not explicitly described that the embodiments can be combined, provided there is no harm in the combination.

First Embodiment

(57) Hereinafter, a first embodiment will be described with reference to the drawings. A soil sensor according to the present embodiment is a sensor that detects physical quantities related to soil. The soil is a foundation for growing crops, and includes earth, sand, and clay.

(58) As illustrated in FIG. **1**, a soil sensor **100** includes a base **110**, a first detection unit **120**, a second detection unit **130**, a third detection unit **140**, a fourth detection unit **150**, a fifth detection unit **160**, and a circuit unit **170**.

(59) The base **110** is a component to which each of the detection units **120** to **160** is installed. The base **110** is, for example, a printed circuit board having one surface **111**. The base **110** may be a flexible substrate. The base **110** has, for example, a rectangular parallelepiped shape. For example, one end side of the base **110** is formed in an arc shape. The other end side of the base **110** is integrated with the circuit unit **170**. Alternatively, the other end side of the base **110** is inserted into the circuit unit **170**. The base **110** has a shape formed along an arrangement direction, when a direction in which the base **110** and the circuit unit **170** are aligned is defined as the arrangement direction.

(60) The first detection unit **120** is a component for measuring the water content of the soil and the electric conductivity of the soil. The water content is the ratio of water contained in the soil. That is, the water content is the volume water content of the soil. The water content is expressed in units of, for example, percent (%). The electric conductivity is a physical quantity corresponding to the salinity concentration of the soil.

(61) The first detection unit **120** includes a first signal line **121** and a first ground (GND) line **122**. The first signal line **121** and the first GND line **122** are arranged on the one surface **111** of the base **110**. Each of the first signal line **121** and the first GND line **122** is metal wiring formed of Cu or the like.

(62) The first signal line **121** is a wiring pattern arranged on an outer edge portion of the one surface **111** of the base **110**. The first signal line **121** is arranged along the outline of the one surface **111** of the base **110** such that one end portion **121**A and the other end portion **121**B of the first signal line **121** are positioned on the other end side of the one surface **111** of the base **110**.

(63) Specifically, the first signal line **121** includes a wiring pattern projected on the one surface **111** of the base **110**, and this wiring pattern is a circular wiring pattern. In the present embodiment, the first signal line **121** is arranged on the one surface **111** of the base **110**. The wiring pattern of the first signal line **121** projected on the one surface **111** of the base **110** and the actual wiring pattern of the first signal line **121** can be thus regarded as identical. The wiring pattern of the first signal line **121** projected on the one surface **111** of the base **110** includes a first straight portion **121**C, a second straight portion **121**D, and a connection portion **121**E. The second straight portion **121**D is arranged in parallel with the first straight portion **121**C. In the present embodiment, the first straight portion **121**C and the second straight portion **121**D are arranged in parallel. In addition to the parallel arrangement with the first straight portion **121**C, the second straight portion **121**D may be arranged to be slightly inclined with respect to the first straight portion **121**C. A side of the first straight portion **121**C opposite to the connection portion **121**E corresponds to the one end portion **121**A of the first signal line **121**. A side of the second straight portion **121**D opposite to the connection portion **121**E corresponds to the other end portion **121**B of the first signal line **121**. The connection portion **121**E is arranged in an arc shape along the outline of the one end side of the base **110**. The one end portion **121**A and the other end portion **121**B of the first signal line **121** are

electrically connected to the circuit unit **170**.
(64) The first GND line **122** is a wiring pattern arranged inward of the first signal line **121** on the one surface **111** of the base **110**. That is, the wiring pattern of the first GND line **122** projected on the one surface **111** of the base **110** is arranged within a region surrounded by the first signal line **121** projected on the one surface **111** of the base **110**. The surrounded region is a region wholly surrounded when a portion corresponding to the one end portion **121**A of the first signal line **121** and a portion corresponding to the other end portion **121**B of the first signal line **121** are connected by an imaginary line, within the one surface **111** of the base **110**. In the present embodiment, the first GND line **122** is arranged on the one surface **111** of the base **110**. The wiring pattern of the first GND line **122** projected on the one surface **111** of the base **110** and the actual wiring pattern of the first GND line **122** can be thus regarded as identical. The first GND line **122** is arranged to be spaced from the first signal line **121** at a first interval.
(65) The first GND line **122** is arranged circularly along the first signal line **121** such that one end portion **122**A and the other end portion **122**B of the first GND line **122** are positioned on the other end side of the one surface **111** of the base **110**. That is, the first GND line **122** is a wiring pattern having a form identical to that of the first signal line **121**. The first interval need not have a constant value at every location between the first signal line **121** and the first GND line **122**. The one end portion **122**A and the other end portion **122**B of the first GND line **122** are electrically connected to the circuit unit **170**.
(66) As illustrated in FIG. **2**, the first signal line **121** and the first GND line **122** are covered with an insulating film **112**. The insulating film **112** is a protective film that protects the first signal line **121** and the first GND line **122** from corrosion. In FIG. **1**, the illustration of the insulating film **112** is omitted.
(67) The second detection unit **130** is a component for measuring the water potential of the soil. The water potential is a physical quantity corresponding to the pressure of water contained in the soil. The water potential is expressed in units of, for example, pascal (Pa). The second detection unit **130** is arranged inward of the first GND line **122**. That is, the second detection unit **130** is arranged within a region surrounded by the wiring pattern of the first GND line **122** projected on the one surface **111** of the base **110**.
(68) As illustrated in FIG. **1**, the second detection unit **130** includes a second signal line **131**, a second GND line **132**, and a ceramic body **133**. The second signal line **131** and the second GND line **132** are arranged on the one surface **111** of the base **110**. Each of the second signal line **131** and the second GND line **132** is metal wiring formed of Cu or the like.
(69) Each of the second signal line **131** and the second GND line **132** is a wiring pattern linearly arranged from the other end side to the one end side of the one surface **111** of the base **110**. That is, the second signal line **131** has one end portion **131**A, which is positioned on the one end side of the one surface **111** of the base **110**, and has the other end portion **131**B, which is positioned on the other end side of the one surface **111** of the base **110**. Similarly, the second GND line **132** has one end portion **132**A, which is positioned on the one end side of the one surface **111** of the base **110**, and has the other end portion **132**B, which is positioned on the other end side of the one surface **111** of the base **110**. The one end portion **131**A of the second signal line **131** is one electrode with respect to the ceramic body **133**.
(70) The one end portion **132**A of the second GND line **132** is arranged to be spaced from the one end portion **131**A of the second signal line **131** at a second interval, and is a pattern surrounding the one end portion **131**A of the second signal line **131**. For example, the one end portion **131**A of the second signal line **131** is an annular wiring pattern. The one end portion **132**A of the second GND line **132** is an annular pattern that surrounds the one end portion **131**A of the second signal line **131** while contact is avoided between the one end portion **131**A of the second signal line **131** and the one end portion **132**A of the second GND line **132**. As illustrated in FIG. **2**, the second signal line **131** and the second GND line **132** are covered with the insulating film **112**. The one end portion

132A of the second GND line **132** is the other electrode with respect to the ceramic body **133**.
(71) The ceramic body **133** is arranged above the one end portion **131**A of the second signal line **131** and the one end portion **132**A of the second GND line **132**. Specifically, the ceramic body **133** is positioned above the one end portion **131**A of the second signal line **131** and the one end portion **132**A of the second GND line **132** by being arranged on the insulating film **112**.
(72) For example, cordierite or alumina can be used for the ceramic body **133**. The permittivity of cordierite is 4, and the permittivity of alumina is 9.6. The ceramic body **133** has a cylindrical shape in accordance with the wiring pattern of the one end portion **131**A of the second signal line **131** and the wiring pattern of the one end portion **132**A of the second GND line **132**. For example, when each of the wiring pattern of the one end portion **131**A of the second signal line **131** and the wiring pattern of the one end portion **132**A of the second GND line **132** has a quadrilateral annular pattern, the ceramic body **133** has a rectangular parallelepiped shape.
(73) As illustrated in FIG. **1**, the third detection unit **140** is a component for measuring the temperature of the soil. The third detection unit **140** is arranged inward of the first GND line **122** projected on the one surface **111**, within the one surface **111** of the base **110**, and is arranged in a region where the second detection unit **130** is not arranged.
(74) The third detection unit **140** includes a third signal line **141**, a third GND line **142**, and a thermistor **143**. Each of the third signal line **141** and the third GND line **142** is metal wiring formed of Cu or the like. The third signal line **141** and the third GND line **142** are covered with the insulating film **112**, and are electrically connected to the circuit unit **170**.
(75) Each of the third signal line **141** and the third GND line **142** is a wiring pattern linearly arranged from the other end side to the one end side of the one surface **111** of the base **110**. The third GND line **142** is arranged adjacent to the first GND line **122**. The third signal line **141** is arranged adjacent to one side of the third GND line **142** opposite to the other side thereof adjacent to the first GND line **122**. That is, the third signal line **141** is arranged between the third GND line **142** and the second signal line **131**.
(76) The thermistor **143** is an element for detecting the temperature of the soil. The thermistor **143** is arranged on the insulating film **112**. The thermistor **143** is electrically connected to the third signal line **141** and the third GND line **142** through openings (not illustrated) formed in the insulating film **112**. The element for detecting the temperature may be a thermocouple.
(77) The fourth detection unit **150** is a component for detecting the pH of the soil. The fourth detection unit **150** is arranged inward of the first GND line **122** projected on the one surface **111**, within the one surface **111** of the base **110**, and is arranged in a region where the second detection unit **130** and the third detection unit **140** are not arranged.
(78) The fourth detection unit **150** includes a fourth signal line **151**, a fourth GND line **152**, and a pair of electrodes (not illustrated). Each of the fourth signal line **151** and the fourth GND line **152** is metal wiring formed of Cu or the like. The fourth signal line **151** and the fourth GND line **152** are covered with the insulating film **112**, and are electrically connected to the circuit unit **170**.
(79) Each of the fourth signal line **151** and the fourth GND line **152** is a wiring pattern linearly arranged from the other end side to the one end side of the one surface **111** of the base **110**. The fourth GND line **152** is arranged adjacent to one side of the second GND line **132** opposite to the other side thereof adjacent to the second signal line **131**. The fourth signal line **151** is arranged adjacent to one side of the fourth GND line **152** opposite to the other side thereof adjacent to the second GND line **132**. That is, the fourth GND line **152** is arranged between the second GND line **132** and the fourth signal line **151**.
(80) The fourth detection unit **150** detects a potential difference between the pair of electrodes caused along with adhesion of water contained in the soil to one of the pair of electrodes. The pair of electrodes are, for example, an ion-sensitive field-effect transistor (ISFET) electrode and a comparison electrode.
(81) The fifth detection unit **160** is a component for detecting the redox potential of the soil. The

redox potential or oxidation-reduction potential (ORP) is a physical quantity expressing the degree of oxidation-reduction of the soil. The redox potential may also be expressed as Eh. When the redox potential is positive, oxygen exists in the soil, that is, the soil is in an oxidized state. When the redox potential is negative, no oxygen exists in the soil, that is, the soil is in a reduced state.
(82) For example, reduction proceeds by filling a paddy field with water, and the reduction further proceeds by consuming oxygen when organic substances are decomposed. The soil chemical-reduction sterilization can make the soil oxygen-free by applying an organic substance such as rice bran, bran, or molasses, which is a reducing material, into the soil, and can remove diseases and pests. The state of oxygen-free in the soil is an oxygen-deprived state, a reduced state, or a state in which the redox potential is negative.
(83) The fifth detection unit **160** is arranged inward of the first GND line **122** projected on the one surface **111**, within the one surface **111** of the base **110**, and is arranged in a region where the second detection unit **130**, the third detection unit **140**, and the fourth detection unit **150** are not arranged.
(84) The fifth detection unit **160** includes a fifth signal line **161**, a fifth GND line **162**, and a pair of electrodes (not illustrated). Each of the fifth signal line **161** and the fifth GND line **162** is metal wiring formed of Cu or the like. The fifth signal line **161** and the fifth GND line **162** are covered with the insulating film **112**, and are electrically connected to the circuit unit **170**.
(85) Each of the fifth signal line **161** and the fifth GND line **162** is a wiring pattern linearly arranged from the other end side to the one end side of the one surface **111** of the base **110**. The fifth GND line **162** is arranged adjacent to the first GND line **122**. The fifth signal line **161** is arranged between the fifth GND line **162** and the fourth signal line **151**.
(86) The fifth detection unit **160** includes a detection electrode and a reference electrode as the pair of electrodes. The fifth detection unit **160** detects a potential difference between the detection electrode and the reference electrode caused along with adhesion of water contained in the soil to the detection electrode.
(87) The circuit unit **170** obtains the water content of the soil, the water potential of the soil, the electric conductivity of the soil, the temperature of the soil, the pH of the soil, and the redox potential of the soil, based on the detection results from the detection units **120** to **160**.
(88) The circuit unit **170** includes electronic components such as a microcomputer and an integrated circuit (IC) for controlling each of the detection units **120** to **160**. The electronic components are mounted on a printed circuit board dedicated to the circuit unit **170**. Alternatively, the electronic components are mounted on the other end side of the base **110**. That is, the base **110** may form a part of the circuit unit **170**.
(89) The description has been made for the overall configuration of the soil sensor **100** according to the present embodiment. Portions of the base **110** unrelated to sensing may be covered with a coating film. The portions covered with the coating film is thus protected. Alternatively, corrosion of the metal portion is reduced.
(90) As illustrated in FIG. **3**, the soil sensor **100** is arranged in a hole **210** provided in soil **200**. The soil sensor **100** is then buried in the soil **200**. The soil sensor **100** includes a line **180** connected to the circuit unit **170**. The soil sensor **100** receives power from a power supply, outputs a detection signal, and performs other operations, through the line **180**.
(91) The soil sensor **100** is arranged such that the arrangement direction is perpendicular to the gravity direction. That is, the base **110** and the circuit unit **170** are arranged along a direction perpendicular to the gravity direction. The soil sensor **100** may not be arranged strictly perpendicular to the gravity direction in terms of the arrangement direction thereof. The arrangement may be acceptable as long as the soil sensor **100** is arranged to be laid down with respect to the gravity direction.
(92) This arrangement allows raindrops to be easily guided to the base **110** of the soil sensor **100** as illustrated in FIG. **4**, in a case of rain. In contrast, a case may exist in which the soil sensor **100** is

arranged such that the arrangement direction is along the gravity direction, as illustrated in FIG. **5**. That is, a case may exist in which the soil sensor **100** is arranged upright along the gravity direction. In such a case, the movement of raindrops is restricted by the circuit unit **170**.
(93) A method will be described for obtaining the water content of the soil **200**, the electric conductivity of the soil **200**, the water potential of the soil **200**, the temperature of the soil **200**, the pH of the soil **200**, and the redox potential of the soil **200**.
(94) The first detection unit **120** and the circuit unit **170** measure the water content of the soil **200**, based on, for example, time domain transmission. As illustrated in FIG. **6**, the circuit unit **170** inputs a frequency signal between the one end portion **121**A of the first signal line **121** and the one end portion **122**A of the first GND line **122**, of the first detection unit **120**. In FIG. **6**, the illustration of the third to fifth detection units **140** to **160** is omitted.
(95) The frequency signal is, for example, a pulse wave. Delay occurs in a propagation time of the frequency signal due to presence of the soil **200** and water contained in the soil **200**. The permittivity of the soil **200** is, for example, ±4, and the permittivity of water is, for example, 80. As illustrated in FIG. **2**, a change in permittivity between the first signal line **121** and the first GND line **122** leads to a change in capacitance, and delay occurs in the propagation time of the frequency signal. As illustrated in FIG. **6**, the circuit unit **170** measures a propagation time taken for the frequency signal to reach the other end portion **121**B of the first signal line **121**.
(96) Specifically, the relative permittivity εr of water is determined by the water content of the soil **200**. Apparent permittivity εa around the first detection unit **120** is determined in accordance with the relative permittivity εr of water. When the speed of light is denoted by c, the propagation time is denoted by tm, and the pattern length of the first signal line **121** is denoted by Lp, the apparent permittivity εa is expressed as εa=(c×tm/Lp).sup.2. The apparent permittivity εa is obtained by measuring the propagation time. The relative permittivity εr of water is obtained from the apparent permittivity εa. The water content of the soil **200** is therefore obtained from the relative permittivity εr of water.
(97) The first detection unit **120** and the circuit unit **170** measure the electric conductivity of the soil **200**, based on the steepness of the slope of the rise of the frequency signal reaching the other end portion **121**B of the first signal line **121**. As illustrated in FIG. **6**, the rise of the frequency signal reaching the circuit unit **170** is inclined in accordance with the electric conductivity of the soil **200**. The amplitude of the frequency signal reaching the circuit unit **170** also changes in accordance with the electric conductivity of the soil **200**.
(98) When the electric conductivity is high, the slope of the rise of the frequency signal reaching the circuit unit **170** becomes more gradual. That is, a longer time is required until the amplitude of the frequency signal becomes maximum. When the electric conductivity is high, the amplitude of the frequency signal reaching the circuit unit **170** becomes smaller.
(99) In contrast, when the electric conductivity is low, the slope of the rise of the frequency signal reaching the circuit unit **170** becomes steeper. That is, a shorter time is taken until the amplitude of the frequency signal becomes maximum. When the electric conductivity is low, the amplitude of the frequency signal reaching the circuit unit **170** becomes large.
(100) The circuit unit **170** thus converts the slope of the rise of the frequency signal reaching the circuit unit **170** into the electric conductivity of the soil **200**. Alternatively, the circuit unit **170** converts the amplitude of the frequency signal reaching the circuit unit **170** into the electric conductivity of the soil **200**. Alternatively, the circuit unit **170** converts both the slope of the rise and the maximum amplitude of the frequency signal reaching the circuit unit **170** into the electric conductivity of the soil **200**.
(101) The second detection unit **130** and the circuit unit **170** measure the water potential of the soil **200**, based on capacitance between the one end portion **131**A of the second signal line **131** and the one end portion **132**A of the second GND line **132**. The second detection unit **130** uses the ceramic body **133** as a substitute to determine water absorbency from the soil **200**, that is, water potential.

When water contained in the soil **200** enters the ceramic body **133**, the permittivity changes. As a result, as illustrated in FIG. **2**, capacitance between the second signal line **131** and the second GND line **132** changes.
(102) Specifically, a water absorption rate when water enters the ceramic body **133** is determined in accordance with the water potential of the soil **200**. With this relationship, since the relative permittivity εr when the water enters the ceramic body **133** is determined, the capacitance corresponding to the relative permittivity εr is determined. The water potential of the soil **200** is therefore obtained by converting the capacitance into the water potential. For example, when the water potential is denoted by φ and the capacitance is denoted by pF, the capacitance pF is expressed as $pF=\log_{10}(-10.2\times\varphi)$, and the water potential φ is expressed as $\varphi=10^{pF}/(-10.2)$.
(103) The third detection unit **140** and the circuit unit **170** measure the temperature of the soil **200** by using the thermistor **143**. The circuit unit **170** obtains the temperature of the soil **200**, based on the detection result from the thermistor.
(104) The fourth detection unit **150** and the circuit unit **170** measure the pH of the soil **200**, based on the potential difference between the pair of electrodes. For example, the pair of electrodes includes a semiconductor element such as an ISFET electrode, in a semiconductor electrode type. The circuit unit **170** converts a potential difference generated between the ISFET electrode and the comparison electrode into pH by using impedance conversion. A glass electrode type or a metal electrode type may also be used.
(105) The fifth detection unit **160** and the circuit unit **170** measure the redox potential of the soil **200**, based on the potential difference between the detection electrode and the reference electrode. The detection electrode is, for example, a platinum electrode. The circuit unit **170** obtains the voltage of the comparison electrode with respect to the platinum electrode, as the redox potential of the soil **200**.
(106) For example, when the value of +200 mV is defined as a boundary between oxidation and reduction, the range from +400 mV to +700 mV is defined as an oxidized state, and the range from −250 mV to −300 mV is defined as a reduced state. A dry paddy field is in an oxidized state having a value of, for example, +600 mV.
(107) The circuit unit **170** outputs each of the above physical quantities to an external device. Data obtained with the soil sensor **100** is used for an irrigation system, fertilizer application, and the like. In the irrigation system, a watering amount is adjusted based on information of the water content, the water potential, and the temperature. In the fertilizer application, the amount and components of a fertilizer are adjusted based on the information of the electric conductivity, the pH, and the redox potential.
(108) As described above, in the present embodiment, the second to fifth detection units **130** to **160** are arranged inward of the first GND line **122** of the first detection unit **120**. That is, the second to fifth detection units **130** to **160** are arranged while the second to fifth detection units **130** to **160** avoid the region of an electric field spread by the first signal line **121** and the first GND line **122** of the first detection unit **120**. The first GND line **122** and the second GND line **132** are arranged adjacent to each other. Similarly, the first GND line **122** and the third GND line **142** are arranged adjacent to each other. The second GND line **132** and the fourth GND line **152** are arranged adjacent to each other. The first GND line **122** and the fifth GND line **162** are arranged adjacent to each other. Unnecessary capacitance is thus not generated among the detection units **120** to **160**. Mutual influence can be therefore reduced among the detection units **120** to **160**.
(109) The water potential indicates water absorbency of roots, and the electric conductivity indicates the salinity concentration of the soil **200**. The soil sensor **100** can measure the water potential and the electric conductivity. The soil sensor **100** is thus suitable for feedback control regarding the components and amount of a liquid fertilizer for the soil **200**.
(110) The one surface **111** of the base **110** according to the present embodiment corresponds to an

installation surface.

Second Embodiment

(111) In the present embodiment, the description primarily focuses on the portions that differ from the first embodiment. As illustrated in FIGS. **7** and **8**, the base **110** includes the other surface **113** opposite to the one surface **111**. The first detection unit **120** is arranged on each side of the base **110**, that is, both of the one surface **111** of the base **110** and the other surface **113** of the base **110**. The first signal line **121** and the first GND line **122** arranged on the other surface **113** of the base **110** are also covered with another insulating film **112**. The detection units **120** to **160** are also installed to the other surface **113** of the base **110** as well as to the one surface **111** of the base **110**. In FIG. **8**, the illustration of the second to fifth detection units **130** to **160** is omitted.

(112) The above configuration enables an increase in the arrangement density of the wiring patterns of the first detection unit **120** and the second detection unit **130**. That is, a longer wiring pattern can be formed in total within the ranges of the one surface **111** and the other surface **113** of the base **110**. Thus, the sensitivity of the first detection unit **120** and the second detection unit **130** can be enhanced, and the soil sensor **100** can be downsized.

(113) The first signal line **121** and the first GND line **122** of the first detection unit **120** are allowed to be close to each other, and thus the electric field easily permeates through the soil **200**. The sensitivity can be therefore further enhanced.

(114) The other surface **113** of the base **110** according to the present embodiment corresponds to the installation surface.

Third Embodiment

(115) In the present embodiment, the description primarily focuses on the portions that differ from the first and second embodiments. As illustrated in FIG. **9**, the connection portion **121**E of the first detection unit **120** is a wiring pattern folded toward the wiring pattern of the first straight portion **121**C corresponding to the one end portion **121**A of the first signal line **121** and the wiring pattern of the second straight portion **121**D corresponding to the other end portion **121**B of the first signal line **121**. In FIG. **9**, the illustration of the third to fifth detection units **140** to **160** is omitted.

(116) The first GND line **122** is spaced from the first signal line **121** at the first interval. Thus, a portion of the first GND line **122** corresponding to the connection portion **121**E is also a wiring pattern folded toward the one end portion **122**A of the first GND line **122** and the other end portion **122**B of the first GND line **122**.

(117) For example, the soil **200** having absorbed water has high permittivity. A difference in permittivity between the base **110** and the soil **200** thus increases. As illustrated in FIG. **10**, the total reflection of each electric field **114** therefore occurs at the interface between the base **110** and the soil **200**. That is, the electric field **114** does not pass through the soil **200**, and thus the sensitivity to a change in permittivity of the soil **200** decreases.

(118) In contrast, when the connection portion **121**E is the folded wiring pattern as described above, the density of the wiring pattern in which the connection portion **121**E is folded is higher than the density of the wiring pattern in which the connection portion **121**E is not folded. The angle of incidence of each electric field with respect to the interface between the base **110** and the soil **200** thus increases. The total reflection of each electric field **114** therefore does not occur at the interface between the base **110** and the soil **200**, as illustrated in FIG. **11**. The sensitivity of the first detection unit **120** can be therefore enhanced.

(119) As a modification, the connection portion **121**E may be folded not once but a plurality of times. In this case, the connection portion **121**E is a meandering wiring pattern.

Fourth Embodiment

(120) In the present embodiment, the description primarily focuses on the portions that differ from the above embodiments. As illustrated in FIG. **12**, the second straight portion **121**D of the first signal line **121** includes a wiring pattern portion **121**F having a meandering pattern. The meandering pattern is a wavelike pattern or a repeated pattern. In FIG. **12**, the illustration of the

third to fifth detection units **140** to **160** is omitted.
(121) The first GND line **122** is a wiring pattern spaced from the first signal line **121** at the first interval. A portion of the first GND line **122** corresponding to the second straight portion **121**D of the first signal line **121** is thus a meandering pattern. The above configuration enables an increase in the density of the wiring pattern of the first detection unit **120**. An effect similar to that of the third embodiment can be thus obtained.
(122) As a modification, the first straight portion **121**C may include a meandering wiring pattern portion. That is, one of the first straight portion **121**C and the second straight portion **121**D includes a meandering pattern portion.
(123) As another modification, one of the first straight portion **121**C and the second straight portion **121**D may include a meandering wiring pattern portion, and the connection portion **121**E may include a folded wiring pattern.
Fifth Embodiment
(124) In the present embodiment, the description primarily focuses on the portions that differ from the fourth embodiment. As illustrated in FIG. **13**, the first straight portion **121**C of the first signal line **121** includes a first wiring pattern portion **121**G having a meandering pattern. The second straight portion **121**D of the first signal line **121** includes a second wiring pattern portion **121**F having a meandering pattern. In FIG. **13**, the illustration of the third to fifth detection units **140** to **160** is omitted. In the first GND line **122**, respective portions corresponding to the straight portions **121**C, **121**D of the first signal line **121** are respective meandering wiring patterns. According to the above configuration, an effect similar to that of the third embodiment can be obtained.
(125) As a modification, both the first straight portion **121**C and the second straight portion **121**D may include respective meandering wiring pattern portions, and the connection portion **121**E may include a folded wiring pattern.
Sixth Embodiment
(126) In the present embodiment, the description primarily focuses on the portions that differ from the above embodiments. As illustrated in FIG. **14**, the soil sensor **100** is arranged such that the circuit unit **170** is positioned on the upper side of the base **110** in the gravity direction. That is, the arrangement direction and the gravity direction are parallel to each other. The arrangement direction may be slightly inclined with respect to the gravity direction as well as being parallel to the gravity direction.
(127) For example, when the soil **200** is culture soil, a fertilizer and water are mixed at a certain proportion. The culture soil is soil in which a fertilizer, and other components including leaf mold, sand, peat moss, vermiculite, and lime are mixed at a certain proportion to cultivate plants. Accordingly, the soil sensor **100** can be vertically arranged in the soil **200**, as illustrated in FIG. **14**.
Seventh Embodiment
(128) In the present embodiment, the description primarily focuses on the portions that differ from the first embodiment. As illustrated in FIG. **15**, the soil sensor **100** includes a plurality of first detection units **120**, a plurality of second detection units **130**, a plurality of third detection units **140**, a plurality of fourth detection units **150**, and a plurality of fifth detection units **160**. Specifically, the soil sensor **100** includes a plurality of bases **110**. The plurality of bases **110** is arranged in the gravity direction to obtain physical quantities such as water contents, electric conductivity, and water potentials at different positions in the gravity direction. Each set of the detection units **120** to **160** is installed in a corresponding one of respective one surfaces **111** of the bases **110**.
(129) The soil sensor **100** is arranged in the soil **200** such that the arrangement direction is oriented in a direction perpendicular to the gravity direction. As a result, physical quantities can be measured for each level in the depth direction of the soil **200**. The soil sensor **100** may be arranged in the soil **200** such that the arrangement direction is along the gravity direction.
(130) As a modification, a single base **110** may be provided, and each set of the detection units **120**

to **160** may be installed to one surface **111** of the single base **110**, as illustrated in FIG. **16**.
(131) As another modification, all the detection units **120** to **160** may not be arranged at different positions in the gravity direction. That is, one or some of the detection units **120** to **160** may be arranged at different positions in the gravity direction. For example, only the first detection unit **120** may be arranged at a different position in the gravity direction, or only the second detection unit **130** may be arranged at a different position in the gravity direction.
Eighth Embodiment
(132) In the present embodiment, the description primarily focuses on the portions that differ from the seventh embodiment. As illustrated in FIGS. **17** and **18**, the soil sensor **100** is configured such that the circuit unit **170** is arranged on the upper side in the gravity direction, in the present embodiment. In FIG. **17**, the illustration of the third to fifth detection units **140** to **160** is omitted.
(133) The base **110** includes a first base **115** and a second base **116** that have different lengths in the arrangement direction. The first base **115** has a length “a” in the arrangement direction. The second base **116** has a length “b” in the arrangement direction, which is longer than the length “a”. A part of the second base **116** on one end side thereof is exposed, by overlapping and integrating the first base **115** with the second base **116**.
(134) The above configuration enables measurement of each physical quantity at a depth corresponding to the tip portion of the second base **116**, that is, the portion of the second base **116** having a range obtained by subtracting “a” from “b”. The soil sensor **100** may be arranged in the soil **200** such that the arrangement direction is oriented in the direction perpendicular to the gravity direction.
(135) As a modification, the base **110** may further include a third base **117** that has a length c in the arrangement direction longer than the length b, as illustrated in FIGS. **19** and **20**. The second base **116** is overlapped and integrated with the third base **117**. This configuration enables measurement of each physical quantity at a depth corresponding to the tip portion of the third base **117**, that is, the portion of the third base **117** having a range obtained by subtracting b from c, as well as the depth corresponding to the tip portion of the second base **116**.
(136) As another modification, the base **110** may be a single base, as illustrated in FIG. **21**. Each set of the detection units **120** to **160** is arranged in two stages in the arrangement direction in the one surface **111** of the base **110**. Alternatively, each set of the detection units **120** to **160** may be arranged in three stages in the arrangement direction in the one surface **111** of the base **110**, as illustrated in FIG. **22**. In FIGS. **21** and **22**, the illustration of the third to fifth detection units **140** to **160** is omitted.
Ninth Embodiment
(137) In the present embodiment, the description primarily focuses on the portions that differ from the above embodiments. As illustrated in FIG. **23**, the base **110** is not formed as a board or a substrate, but is formed as a sphere. The surface of the sphere corresponds to the one surface **111**. The sphere is, for example, a resin ball.
(138) Each of the detection units **120** to **160** is arranged to the surface of the sphere. The wiring pattern of each of the detection units **120** to **160** is printed on the surface of the sphere, for example. In FIG. **23**, the illustration of the second to fifth detection units **130** to **160** is omitted.
(139) The above configuration allows the wiring patterns of the first detection unit **120** to be formed on the sphere in a repeatedly circling manner. The wiring patterns of the first detection unit **120** can be thus lengthened. The sensitivity of the first detection unit **120** can be therefore enhanced.
(140) As a modification, the base **110** may have a slightly deformed shape such as an ellipsoid, instead of being formed as a complete sphere.
Tenth Embodiment
(141) In the present embodiment, the description primarily focuses on the portions that differ from the above embodiments. As illustrated in FIG. **24**, the ceramic body **133** includes an obverse

surface **134**, a reverse surface **135**, and a side surface **136**. The ceramic body **133** is arranged such that the reverse surface **135** is positioned on the side of the one end portion **131**A of the second signal line **131** and the one end portion **132**A of the second GND line **132**. That is, the reverse surface **135** of the ceramic body **133** is contact with the insulating film **112**. In FIG. **24**, the illustration of the third to fifth detection units **140** to **160** is omitted.
(142) The second detection unit **130** includes a metal body **137**. The metal body **137** is arranged on the entire area of the obverse surface **134** of the ceramic body **133**. The metal body **137** is formed of, for example, a metal material having excellent corrosion resistance such as aluminum or stainless steel. The metal body **137** may include a single layer or a plurality of layers. When the metal body **137** includes a plurality of layers, the plurality of layers may be formed of the same metal material, or the plurality of layers may be formed of different metal materials.
(143) The metal body **137** is connected to a part of the second GND line **132** (not illustrated) arranged on the side surface **136** of the ceramic body **133**. The metal body **137** is thus electrically connected to the second GND line **132**. The metal body **137** is the other electrode with respect to the ceramic body **133**.
(144) The above configuration allows capacitance to be also generated between the one end portion **131**A of the second signal line **131** positioned on the one surface **111** of the base **110** and the metal body **137**. When capacitance necessary for measuring the water potential is denoted by C, an area is denoted by S, and a distance between the electrodes is denoted by d, the capacitance C is expressed as $C=\varepsilon\times(S/d)$. Accordingly, obtainable capacitance increases because the area of the electrode increases by the area of the metal body **137**. The sensitivity of the second detection unit **130** can be therefore enhanced.
(145) As a modification, the metal body **137** may be arranged on at least a part of the obverse surface **134** of the ceramic body **133**.
Eleventh Embodiment
(146) In the present embodiment, the description primarily focuses on the portions that differ from the tenth embodiment. As illustrated in FIG. **25**, the second detection unit **130** includes a metal body **138**. The metal body **138** is arranged on the entire area of the obverse surface **134** of the ceramic body **133**. In FIG. **25**, the illustration of the third to fifth detection units **140** to **160** is omitted.
(147) The metal body **138** is connected to a part of the second signal line **131** (not illustrated) arranged on the side surface **136** of the ceramic body **133**. The metal body **138** is thus electrically connected to the second signal line **131**. The metal body **138** is the one electrode with respect to the ceramic body **133**.
(148) According to the above configuration, obtainable capacitance increases because the area of the electrode increases by the area of the metal body **138**, similarly to the tenth embodiment. The sensitivity of the second detection unit **130** can be therefore enhanced.
(149) As a modification, the metal body **138** may be arranged on at least a part of the obverse surface **134** of the ceramic body **133**.
Twelfth Embodiment
(150) In the present embodiment, the description primarily focuses on the portions that differ from the above embodiments. As illustrated in FIG. **26**, the one end portion **131**A of the second signal line **131** is arranged on the one surface **111** of the base **110**. The one end portion **131**A of the second signal line **131** has, for example, a circular planar shape. In FIG. **26**, the illustration of the third to fifth detection units **140** to **160** is omitted.
(151) The ceramic body **133** is arranged such that the reverse surface **135** is positioned above the one end portion **131**A of the second signal line **131**. That is, the ceramic body **133** is arranged such that the reverse surface **135** is positioned on the side of the one end portion **131**A of the second signal line **131**.
(152) The one end portion **132**A of the second GND line **132** is arranged on the entire area of the

obverse surface **134** of the ceramic body **133**. The one end portion **132**A of the second GND line **132** is electrically connected to a part of the second GND line **132** arranged on the side surface **136** of the ceramic body **133**.
(153) According to the above configuration, the area of the electrode formed by the one end portion **131**A of the second signal line **131** and the one end portion **132**A of the second GND line **132** becomes larger than that in the case of the first embodiment, and thus obtainable capacitance increases. The sensitivity of the second detection unit **130** can be therefore enhanced.
(154) As a modification, the planar shape of the one end portion **131**A of the second signal line **131** may be an elliptical shape or a polygonal shape. The one end portion **132**A of the second GND line **132** may be arranged on at least a part of the obverse surface **134** of the ceramic body **133**.
(155) As another modification, the second GND line **132** may be connected to the first GND line **122** of the first detection unit **120**. This configuration allows the second GND line **132** to be shared through the first GND line **122**.
Thirteenth Embodiment
(156) In the present embodiment, the description primarily focuses on the portions that differ from the twelfth embodiment. As illustrated in FIG. **27**, the one end portion **132**A of the second GND line **132** is arranged on the one surface **111** of the base **110**. The one end portion **132**A of the second GND line **132** has, for example, a circular planar shape. In FIG. **27**, the illustration of the third to fifth detection units **140** to **160** is omitted.
(157) The ceramic body **133** is arranged such that the reverse surface **135** is positioned above the one end portion **132**A of the second GND line **132**. That is, the ceramic body **133** is arranged such that the reverse surface **135** is positioned on the side of the one end portion **132**A of the second GND line **132**.
(158) The one end portion **131**A of the second signal line **131** is arranged on the entire area of the obverse surface **134** of the ceramic body **133**. The one end portion **131**A of the second signal line **131** is electrically connected to a part of the second signal line **131** arranged on the side surface **136** of the ceramic body **133**.
(159) According to the above configuration, obtainable capacitance increases, similarly to the twelfth embodiment. The sensitivity of the second detection unit **130** can be therefore enhanced.
(160) As a modification, the planar shape of the one end portion **132**A of the second GND line **132** may be an elliptical shape or a polygonal shape. The one end portion **131**A of the second signal line **131** may be arranged on at least a part of the obverse surface **134** of the ceramic body **133**.
Fourteenth Embodiment
(161) In the present embodiment, the description primarily focuses on the portions that differ from the twelfth embodiment. The one end portion **131**A of the second signal line **131** has, for example, an annular planar shape. As illustrated in FIG. **28**, the one end portion **132**A of the second GND line **132** is arranged on the entire area of the side surface **136** of the ceramic body **133**. In FIG. **28**, the illustration of the third to fifth detection units **140** to **160** is omitted.
(162) The above configuration allows capacitance to be generated between the one end portion **132**A of the second GND line **132** positioned on the side surface **136** of the ceramic body **133** and the one end portion **131**A of the second signal line **131** positioned on the one surface **111** of the base **110**. The one end portion **132**A of the second GND line **132** is arranged on the entire area of the side surface **136** of the ceramic body **133**, and thus obtainable capacitance increases. The sensitivity of the second detection unit **130** can be therefore enhanced.
(163) As a modification, the planar shape of the one end portion **131**A of the second signal line **131** may be an elliptical annular shape or a polygonal annular shape. The one end portion **132**A of the second GND line **132** may be arranged on at least a part of the side surface **136** of the ceramic body **133**.
Fifteenth Embodiment
(164) In the present embodiment, the description primarily focuses on the portions that differ from

the thirteenth embodiment. The one end portion **132**A of the second GND line **132** has, for example, an annular planar shape. As illustrated in FIG. **29**, the one end portion **131**A of the second signal line **131** is arranged on the entire area of the side surface **136** of the ceramic body **133**. In FIG. **29**, the illustration of the third to fifth detection units **140** to **160** is omitted.
(165) According to the above configuration, obtainable capacitance increases, similarly to the fourteenth embodiment. The sensitivity of the second detection unit **130** can be therefore enhanced.
(166) As a modification, the planar shape of the one end portion **132**A of the second GND line **132** may be an elliptical annular shape or a polygonal annular shape. The one end portion **131**A of the second signal line **131** may be arranged on at least a part of the side surface **136** of the ceramic body **133**.
Sixteenth Embodiment
(167) In the present embodiment, the description primarily focuses on the portions that differ from the fourteenth embodiment. As illustrated in FIG. **30**, the one end portion **132**A of the second GND line **132** is arranged on the obverse surface **134** and the side surface **136** of the ceramic body **133**. The one end portion **132**A of the second GND line **132** includes a through hole **132**C through which the ceramic body **133** is impregnated with the moisture of the soil **200**. In FIG. **30**, the illustration of the third to fifth detection units **140** to **160** is omitted.
(168) According to the above configuration, obtainable capacitance increases, similarly to the fourteenth embodiment. The sensitivity of the second detection unit **130** can be therefore enhanced.
Seventeenth Embodiment
(169) In the present embodiment, the description primarily focuses on the portions that differ from the fifteenth embodiment. As illustrated in FIG. **31**, the one end portion **131**A of the second signal line **131** is arranged on the obverse surface **134** and the side surface **136** of the ceramic body **133**. The one end portion **131**A of the second signal line **131** includes a through hole **131**C through which the ceramic body **133** is impregnated with the moisture of the soil **200**. In FIG. **31**, the illustration of the third to fifth detection units **140** to **160** is omitted.
(170) According to the above configuration, obtainable capacitance increases, similarly to the fifteenth embodiment. The sensitivity of the second detection unit **130** can be therefore enhanced.
Eighteenth Embodiment
(171) In the present embodiment, the description primarily focuses on the portions that differ from the above embodiments. As illustrated in FIG. **32**, installation of the first signal line **121** and the first GND line **122** is also made inside the base **110**, in addition to the installation on each of the one surface **111** and the other surface **113** of the base **110**. In FIG. **32**, the illustration of the second to fifth detection units **130** to **160** is omitted.
(172) The first signal line **121** includes a plurality of branched patterns branched in a plural manner between the one end portion **121**A and the other end portion **121**B. For example, the first signal line **121** includes four branched patterns connected in parallel between the one end portion **121**A and the other end portion **121**B. The four branched patterns extend along the one surface **111** of the base **110**, and are in different positions in a thickness direction defined with respect to the one surface **111** of the base **110**. The four branched patterns are thus layer-like wiring patterns. That is, the first signal line **121** includes four-level wiring patterns.
(173) Similarly, the first GND line **122** also includes four branched patterns that extend along the one surface **111** of the base **110**, and that are in different positions in the thickness direction defined with respect to the one surface **111** of the base **110**. Each of the branched patterns of the first GND line **122** and a corresponding one of the branched patterns of the first signal line **121** are arranged at the same level.
(174) The base **110** is, for example, a multi-layer substrate. With this configuration, the branched patterns of the first signal line **121** and the branched patterns of the first GND line **122** are decentralized in the thickness direction through vias formed in the multi-layer substrate. Each of the branched patterns of the first signal line **121** is converged into the one end portion **121**A and the

other end portion **121**B. Similarly, each of the branched patterns of the first GND line **122** is converged into the one end portion **122**A and the other end portion **122**B.

(175) According to the above configuration, electric field intensity increases by a degree corresponding to the additional provision of the branched patterns of the first signal line **121** and the branched patterns of the first GND line **122**. The sensitivity of the first detection unit **120** can be therefore enhanced.

(176) As a modification, the first signal line **121** and the first GND line **122** may not be arranged on the side of the other surface **113** of the base **110**. That is, an arrangement of the first signal line **121** and the first GND line **122** may be made on the one surface **111** of the base **110** and inside the base **110**.

(177) As another modification, the number of levels at which the respective branched patterns of the first signal line **121** and the respective branched patterns of the first GND line **122** are positioned is not limited to four, and may be three or more. For example, the number of levels for the branched patterns of the first signal line **121** and the branched patterns of the first GND line **122** can be any of 6, 8, 10, and 12.

Nineteenth Embodiment

(178) In the present embodiment, the description primarily focuses on the portions that differ from the eighteenth embodiment. As illustrated in FIG. **33**, an arrangement of the first signal line **121** and an arrangement of the first GND line **122** are made at different depths defined with respect to the one surface **111** of the base **110**, in a thickness direction perpendicular to the one surface **111** of the base **110**. In the present embodiment, the first signal line **121** is arranged on each of the one surface **111** and the other surface **113** of the base **110**. In contrast, an arrangement of the first GND line **122** is made inside the base **110**. In FIG. **33**, the illustration of the second to fifth detection units **130** to **160** is omitted.

(179) According to the above configuration, electric field intensity can be increased in the thickness direction of the base **110**. The sensitivity of the first detection unit **120** can be therefore enhanced.

(180) As a modification, an arrangement of the first signal line **121** may be made inside the base **110**, while an arrangement of the first GND line **122** may be made on each of the one surface **111** and the other surface **113** of the base **110**.

(181) As another modification, an arrangement of the first signal line **121** may be made inside the base **110**, an arrangement of the first GND line **122** may be made on the one surface **111** of the base **110**, another arrangement of the first signal line **121** may be made on the other surface **113** of the base **110**, and another arrangement of the first GND line **122** may be made inside the base **110**.

(182) As still another modification, an arrangement of the first signal line **121** may be made on the one surface **111** of the base **110**, an arrangement of the first GND line **122** may be made inside the base **110**, another arrangement of the first signal line **121** may be made inside the base **110**, and another arrangement of the first GND line **122** may be made on the other surface **113** of the base **110**.

(183) As yet another modification, an arrangement of the first signal line **121** and the first GND line **122** may be made entirely inside the base **110**.

Twentieth Embodiment

(184) In the present embodiment, the description primarily focuses on the portions that differ from the above embodiments. As illustrated in FIGS. **34** and **35**, the first signal line **121** is formed as wavelike wiring patterns whose amplitude changes in the thickness direction perpendicular to the one surface **111** of the base **110**. In FIGS. **34** and **35**, the illustration of the second to fifth detection units **130** to **160** is omitted.

(185) The first signal line **121** is configured, for example, by electrically connecting intermittent wiring patterns at four levels formed inside the base **110**, in the thickness direction, with vias or the like. In the first signal line **121**, regarding the side of the one surface **111** of the base **110**, two levels on the side of the one surface **111** of the base **110** are electrically connected in the thickness

direction with vias or the like. In the first signal line **121**, regarding the side of the other surface **113** of the base **110**, two levels on the side of the other surface **113** of the base **110** are electrically connected in the thickness direction with vias or the like. The first GND line **122** is also formed as wavelike wiring patterns similar to those of the first signal line **121**.
(186) The above configuration allows the first signal line **121** and the first GND line **122** to be lengthened. The sensitivity of the first detection unit **120** can be therefore enhanced, similarly to the second embodiment.
(187) Of course, combination can be made with other embodiments. For example, a wavelike wiring pattern may also be formed in the folded wiring pattern on the one surface **111** of the base **110** illustrated in FIG. **9** such that the wiring pattern has an amplitude changing in the thickness direction of the base **110**. Similarly, the wiring pattern according to the present embodiment can also be applied to the respective wiring patterns illustrated in FIGS. **12** to **33**.
(188) As a modification, a part of the first signal line **121** may be arranged on each of the one surface **111** and the other surface **113** of the base **110**. Similarly, a part of the first signal line **121** may be arranged on each of the one surface **111** and the other surface **113** of the base **110**.
(189) As another modification, the first signal line **121** and the first GND line **122** may not be arranged on the side of the other surface **113** of the base **110**. When an arrangement of the first signal line **121** and the first GND line **122** is made at a plurality of levels, each of the branched patterns is formed as a wavelike wiring pattern whose amplitude changes in the thickness direction.
(190) The present disclosure is not limited to the embodiments described above, and can be variously modified as follows without departing from the gist of the present disclosure. For example, the above embodiments can be appropriately combined. When the formation of the wiring pattern is made on each of the one surface **111** and the other surface **113** of the base **110**, the wiring pattern on the one surface **111** and the wiring pattern on the other surface **113** are desirably the same.
(191) The soil sensor **100** may be configured to measure the water content and the water potential among the physical quantities. Alternatively, the soil sensor **100** may be configured to measure the water content, the water potential, and the electric conductivity among the physical quantities. Alternatively, the soil sensor **100** may be configured to measure the water content, the water potential, the electric conductivity, and the temperature among the physical quantities. Alternatively, the soil sensor **100** may be configured to measure the water content, the water potential, the electric conductivity, the temperature, and the pH among the physical quantities. Alternatively, the soil sensor **100** may be configured to measure the water content, the water potential, the electric conductivity, the temperature, and the redox potential among the physical quantities. Alternatively, the soil sensor **100** may be configured to measure the water content, the water potential, the electric conductivity, the pH, and the redox potential among the physical quantities. Alternatively, the soil sensor **100** may be configured to measure the water content, the water potential, the electric conductivity, and the redox potential among the physical quantities. Alternatively, the soil sensor **100** may be configured to measure the water content, the water potential, and the temperature among the physical quantities. Alternatively, the soil sensor **100** may be configured to measure the water content, the water potential, the temperature, the pH, and the redox potential among the physical quantities. Alternatively, the soil sensor **100** may be configured to measure the water content, the water potential, the temperature, and the redox potential among the physical quantities. Alternatively, the soil sensor **100** may be configured to measure the water content, the water potential, and the pH among the physical quantities. Alternatively, the soil sensor **100** may be configured to measure the water content, the water potential, the pH, and the redox potential among the physical quantities. Alternatively, the soil sensor **100** may be configured to measure the water content, the water potential, and the redox potential among the physical quantities.
(192) The soil sensor **100** may be configured to measure the electric conductivity and the water

potential among the physical quantities. Alternatively, the soil sensor **100** may be configured to measure the electric conductivity, the water potential, and the water content among the physical quantities. Alternatively, the soil sensor **100** may be configured to measure the electric conductivity, the water potential, the water content, and the temperature among the physical quantities. Alternatively, the soil sensor **100** may be configured to measure the electric conductivity, the water potential, the water content, the temperature, and the pH among the physical quantities. Alternatively, the soil sensor **100** may be configured to measure the electric conductivity, the water potential, the water content, the temperature, the pH, and the redox potential among the physical quantities. Alternatively, the soil sensor **100** may be configured to measure the electric conductivity, the water potential, the water content, the temperature, and the redox potential among the physical quantities. Alternatively, the soil sensor **100** may be configured to measure the electric conductivity, the water potential, the water content, the pH, and the redox potential among the physical quantities. Alternatively, the soil sensor **100** may be configured to measure the electric conductivity, the water potential, the water content, and the redox potential among the physical quantities. Alternatively, the soil sensor **100** may be configured to measure the electric conductivity, the water potential, and the temperature among the physical quantities. Alternatively, the soil sensor **100** may be configured to measure the electric conductivity, the water potential, the temperature, the pH, and the redox potential among the physical quantities. Alternatively, the soil sensor **100** may be configured to measure the electric conductivity, the water potential, the temperature, and the redox potential among the physical quantities. Alternatively, the soil sensor **100** may be configured to measure the electric conductivity, the water potential, and the pH among the physical quantities. Alternatively, the soil sensor **100** may be configured to measure the electric conductivity, the water potential, the pH, and the redox potential among the physical quantities. Alternatively, the soil sensor **100** may be configured to measure the electric conductivity, the water potential, and the redox potential among the physical quantities.

(193) The soil sensor **100** may be configured to measure the water content and the electric conductivity among the physical quantities. Of course, similarly to the above, appropriate combination for the configuration of the soil sensor **100** may be made among each configuration configured to measure a corresponding one of the water potential, the temperature, the pH, and the redox potential, based on the configuration configured to measure the water content and the electric conductivity.

(194) The soil sensor **100** may be configured to measure the electric conductivity and the water potential among the physical quantities. Alternatively, the soil sensor **100** may be configured to measure the electric conductivity, the water potential, and the water content among the physical quantities. Alternatively, the soil sensor **100** may be configured to measure the electric conductivity, the water potential, the water content, and the temperature among the physical quantities. Alternatively, the soil sensor **100** may be configured to measure the electric conductivity, the water potential, the water content, the temperature, and the pH among the physical quantities. Alternatively, the soil sensor **100** may be configured to measure the electric conductivity, the water potential, the water content, the temperature, and the redox potential among the physical quantities. Alternatively, the soil sensor **100** may be configured to measure the electric conductivity, the water potential, the water content, the pH, and the redox potential among the physical quantities. Alternatively, the soil sensor **100** may be configured to measure the electric conductivity, the water potential, the water content, and the redox potential among the physical quantities. Alternatively, the soil sensor **100** may be configured to measure the electric conductivity, the water potential, and the temperature among the physical quantities. Alternatively, the soil sensor **100** may be configured to measure the electric conductivity, the water potential, the temperature, the pH, and the redox potential among the physical quantities. Alternatively, the soil sensor **100** may be configured to measure the electric conductivity, the water potential, the temperature, and the redox potential among the physical quantities. Alternatively, the soil sensor

100 may be configured to measure the electric conductivity, the water potential, and the pH among the physical quantities. Alternatively, the soil sensor **100** may be configured to measure the electric conductivity, the water potential, the pH, and the redox potential among the physical quantities. Alternatively, the soil sensor **100** may be configured to measure the electric conductivity, the water potential, and the redox potential among the physical quantities.

(195) The soil sensor **100** may be configured to measure the electric conductivity and the water content among the physical quantities. Alternatively, the soil sensor **100** may be configured to measure the electric conductivity, the water content, and the water potential among the physical quantities. Alternatively, the soil sensor **100** may be configured to measure the electric conductivity, the water content, the water potential, and the temperature among the physical quantities. Alternatively, the soil sensor **100** may be configured to measure the electric conductivity, the water content, the water potential, the temperature, and the pH among the physical quantities. Alternatively, the soil sensor **100** may be configured to measure the electric conductivity, the water content, the water potential, the temperature, the pH, and the redox potential among the physical quantities. Alternatively, the soil sensor **100** may be configured to measure the electric conductivity, the water content, the water potential, the temperature, and the redox potential among the physical quantities. Alternatively, the soil sensor **100** may be configured to measure the electric conductivity, the water content, the water potential, the pH, and the redox potential among the physical quantities. Alternatively, the soil sensor **100** may be configured to measure the electric conductivity, the water content, the water potential, and the redox potential among the physical quantities. Alternatively, the soil sensor **100** may be configured to measure the electric conductivity, the water content, and the temperature among the physical quantities. Alternatively, the soil sensor **100** may be configured to measure the electric conductivity, the water content, the temperature, the pH, and the redox potential among the physical quantities. Alternatively, the soil sensor **100** may be configured to measure the electric conductivity, the water content, the temperature, and the redox potential among the physical quantities. Alternatively, the soil sensor **100** may be configured to measure the electric conductivity, the water content, and the pH among the physical quantities. Alternatively, the soil sensor **100** may be configured to measure the electric conductivity, the water content, the pH, and the redox potential among the physical quantities. Alternatively, the soil sensor **100** may be configured to measure the electric conductivity, the water content, and the redox potential among the physical quantities.

(196) The soil sensor **100** may be configured to measure the water potential and the water content among the physical quantities. Of course, similarly to the above, appropriate combination for the configuration of the soil sensor **100** may be made among each configuration configured to measure a corresponding one of the electric conductivity, the temperature, the pH, and the redox potential, based on the configuration configured to measure the water potential and the water content.

(197) Although the present disclosure has been described in accordance with the embodiments, it is to be understood that the present disclosure is not limited to the embodiments and structures. The present disclosure also includes various modifications and variations within the scope of equivalents. Various combinations or forms, or other combinations or forms, in which only one element, one or more elements, or one or less elements are added to the various combinations or forms, are also within the scope and idea of the present disclosure.

Claims

1. A soil sensor comprising: a base having an installation surface; a first detection unit including a first signal line and a first GND line arranged on the base; a second detection unit including a second signal line and a second GND line arranged on the installation surface of the base, and a ceramic body, the second signal line having one end portion that is one electrode with respect to the ceramic body, the second GND line having one end portion that is the other electrode with respect

to the ceramic body; and a circuit unit configured to input a frequency signal between one end portion of the first signal line and one end portion of the first GND line, obtain water content of soil, in which the base is arranged, based on a propagation time taken for the frequency signal to reach the other end portion of the first signal line, and measure a water potential of the soil based on capacitance between the one end portion of the second signal line and the one end portion of the second GND line, the capacitance being changed by water entering the ceramic body from the soil, wherein the first signal line has a circular wiring pattern, when being projected on the installation surface of the base, the first GND line is arranged to be spaced from the first signal line, and has a wiring pattern, when being projected on the installation surface of the base, within a region surrounded by the wiring pattern of the first signal line projected on the installation surface, and the second detection unit is arranged within a region surrounded by the wiring pattern of the first GND line projected on the installation surface of the base.

2. The soil sensor according to claim 1, wherein the circuit unit is configured to obtain electric conductivity of the soil, based on steepness of a slope of a rise of the frequency signal reaching the other end portion of the first signal line.

3. The soil sensor according to claim 1, further comprising a third detection unit arranged on the installation surface of the base within a region surrounded by the first GND line projected on the installation surface, so as to detect a temperature of the soil, wherein the circuit unit is configured to obtain the temperature of the soil, based on a detection result from the third detection unit.

4. The soil sensor according to claim 1, further comprising a fourth detection unit arranged on the installation surface of the base within a region surrounded by the first GND line projected on the installation surface, so as to detect a potential difference between a pair of electrodes, the potential difference being caused along with adhesion of the water contained in the soil to one of the pair of electrodes, wherein the circuit unit is configured to obtain pH of the soil, based on the potential difference between the pair of electrodes.

5. The soil sensor according to claim 1, further comprising a fifth detection unit arranged on the installation surface of the base within a region surrounded by the first GND line projected on the installation surface, so as to detect a potential difference between a detection electrode and a reference electrode, the potential difference being caused along with adhesion of the water contained in the soil to the detection electrode, wherein the circuit unit is configured to obtain a redox potential of the soil, based on the potential difference between the detection electrode and the reference electrode.

6. The soil sensor according to claim 1, wherein the first detection unit is one of a plurality of first detection units installed to the base to obtain the water content at different positions in a gravity direction.

7. A soil sensor comprising: a base having an installation surface; a first detection unit including a first signal line and a first GND line arranged on the base; a second detection unit including a second signal line and a second GND line arranged on the installation surface of the base, and a ceramic body, the second signal line having one end portion that is one electrode with respect to the ceramic body, the second GND line having one end portion that is the other electrode with respect to the ceramic body; and a circuit unit configured to input a frequency signal between one end portion of the first signal line and one end portion of the first GND line, obtain electric conductivity of soil, in which the base is arranged, based on steepness of a slope of a rise of the frequency signal reaching the other end portion of the first signal line, and measure a water potential of the soil based on capacitance between the one end portion of the second signal line and the one end portion of the second GND line, the capacitance being changed by water entering the ceramic body from the soil, wherein the first signal line has a circular wiring pattern, when being projected on the installation surface of the base, the first GND line is arranged to be spaced from the first signal line, and has a wiring pattern, when being projected on the installation surface of the base, within a region surrounded by the wiring pattern of the first signal line projected on the

installation surface, and the second detection unit is arranged within a region surrounded by the wiring pattern of the first GND line projected on the installation surface of the base.
8. The soil sensor according to claim 7, wherein the circuit unit is configured to obtain water content of the soil, based on a propagation time taken for the frequency signal to reach the other end portion of the first signal line.
9. The soil sensor according to claim 7, further comprising a third detection unit arranged on the installation surface of the base within a region surrounded by the first GND line projected on the installation surface, so as to detect a temperature of the soil, wherein the circuit unit is configured to obtain the temperature of the soil, based on a detection result from the third detection unit.
10. The soil sensor according to claim 7, further comprising a fourth detection unit arranged on the installation surface of the base within a region surrounded by the first GND line projected on the installation surface, so as to detect a potential difference between a pair of electrodes, the potential difference being caused along with adhesion of the water contained in the soil to one of the pair of electrodes, wherein the circuit unit is configured to obtain pH of the soil, based on the potential difference between the pair of electrodes.
11. The soil sensor according to claim 7, further comprising a fifth detection unit arranged on the installation surface of the base within a region surrounded by the first GND line projected on the installation surface, so as to detect a potential difference between a detection electrode and a reference electrode, the potential difference being caused along with adhesion of the water contained in the soil to the detection electrode, wherein the circuit unit is configured to obtain a redox potential of the soil, based on the potential difference between the detection electrode and the reference electrode.
12. The soil sensor according to claim 7, wherein the first detection unit is one of a plurality of first detection units installed to the base to obtain the electric conductivity at different positions in a gravity direction.
13. The soil sensor according to claim 1, wherein the second detection unit is one of a plurality of second detection units installed to the installation surface of the base to obtain the water potential at different positions in a gravity direction.
14. The soil sensor according to claim 1, wherein the base is a substrate, and the installation surface is one surface of the substrate.
15. The soil sensor according to claim 1, wherein the base is a substrate, the installation surface has one surface of the substrate and the other surface of the substrate opposite to the one surface, and the first detection unit is arranged on the one surface of the substrate and the other surface of the substrate.
16. The soil sensor according to claim 1, wherein the wiring pattern of the first signal line projected on the installation surface of the base includes a first straight portion, a second straight portion arranged in parallel with the first straight portion, and a connection portion connecting the first straight portion and the second straight portion, a side of the first straight portion opposite to the connection portion corresponds to the one end portion of the first signal line, a side of the second straight portion opposite to the connection portion corresponds to the other end portion of the first signal line, and the connection portion is a wiring pattern folded toward a wiring pattern of the first straight portion corresponding to the one end portion of the first signal line and a wiring pattern of the second straight portion corresponding to the other end portion of the first signal line.
17. The soil sensor according to claim 1, wherein the wiring pattern of the first signal line projected on the installation surface of the base includes a first straight portion, a second straight portion arranged in parallel with the first straight portion, and a connection portion connecting the first straight portion and the second straight portion, and one of the first straight portion and the second straight portion includes a wiring pattern portion having a meandering pattern.
18. The soil sensor according to claim 1, wherein the wiring pattern of the first signal line projected on the installation surface of the base includes a first straight portion, a second straight portion

arranged in parallel with the first straight portion, and a connection portion connecting the first straight portion and the second straight portion, the first straight portion includes a first wiring pattern portion having a meandering pattern, and the second straight portion includes a second wiring pattern portion having a meandering pattern.
19. The soil sensor according to claim 1, wherein the base and the circuit unit are integrated, and are arranged along a direction perpendicular to a gravity direction.
20. The soil sensor according to claim 1, wherein the base and the circuit unit are integrated, and the circuit unit is arranged to be positioned on an upper side of the base in a gravity direction.
21. The soil sensor according to claim 1, wherein the one end portion of the second signal line and the one end portion of the second GND line are arranged on the installation surface of the base, the ceramic body is arranged above the one end portion of the second signal line and the one end portion of the second GND line, and the one end portion of the second GND line is arranged to be spaced from the one end portion of the second signal line, and is a wiring pattern surrounding the one end portion of the second signal line.
22. The soil sensor according to claim 21, wherein the ceramic body has an obverse surface and a reverse surface, and the reverse surface is arranged on a side of the one end portion of the second signal line and the one end portion of the second GND line, the second detection unit includes a metal body arranged on the obverse surface of the ceramic body and electrically connected to the second GND line, and the metal body is the other electrode with respect to the ceramic body.
23. The soil sensor according to claim 21, wherein the ceramic body has an obverse surface and a reverse surface, and the reverse surface is arranged on a side of the one end portion of the second signal line and the one end portion of the second GND line, the second detection unit includes a metal body arranged on the obverse surface of the ceramic body and electrically connected to the second signal line, and the metal body is the one electrode with respect to the ceramic body.
24. The soil sensor according to claim 1, wherein the one end portion of the second signal line is arranged on the installation surface of the base, the ceramic body has an obverse surface, a reverse surface, and a side surface, and the reverse surface is positioned above the one end portion of the second signal line, a part of the second GND line is arranged on the side surface of the ceramic body, and the one end portion of the second GND line is arranged on the obverse surface of the ceramic body.
25. The soil sensor according to claim 1, wherein the one end portion of the second GND line is arranged on the installation surface of the base, the ceramic body has an obverse surface, a reverse surface, and a side surface, and the reverse surface is positioned above the one end portion of the second GND line, a part of the second signal line is arranged on the side surface of the ceramic body, and the one end portion of the second signal line is arranged on the obverse surface of the ceramic body.
26. The soil sensor according to claim 1, wherein the one end portion of the second signal line is arranged on the installation surface of the base, the ceramic body has an obverse surface, a reverse surface, and a side surface, and the reverse surface is positioned above the one end portion of the second signal line, and the one end portion of the second GND line is arranged on the side surface of the ceramic body.
27. The soil sensor according to claim 1, wherein the one end portion of the second GND line is arranged on the installation surface of the base, the ceramic body has an obverse surface, a reverse surface, and a side surface, and the reverse surface is positioned above the one end portion of the second GND line, and the one end portion of the second signal line is arranged on the side surface of the ceramic body.
28. The soil sensor according to claim 1, wherein the one end portion of the second signal line is arranged on the installation surface of the base, the ceramic body has an obverse surface, a reverse surface, and a side surface, and the reverse surface is positioned above the one end portion of the second signal line, and the one end portion of the second GND line is arranged on the obverse

surface and the side surface of the ceramic body.

29. The soil sensor according to claim 1, wherein the one end portion of the second GND line is arranged on the installation surface of the base, the ceramic body has an obverse surface, a reverse surface, and a side surface, and the reverse surface is positioned above the one end portion of the second GND line, and the one end portion of the second signal line is arranged on the obverse surface and the side surface of the ceramic body.

30. The soil sensor according to claim 1, wherein the first signal line has layer-like wiring patterns that extend along the installation surface of the base, and that are in different positions in a thickness direction defined with respect to the installation surface of the base, and the first GND line has layer-like wiring patterns that extend along the installation surface of the base, and that are in different positions in a thickness direction defined with respect to the installation surface of the base.

31. The soil sensor according to claim 1, wherein the first signal line and the first GND line are arranged at different depths defined with respect to the installation surface, in a thickness direction perpendicular to the installation surface of the base.

32. The soil sensor according to claim 1, wherein the first signal line and the first GND line are wavelike wiring patterns whose amplitudes change in a thickness direction perpendicular to the installation surface of the base.