

Description

Title of Invention:

ODOR SUBSTANCE RECEIVING LAYER, SENSOR
ELEMENT USING SAME, ODOR SENSOR, ODOR
5 MEASUREMENT DEVICE, AND COMPUTER-READABLE
STORAGE MEDIUM

Technical Field

10 [0001]

The present invention relates to an odor (smell)
substance receiving layer, a sensor element using the same,
an odor (smell) sensor, an odor (smell) measuring device, and
computer-readable storage medium.

15

Background Art

[0002]

In a case where recent development of information
processing technology makes it possible to quantify, in some
20 way, the sense of smell which is among the five senses of
humans and mechanical measurement of which has not been
sufficiently achieved, such quantification is expected to be
available in a wide range of industrial fields such a medical
field, environmental and safety fields, and a marketing field.
25 As for a method for detecting a specific gaseous substance

(gas), high accuracy and high sensitivity measurement has been achieved so far by a semiconductor gas sensor or the like.

[0003]

5 The invention disclosed in Patent Literature 1 proposes a mechanism for replacing a semiconductor of a semiconductor gas sensor with an electrically conductive polymer to detect adsorption of an odor component on a surface of the electrically conductive polymer. Patent
10 Literature 1 reports that it is possible to detect an odor component which is easily thermally decomposed and a substance which is not subjected to an oxidation-reduction reaction on a surface of a detection section of a sensor.

[0004]

15 Further, Patent Literature 2 focuses on a property such that an electrical resistance of a mixture of an organic polymer and an electrically conductive substance is changed by exposure to an organic gas. Patent Literature 2 indicates that a plurality of combinations of an organic polymer and an
20 electrically conductive substance which combinations differ in makeup of the organic polymer of the mixture are prepared, and using these as electrical resistance arrays for sensors causes the sensors to differ from each other in change in electrical resistance while being exposed to an identical
25 organic gas. Patent Literature 2 has reported that using this

makes it possible to identify an odor by attribution of a pattern of a change in electrical resistance and a type of odor (= mixture of organic gases).

[0005]

5 Furthermore, Patent Literature 3 reports that adding a plasticizer to the above-described organic polymer results in an increase in response speed of a sensor.

Citation List

10 [Patent Literature]

[0006]

[Patent Literature 1]

Japanese Patent Application Publication Tokukaihei No. 11-23508

15 [Patent Literature 2]

Published Japanese Translation of PCT International Application Tokuhyohei No. 11-503231

[Patent Literature 3]

20 Published Japanese Translation of PCT International Application Tokuhyo No. 2002-519633

Summary of Invention

Technical Problem

[0007]

25 However, the conventional techniques as described in

Patent Literatures 1 to 3 have room for improvement from the viewpoint of odor identification performance.

[0008]

An object of an aspect of the present invention is to provide an odor substance receiving layer in which a hardly dispersible filler is favorably dispersed and which has improved odor identification performance, a sensor element using the odor substance receiving layer, an odor sensor, and an odor measuring device.

Solution to Problem

[0009]

An aspect of the present invention is: an odor substance receiving layer containing a resin composition that contains a polyesteramide (A) and a filler (B); a sensor element including the odor substance receiving layer; an odor sensor; and an odor measuring device.

Advantageous Effects of Invention

[0010]

According to an aspect of the present invention, it is possible to provide: an odor substance receiving layer in which a hardly dispersible filler is favorably dispersed and which has improved odor identification performance; a sensor element including the odor substance receiving layer; an odor sensor; and an odor measuring device.

Brief Description of Drawings

[0011]

Fig. 1 is a view schematically illustrating an example configuration of an odor sensor in accordance with an embodiment of the present invention.

Fig. 2 is a top view illustrating an example configuration of a sensor element.

Fig. 3 is a cross-sectional view illustrating an example configuration of the sensor element illustrated in Fig. 2.

Fig. 4 is a view schematically illustrating an example configuration of an odor measuring device in accordance with an embodiment of the present invention.

Fig. 5 is a functional block diagram illustrating an example configuration of an odor measuring device.

Fig. 6 is a flowchart showing an example flow of a process in which an estimation device generates an estimation model.

Fig. 7 is a functional block diagram illustrating an example configuration of an odor measuring device.

Fig. 8 is a flowchart showing an example flow of a process in which an estimation device estimates an odor substance.

Fig. 9 is a top view illustrating an example configuration of a sensor element of the present invention.

Fig. 10 is a top view illustrating an example

configuration of a sensor element of the present invention.

Fig. 11 is a perspective view illustrating an example configuration of a sensor element of the present invention.

Fig. 12 is a schematic diagram for describing a method
5 for manufacturing a sensor substrate used in Examples.

Fig. 13 is a schematic diagram for describing a method for manufacturing a sensor substrate used in Examples.

Fig. 14 is a view schematically illustrating a configuration of a front surface of the sensor substrate used
10 in Examples.

Fig. 15 is a view schematically illustrating a configuration of a back surface of the sensor substrate used in Examples.

15 Description of Embodiments

[0012]

The following description will discuss an embodiment of the present invention. However, the present invention is not limited to the embodiment below. In addition, any numerical
20 range expressed as "A to B" in the present specification means "not less than A and not more than B", unless otherwise stated.

[0013]

[1. Odor substance receiving layer]

25 The inventors of the present invention conducted

studies in order to attain the object, and consequently arrived at the present invention.

[0014]

An odor substance receiving layer in accordance with an embodiment of the present invention contains a resin composition that contains a polyesteramide (A) and a filler (B). This resin composition is applied onto a substrate for a sensor element and is heated and dried to obtain a dry solid product, and the dry solid product is used as an odor substance receiving layer.

[0015]

<Resin composition>

A resin composition in accordance with an embodiment of the present invention is a resin composition that is for forming an odor substance receiving layer and that contains a polyesteramide (A) and a filler (B).

[0016]

In the present specification, the term "odor substance" means in a broad sense a substance that can be adsorbed on an odor substance receiving layer. Thus, the "odor substance" also includes a substance that is generally not considered to be an odor-causing substance. In many cases, an odor substance causing the "odor" is a mixture of a plurality of types of substances. In some cases, there may be a substance that is not recognized as an odor substance or an unknown

odor substance. An embodiment of the present invention focuses on the fact that an amount of odor substance adsorbed on an odor substance receiving layer varies depending on a type of odor substance.

5 [0017]

Note that, in the present specification, mere description as "odor substance" sometimes means not an individual odor substance but an "aggregate of odor substances" that can include a plurality of odor substances.

10 [0018]

The "odor substance" is exemplified by, but not particularly limited to, hexane, ethyl acetate, methanol, diethyl carbonate, toluene, d-limonene, bornan-2-one, cis-3-hexenol, β -phenylethyl alcohol, citral, L-carvone, γ -undecalactone, eugenol, linalyl acetate, menthol, benzaldehyde, vanillin, hexanal, ethanol, pentyl valerate, linalool, and 2-propanol.

15 [0019]

In the present specification, the "odor substance receiving layer" means a layer that adsorbs an odor substance to be identified. The odor substance receiving layer is formed from the foregoing resin composition. The odor substance receiving layer can be provided as part of a sensor element which will be described later.

20 [0020]

25

It is considered possible for the sensor disclosed in Patent Literature 1 to detect an odor consisting of a compound of a simple substance. Meanwhile, many odors are a mixture of a plurality of substances. The sensor disclosed in Patent Literature 1 has no function to cause a detection section to identify an odor component. Thus, odor identification performance with respect to a mixture is insufficient. Patent Literature 2 indicates the following technique: an odor which is a mixture is recognized by using a difference in chemical structure of electrically conductive polymers used for a detection section to cause responses made by the detection section via each of the electrically conductive polymers to various compounds to differ. However, a chemical structure of an electrically conductive polymer is limited. Thus, it is difficult to separate responses of the detection section to any odor component with high sensitivity. Therefore, it is difficult for the sensor disclosed in Patent Literature 2 to distinguish, from each other, odors consisting of similar components. Patent Literature 3 proposes a method in which a mixture containing an organic polymer, a plasticizer, and an electrically conductive substance is used as a detection material for the detection section to detect, as an electrical resistance change of the mixture, permeation of an odor component into the organic polymer. By using the fact that using organic polymers having different makeups causes

different odor components to permeate into the organic polymers, an odor as a mixture can be recognized by an odor sensor that uses an array which is obtained by arranging side by side a plurality of detection sections made of the detection material containing the organic polymers having different makeups. However, in the above-described organic polymer and an organic polymer containing a plasticizer, even in a case where a plurality of combinations of an organic polymer and an electrically conductive substance are prepared, a difference in chemical property between the organic polymers is small. Thus, odor identification performance of the odor sensor is insufficient. These conventional techniques make it impossible to accurately detect, for example, an actual odor pattern in which a plurality of substances interact with each other or an actual odor pattern caused by a substance whose makeup is unknown.

[0021]

The inventors of the present invention focused on the fact that electrical conductivity of the foregoing resin composition varies depending on an amount of an odor substance adsorbed on the resin composition and the fact that a process of adsorption of an odor substance on the foregoing resin composition varies for each odor substance, and completed the invention of an odor substance receiving layer, a sensor element, and the like in accordance with of an

embodiment of the present invention. Furthermore, using such an odor substance receiving layer makes it possible to improve odor identification performance. For example, it is also possible to identify an actual odor pattern in which a plurality of substances interact with each other or an actual odor pattern caused by a substance whose makeup is unknown.

[0022]

<Polyesteramide (A)>

The polyesteramide (A) is a polymer that contains an amide bond and an ester bond.

[0023]

The polyesteramide (A) preferably includes a structural unit of an ester unit and/or an amide unit from the viewpoint of repeatability of electrical conductivity measurement.

[0024]

A main chain of the polyesteramide (A) is preferably one or more kinds selected from the group consisting of polyallylamine and polyester, and more preferably polyallylamine. A side chain of the polyesteramide (A) is preferably one or more kinds selected from the group consisting of a polyester chain, a block polymer of a polyester and a polyamide, a random polymer of an ester and an amino, more preferably a polyester chain and a block polymer of a polyester and a polyamide, and even more preferably a

polyester chain. Particularly preferably, the main chain of the polyesteramide (A) is polyallylamine, and the side chain of the polyesteramide (A) is a polyester chain.

[0025]

5 Examples of specific compounds of the polyesteramide (A) include polyallylamine derivatives PA-1, PA-9, and PA-10 which are described in Japanese Patent No. 3718915. One type of these examples of the polyesteramide (A) may be used alone, or two or more types thereof may be used in
10 combination.

[0026]

 The polyesteramide (A) can be prepared by, for example, reacting a polyester having a carboxyl group with an amine or an amide. The polyester having the carboxyl group can be
15 prepared by, for example, polymerizing a hydroxycarboxylic acid, a lactone, a mixture of a hydroxycarboxylic acid and a lactone, a mixture of (i) a dicarboxylic acid or an anhydride thereof and (ii) a dihydroxy compound, or the like. A method for reacting or polymerizing these compounds is not
20 particularly limited, and the reaction or the polymerization can be carried out by a known method.

[0027]

 Examples of the hydroxycarboxylic acid include lactic acid, ricinoleic acid, ricinoleic acid, 9-hydroxystearic acid,
25 10-hydroxystearic acid, 12-hydroxystearic acid, castor oil

fatty acid, and hydrogenated castor oil fatty acid. Examples of the lactone include β -propiolactone, γ -butyrolactone, δ -valerolactone, and ϵ -caprolactone. Examples of the dicarboxylic acid or the anhydride thereof include anhydride maleic acid, fumaric acid, succinic acid, glutaric acid, adipic acid, sebacic acid, phthalic anhydride, and terephthalic acid. Examples of the dihydroxy compound include ethylene glycol, propylene glycol, diethylene glycol, dipropylene glycol, triethylene glycol, neopentyl glycol, tetramethylene glycol, and 1,6-hexanediol.

[0028]

A number-average molecular weight of the polyester having the carboxyl group is preferably 500 to 10000, and more preferably 1000 to 7000. In a case where the number-average molecular weight falls within the above-described range, the dispersibility of the filler is improved. Note that the number-average molecular weight is measured by the method described in Examples.

[0029]

Examples of the amine include poly-lower alkylene amines such as polyallylamine, polyvinylamine, and polyethylene polyimine. Examples of the amide include a polymer of a dicarboxylic acid and a diamine. Examples of the dicarboxylic acid include malonic acid, succinic acid, glutaric acid, adipic acid, pimelic acid, suberic acid, azelaic acid,

sebacic acid, dodecanedioic acid, tetradecanedioic acid, hexadecanedioic acid, octadecanedioic acid, eicosanedioic acid, and diglycolic acid. Examples of the diamine include hexamethylenediamine, 2-methylpentamethylenediamine, and
5 2-methyl-1,8-octanediamine.

[0030]

In a case where the number-average molecular weight falls within the above-described range, the dispersibility of the filler is improved. Note that the number-average molecular
10 weight is measured by the method described in Examples.

[0031]

As a method for preparing the polyesteramide (A), for example, the polyesteramide (A) is obtained by an amidation reaction or an esterification reaction of a polyester having a
15 carboxyl group and an amine or an amide in the presence of a non-catalyst, an acid catalyst, a metal catalyst, or an alkali catalyst. As the acid catalyst, for example, paratoluenesulfonic acid, methanesulfonic acid, sulfuric acid, hydrochloric acid, phosphoric acid, and the like can be used.
20 As the metal catalyst, for example, dibutyltin oxide, zinc acetate, and the like can be used. As the alkali catalyst, potassium hydroxide, sodium hydroxide, 1,8-diazabicyclo[5,4,0]undecene (DBU), hexaethylenetetramine, and the like can be used. The amount of the catalyst used is
25 preferably 0.01% by weight to 3% by weight, where 100% by

weight represents a total introduction amount.

[0032]

The preparation of the polyesteramide (A) can be carried out under a normal pressure, under an increased pressure, or under a reduced pressure. A reaction temperature is, for example, 70°C to 250°C, and a reaction time is, for example, 1 hour to 30 hours. In the preparation of the polyesteramide (A), two or more kinds of polyester having a carboxyl group and two or more kinds of amine or amide may be used. Further, after the preparation, the polyesteramide (A) may be purified by subjecting the catalyst and the like to an adsorption process using an adsorbent (for example, activated clay, silica gel, or the like). In this case, the adsorption process may be carried out, for example, at 70°C to 130°C for 0.5 hour to 2 hours. The amount of the adsorbent is, for example, 0.1% by weight to 2% by weight, where 100% by weight represents a reaction product after the reaction.

[0033]

The polyesteramide has an acid value of preferably 0.3 g KOH/g to 50.0 g KOH/g, more preferably 10.0 mg KOH/g to 40.0 mg KOH/g, even more preferably 11.0 mg KOH/g to 30.0 mg KOH/g, and particularly preferably 12.0 mg KOH/g to 25.0 mg KOH/g. In a case where the polyesteramide has an acid value of 10.0 mg KOH/g, a hardly dispersible filler is easily dispersed. In addition, in a case where the polyesteramide has

an acid value of 40.0 mg KOH/g, the resin composition is suitable for use as the odor substance receiving layer. The acid value of the polyesteramide can be measured by the method described in Examples.

5 [0034]

The polyesteramide (A) has a number-average molecular weight (hereinafter referred to as Mn) of preferably 600 to 50000, more preferably 1000 to 45000, particularly preferably 3000 to 40000, and most preferably 4000 to 35000. The Mn of not less than 600 makes the viscosity fall within an optimum range and thus provides favorable repeatability of electrical conductivity measurement. The Mn of not more than 50000 provides favorable accuracy of electrical conductivity measurement. The Mn of the polyesteramide can be measured by the method described in Examples.

15 [0035]

The resin composition in accordance with an embodiment of the present invention contains the polyesteramide (A) and thus enhances aggregability of the odor substance receiving layer. This improves adhesion of the odor substance receiving layer to the substrate, further enhances the strength of the odor substance receiving layer, and makes cracking less likely to occur. The improvement in the adhesion of the odor substance receiving layer enables a change that occurs in a case where an odor substance is

adsorbed to be correctly measured. In addition, the improvement in the strength of the odor substance receiving layer makes an adsorption amount of an odor substance less likely to vary. Therefore, the resin composition in accordance
5 with an embodiment of the present invention can exhibit a high accuracy when used as an odor sensor.

[0036]

<Filler (B)>

The resin composition in accordance with an
10 embodiment of the present invention contains the filler (B). The foregoing resin composition is in a state in which the filler (B) is dispersed in the polyesteramide (A). In a case where fillers (B) are in contact with each other to form an electrically
15 conductive path, the resin composition is electrically conductive. Examples of the filler (B) include an electrically conductive carbon material, a pigment, silica, and metal powder. Among these, the electrically conductive carbon material is preferable from the viewpoint of enhancing electrical conductivity of the resin composition.

20 [0037]

From the viewpoint of reception sensitivity to an odor substance, a content of the filler (B) is preferably 5% by weight to 50% by weight, more preferably 10% by weight to 48% by weight, even more preferably 15% by weight to 45% by weight,
25 and particularly preferably 20% by weight to 40% by weight,

with respect to 100% by weight of a total of the polyesteramide (A) and the filler (B).

[0038]

In the present specification, the electrically conductive carbon material refers to a carbon material having a volume resistivity of not more than $0.1 \Omega \cdot \text{cm}$. The foregoing resin composition is in a state in which the electrically conductive carbon material that is the filler (B) is dispersed in the polyesteramide (A). In a case where the electrically conductive carbon materials are in contact with each other to form an electrically conductive path, the resin composition is electrically conductive. Examples of the electrically conductive carbon material include carbon black, a carbon nanotube, and graphene.

[0039]

Examples of a commercially available product of the carbon black include Ketjen Black EC (product name manufactured by Akzo Novel N.V., Netherlands), Ketjen Black EC-300J (product name manufactured by LION SPECIALTY CHEMICALS Co., Ltd.), Ketjen Black EC-600JD (product name manufactured by LION SPECIALTY CHEMICALS Co., Ltd.), SEAST G116, 116 (product name manufactured by TOKAI CARBON CO., LTD.), Niteron #10 (product name manufactured by NIPPON STEEL CHEMICAL CO., LTD.), DENKA BLACK (product name manufactured by Denki Kagaku Kogyo

Kabushiki Kaisha), and SUPER C-65 (MTI Corporation, US).

[0040]

Examples of a commercially available product of the carbon nanotube include VGCF-H (product name manufactured by Showa Denko K.K.).

[0041]

Examples of a commercially available product of the graphene include graphene manufactured by Sigma-Aldrich.

[0042]

The electrically conductive carbon material preferably has a fibrous or particulate shape. In an embodiment, the electrically conductive carbon material may be spherical.

[0043]

The electrically conductive carbon material that has a fibrous shape has a fiber diameter of preferably 0.1 μm to 10 μm , and more preferably 0.1 μm to 5 μm . The electrically conductive carbon material that has a fibrous shape has a fiber length of preferably 0.1 μm to 10 μm , and more preferably 1 μm to 10 μm .

[0044]

The electrically conductive carbon material that has a particulate shape has a primary particle size of preferably 10 nm to 200 nm, and more preferably 20 nm to 150 nm.

[0045]

In a case where carbon black is used as the filler (B), a

DBP oil absorption amount of the carbon black is not particularly limited, but is preferably not less than 130 ml/100 g, and more preferably not less than 140 ml/100 g. An upper limit value of the DBP oil absorption amount of the carbon black can be, for example, 800 ml/100 g, and is preferably 700 ml/100 g, and more preferably 600 ml/100 g. In a case where the DBP oil absorption amount of the carbon black falls within the above-described range, the electrical conductivity of the resin composition can be further increased.

[0046]

The DBP oil absorption amount of the carbon black can be obtained by calculating a DBP dripping amount at a torque which is 70% of a maximum torque in accordance with JIS K 6217-4. The DBP oil absorption amount can be measured with use of, for example, an absorption amount measuring instrument (product number "S-500" manufactured by Asahisouken Corporation).

[0047]

Although a pH of the carbon black is not particularly limited, the pH of the carbon black is preferably 5 to 10. In a case where the pH of the carbon black is not less than 5, the resin composition of the present invention exhibits excellent thermal deterioration resistance. Although there is no particular upper limit for the pH of the carbon black, the

upper limit of the pH of the carbon black is preferably not more than 10 in consideration of cost, availability, and the like.

[0048]

5 The pH of the carbon black can be measured by a known method, and, for example, a method such as a method of measuring a mixed liquid of carbon black and distilled water with use of a glass electrode pH meter can be employed.

[0049]

10 A primary particle size of the carbon black is not particularly limited, but is preferably not less than 23 nm and is preferably not more than 50 nm. In a case where the primary particle size of the carbon black falls within the above-described range, it is possible to obtain higher
15 electrical conductivity with a lower concentration of carbon black content. The primary particle size of the carbon black is, for example, an average primary particle size which is determined using image data of carbon black obtained by a transmission electron microscope. As the transmission
20 electron microscope, for example, a product name "JEM-2200FS" manufactured by JEOL Ltd. can be used.

[0050]

<Surfactant (C)>

25 An odor substance receiving layer in accordance with an embodiment of the present invention may contain a surfactant

(C), if necessary.

[0051]

<Method for producing resin composition>

A specific example of a method for producing a resin
composition according to an embodiment of the present
invention is presented as below.

[0052]

The resin composition is obtained as a slurry by mixing
the polyesteramide (A) and the filler (B), and, if necessary, the
surfactant (C) and the solvent (D), and using a stirrer to
uniformly kneading a resulting mixture. This resin
composition is applied to a gap between two metal wires as
one set and is then heated and dried. A resulting dry solid
product is the odor substance receiving layer.

[0053]

The solvent (D) is not particularly limited, provided that
the solvent (D) is a medium which can be removed by drying,
but preferable examples of the solvent (D) include N-
methylpyrrolidone, N,N-dimethylformamide, N,N-
dimethylacetamide, ethyl acetate, water, toluene, isopropyl
alcohol, and xylene.

[0054]

[2. Sensor element 31]

In the foregoing resin composition, a case where an odor
substance A is adsorbed on the resin composition and a case

where an odor substance B different from the odor substance A is adsorbed on the resin composition differ in change over time in electrical conductivity. Using such a property makes it possible to achieve a sensor element 31 that can detect and
5 identify an odor substance.

[0055]

The following description will discuss an overview and an effect of the sensor element 31 to which the resin composition in accordance with an embodiment of the present
10 invention is applied.

[0056]

The sensor element 31 includes an odor substance receiving layer 315 containing the foregoing resin composition, a first metal wire 313A, and a second metal wire 313B. In the following description, the first metal wire 313A
15 and the second metal wire 313B that are not distinguished from each other are each sometimes referred to as a metal wire 313.

[0057]

The following description will discuss the first metal wire 313A and the second metal wire 313B with reference to Figs. 2 and 3. Fig. 2 is a top view illustrating an example configuration of the sensor element 31. Fig. 3 is a cross-sectional view illustrating an example configuration of the
20 sensor element 31 illustrated in Fig. 2.

[0058]

The first metal wire 313A and the second metal wire 313B are metal wires functioning as electrodes for measuring a change in electrical conductivity of the odor substance receiving layer 315 (i.e., the resin composition). That is, the first metal wire 313A and the second metal wire 313B are spaced apart from each other, and the odor substance receiving layer 315 is in contact with at least part of the first metal wire and at least part of the second metal wire. For example, the first metal wire 313A and the second metal wire 313B are metal wires that are not in direct contact with each other, and, as illustrated in Fig. 2, may be metal wires that are substantially parallel to each other.

[0059]

As illustrated in Fig. 2, the metal wire 313 including the first metal wire 313A and the second metal wire 313B may be disposed on a substrate 311. The substrate 311 can be a substrate that is commonly used for an electronic circuit and that is, for example, a glass epoxy substrate. The metal wire 313 can be a metal wire made of, for example, copper or gold. A thickness, as viewed in a direction perpendicular to a surface of the substrate, of each of the first metal wire 313A and the second metal wire 313B is preferably 10 μm to 2 mm, and more preferably 10 μm to 1 mm. A height, i.e., a thickness, as viewed in a direction parallel to the surface of

the substrate, of each of the first metal wire 313A and the second metal wire 313B is preferably 1 μm to 100 μm , and more preferably 10 μm to 50 μm . An interval between the first metal wire 313A and the second metal wire 313B is preferably
5 1 μm to 1 mm, and more preferably 1 μm to 100 μm . A length of the metal wire 313 is preferably 10 μm to 50 mm, and more preferably 10 μm to 30 mm.

[0060]

Fig. 3 illustrates a cross section taken along the line A-A in Fig. 2. The odor substance receiving layer 315 may be in
10 contact with at least part of the first metal wire 313A and at least part of the second metal wire 313B. For example, as illustrated in Figs. 2 and 3, the odor substance receiving layer 315 may be disposed so as to fill a region sandwiched between
15 the first metal wire 313A and the second metal wire 313B.

[0061]

In a case where electrical conductivity of the odor substance receiving layer 315 (i.e., electrical conductivity of the sensor element 31) is low, the interval between the first
20 metal wire 313A and the second metal wire 313B is desirably not more than a predetermined distance (for example, 500 μm).

[0062]

The sensor element 31 can detect and identify various
25 odor substances by applying a resin composition in which a

case where the odor substance A is adsorbed on the resin composition and a case where the odor substance B different from the odor substance A is adsorbed on the resin composition differ in change over time in electrical conductivity. Note that, in an odor sensor 30 described later, a plurality of sensor elements 31 each including a substrate 311 in which a component for detecting an odor substance (the metal wire 313 and the odor substance receiving layer 315) is provided may be disposed. A plurality of sets including the odor substance receiving layer 315 of the same composition may be disposed on each substrate 311. In a case where a plurality of sensor elements 31 are disposed, a constant voltage power source and a voltmeter are provided for each sensor element 31. In the odor sensor 30, one component (the metal wire 313 and the odor substance receiving layer 315) for detecting an odor substance may be disposed on each substrate 311. Alternatively, in the odor sensor 30, a plurality of sets of the component for detecting an odor substance (the metal wire 313 and the odor substance receiving layer 315) may be disposed on one substrate 311. In the latter case, a constant voltage power source and a voltmeter are connected to each set provided on the substrate 311.

[0063]

[3. Odor sensor 30]

The following description will discuss, with reference to Fig. 4, an overview and an effect of an odor sensor 30 to which the sensor element 31 is applied. Fig. 4 is a block diagram illustrating an example configuration of the odor sensor 30 to which the sensor element 31 is applied.

[0064]

The odor sensor 30 includes the sensor element 31 that detects an odor substance, a constant voltage power source 32 (power source), and a voltmeter 33 (measuring instrument).

[0065]

The first metal wire 313A and the second metal wire 313B of the sensor element 31 are connected by a lead wire W. Fig. 4 illustrates an example in which the constant voltage power source 32 and the voltmeter 33 are provided to the lead wire W.

[0066]

The constant voltage power source 32 is a power source for supplying electric power to the sensor element 31. The constant voltage power source 32 supplies a constant voltage to the sensor element 31 via the lead wire. A value of the voltage supplied by the constant voltage power source 32 is 0.5 V to 10 V, and is, for example, 2.5 V or 5.0 V.

[0067]

The voltmeter 33 measures a potential difference that occurs between the first metal wire 313A and the second metal

wire 313B in a case where a constant voltage supplied from the constant voltage power source 32 is supplied to the odor substance receiving layer 315.

[0068]

5 Note that the odor sensor 30 includes, in a circuit for odor substance measurement, an amplifier (not illustrated) at a stage followed by the voltmeter 33, and the amplifier amplifies an acquired signal and supplies the amplified signal to the voltmeter 33.

10 [0069]

 Further, the odor sensor 30 includes a reference circuit, in addition to the circuit for odor substance measurement, and the voltmeter 33 acquires, as a voltage value, a difference (potential difference) between a value acquired in the circuit
15 for odor substance measurement and a value acquired in the reference circuit.

[0070]

 The odor sensor 30 may further include a housing 34, which is not an essential component. The housing 34 is a
20 container that can contain air containing an odor substance. In a case where the odor sensor 30 includes the housing 34, the sensor element 31 is provided in the housing 34.

[0071]

 The housing 34 includes an inlet 341 for introducing an
25 odor substance and an outlet 342 for discharging air

containing the odor substance. The odor substance may be introduced by inserting, via the inlet 341 into the housing 34, for example, filter paper P impregnated with the odor substance, or by inserting, via the inlet 341 into the housing 34, air containing the odor substance. The housing 34 is a container for containing air containing an odor substance having a predetermined concentration (for example, 200 ppm) or more.

[0072]

The outlet 342 of the housing 34 may be provided with an airflow generation fan 35, which is not essential. The airflow generation fan 35 is for generating an airflow in the housing 34 and discharging a gas in the housing 34 via the outlet 342 to outside the housing 34.

[0073]

Note that the odor sensor 30 may include a constant current source (power source) (not illustrated) as an alternative to the constant voltage power source 32 and an ammeter (measuring instrument) (not illustrated) as an alternative to the voltmeter 33. In this case, the constant current source functions as a power source for supplying electric power to the sensor element 31, and applies a constant current via the lead wire to the sensor element 31. Meanwhile, in a case where a constant current value is applied to the odor substance receiving layer 315, the ammeter

measures a value of a current flowing between the first metal wire 313A and the second metal wire 313B. Both the first metal wire 313A and the second metal wire 313B can function as electrodes. Hereinafter, the metal wire 313 functioning as an electrode may also be described as an "electrode 313".

[0074]

The odor sensor 30 outputs a measured value indicating a change over time in electrical conductivity of the sensor element 31 before and after an odor substance is adsorbed on the sensor element 31. This makes it possible to detect and identify various odor substances.

[0075]

[4. Odor measuring device 100]

The odor sensor 30 described earlier can output a change over time in electrical conductivity of the sensor element 31 for each odor substance in a case where various odor substances are adsorbed on the sensor element 31. In a case where the odor sensor 30 is applied, a change over time in electrical conductivity of the sensor element 31 in a case where the odor substance A is adsorbed on the sensor element 31 can be compared with a change over time in electrical conductivity of the sensor element 31 in a case where the odor substance B is adsorbed on the sensor element 31. The odor measuring device 100 that can estimate an odor substance adsorbed on the sensor element 31 can be achieved on the

basis of such a comparison result.

[0076]

Further, the odor measuring device 100 can estimate an odor substance with high accuracy by using an estimation
5 model 22 generated by machine learning. The estimation model 22 can be generated with use of learning data including a combination of (i) a measured value that is measured in a case where each of a plurality of odor substances is adsorbed on at least one sensor element 31 and (ii) identification
10 information specific to an odor substance to which the measured value has been given.

[0077]

The following description will discuss an overview and an effect of the odor measuring device 100 to which the odor
15 sensor 30 is applied. The odor measuring device 100 is a device that estimates, from a change in electrical conductivity which change occurs in the sensor element 31 to which the foregoing resin composition is applied, an odor substance adsorbed on the sensor element 31.

20 [0078]

An odor measuring device 100 of the present embodiment separately includes (i) a sensor chamber 60 including a plurality of sensor elements 31A (hereafter also referred to as a "sensor element group 31A") and (ii) a target
25 sample receiving section 50 into which a target sample

containing an odor substance is introduced and in which a gas containing an odor substance generated from the target sample is contained. In the present embodiment, each sensor element 31 included in the sensor element group 31A is referred to simply as a "sensor element 31". In the odor measuring device 100 of the present embodiment, a configuration is employed in which an odor substance-containing gas inside the target sample receiving section 50 is extruded toward the sensor chamber 60 with use of another gas (carrier gas). In the present embodiment, a gas in the target sample receiving section 50 in a case where the target sample is introduced into the target sample receiving section 50 (i.e., a gas containing an odor substance to be detected) is referred to as a first gas. Meanwhile, a carrier gas for extruding the first gas toward the sensor chamber 60 is referred to as a second gas.

[0079]

Fig. 1 is a view schematically illustrating the odor measuring device 100. As illustrated in Fig. 1, the odor measuring device 100 includes the odor sensor 30, the target sample receiving section 50, the sensor chamber 60, a gas supply section 80, and an estimation device 10. Further, the odor measuring device 100 may further include an adjustment section 51. Further, the odor measuring device 100 may further include an estimation device 10a.

[0080]

Fig. 1 illustrates, as an example, an example in which a gas flows from the gas supply section 80 to the target sample receiving section 50 and the sensor chamber 60 in this order.

5 The gas supply section 80, the target sample receiving section 50, and the sensor chamber 60 are connected with each other by a pipe.

[0081]

[Target sample receiving section 50]

10 The target sample receiving section 50 can retain the first gas by receiving therein a target sample containing an odor substance. The target sample receiving section 50 includes a first port 501 through which the second gas that enters the target sample receiving section 50 passes and a
15 second port 502 through which the first gas and the second gas that exit from inside the target sample receiving section 50 can pass. Fig. 1 illustrates an aspect in which the first port 501 is placed in an upper part of the target sample receiving section 50 in the drawing, and the second port 502
20 is placed in a lower part of the target sample receiving section 50 in the drawing. Note, however, that the present invention is not limited to this. For example, positions of the first port 501 and the second port 502 can be set as appropriate in accordance with, for example, types and combinations of odor
25 components contained in the first gas. For example, the

positions of the first port 501 and the second port 502 may be changed depending on whether an odor component contained in the first gas has a heavier or lighter weight per unit volume (i.e., higher or lower specific gravity) than the second gas. Further, the target sample receiving section 50 may include therein an airflow generation fan 35 as in Fig. 4.

[0082]

The target sample receiving section 50 includes the sample inlet 503 for receiving a liquid, solid, or gaseous target sample. The target sample receiving section 50 may include an installation part (not illustrated) in which a target sample is to be installed. In a case where the target sample is a liquid, the installation part may be a cup for retaining the liquid. In a case where the target sample is a solid, the installation part may be a petri dish in which the solid is allowed to stand still. Into the target sample receiving section 50, the target sample that is in a gaseous state may be introduced as the first gas through the sample inlet 503. The target sample receiving section 50 thus being capable of receiving a liquid or solid target sample makes it possible to adjust a concentration of an odor substance in the first gas. For example, even in a case where the first gas and the second gas contain an identical odor substance, it is easy to adjust a level of the concentration of the odor substance in the first gas.

[0083]

An inner surface of the target sample receiving section 50 may be provided with a material that is inert to an odor substance. The material that is inert to an odor substance is a material that does not greatly change respective concentrations of odor substances contained in a gas to be sent to the sensor chamber 60. For example, the material that is inert to an odor substance is a material on which an odor substance is less likely to be adsorbed or dissolved. Examples of the material that is inert to an odor substance include glass, metal, and resin. In a case where metal is employed, stainless steel (SUS) is preferable. In a case where resin is employed, a fluorine-based resin, polypropylene (PP), polyethylene (PE), an ABS resin, or polyethylene terephthalate (PET) is preferable.

[0084]

In a case where the inner surface of the target sample receiving section 50 is made of a material that adsorbs an odor substance contained in the first gas, adsorption of the odor substance on each part of the inner surface may affect a later measurement.

[0085]

The target sample receiving section 50 whose inner surface is thus made of a material that is inert to an odor substance reduces the fear, for example, that the material of the inner surface might react with the odor substance

contained in the first gas or that the odor substance might be adsorbed on the inner surface. This reduces the fear, for example, that the odor substance contained in the first gas supplied to the sensor chamber 60 might be changed while being contained in the target sample receiving section 50 or that a concentration of the odor substance might be gradually lowered.

[0086]

Even in a case where the target sample is a liquid or a solid, the odor measuring device 100 including the target sample receiving section 50 makes it possible to uniform a concentration of the first gas in the target sample receiving section 50 before sending the first gas to the sensor chamber 60. Further, the odor measuring device 100 including the target sample receiving section 50 can extrude the first gas into the sensor chamber 60 at a constant flow rate. This allows the odor measuring device 100 to send the first gas to the sensor chamber 60 under an identical condition every time even in a case where measurements are repeatedly carried out. This makes it possible to repeatedly carry out stable measurements.

[0087]

The target sample receiving section 50 preferably has an internal volume that is not less than 1 time and not more than 200 times an internal volume of the sensor chamber 60.

In particular, the target sample receiving section 50 preferably has a larger internal volume than the sensor chamber 60. The target sample receiving section 50 more preferably has an internal volume that is not less than 2 times the internal volume of the sensor chamber 60 and even more preferably has an internal volume that is not less than 4 times the internal volume of the sensor chamber 60. Further, the target sample receiving section 50 preferably has an internal volume that is not more than 100 times the internal volume of the sensor chamber 60 and more preferably has an internal volume that is not more than 60 times the internal volume of the sensor chamber 60. In a case where the target sample receiving section 50 has an internal volume that is not less than 1 time the internal volume of the sensor chamber 60, a concentration of an odor substance in the sensor chamber 60 is appropriately adjusted, and a measurement result from a sensor included in the sensor chamber 60 is stably output. Further, in a case where the target sample receiving section 50 has an internal volume that is not more than 200 times the internal volume of the sensor chamber 60, the temperature and humidity in the target sample receiving section 50 are easily adjusted. Thus, a measurement result from a sensor is stably output, and the odor measuring device 100 can have a compact size.

In a case where the target sample receiving section 50 has an internal volume that is less than 1 time the internal volume of the sensor chamber 60, an odor substance generated in the target sample receiving section 50 is diluted in the sensor chamber 60. This may result in a lower measurement sensitivity of a sensor. Further, in a case where the target sample receiving section 50 has an internal volume that is more than 200 times the internal volume of the sensor chamber 60, the uniformity of the concentration, temperature, and humidity of the first gas decreases because the target sample receiving section 50 has a too large volume. This may result in a failure to send the first gas to the sensor chamber 60 under an identical condition in a case where measurements are repeatedly carried out. Further, this may result in an increase in size of the entire odor measuring device 100.

[0089]

Fig. 1 illustrates, as an example, an example in which the target sample receiving section 50 has an internal volume that is 8 times the internal volume of the sensor chamber 60.

[0090]

For example, in a case where an inner surface of a pipe 93 is made of a material that adsorbs an odor substance contained in the first gas, adsorption of the odor substance on each part of the inner surface may affect a later measurement. Thus, as in the case of the inner surface of the

target sample receiving section 50, the inner surface of the pipe 93 through which the first gas is guided from the target sample receiving section 50 to the sensor chamber 60 is preferably provided with a material that is inert to an odor substance. Examples of a material that is inert to the odor substance include glass, metal, and resin. In a case where metal is employed, stainless steel (SUS) is preferable. In a case where resin is employed, a fluorine-based resin, polypropylene (PP), polyethylene (PE), an ABS resin, or polyethylene terephthalate (PET) is preferable.

[0091]

The target sample receiving section 50 may be configured to be attachable to and detachable from a pipe 92 and the pipe 93. In a case where a previous measurement is completed and a subsequent measurement is carried out, the target sample receiving section 50 thus being attachable and detachable can be replaced with a new target sample receiving section 50 without any need to purge an inside of the target sample receiving section 50. This enables the odor measuring device 100 to carry out a plurality of measurements in a short time.

[0092]

Further, the target sample receiving section 50 being attachable and detachable allows a heat-retaining chamber separate from the odor measuring device 100 to be used to

keep the target sample receiving section 50 in which the target sample is introduced at a desired temperature. According to this, for example, even the odor measuring device 100 that cannot be provided with the adjustment section 51 described
5 later can adjust the temperature of the target sample receiving section 50.

[0093]

[Adjustment section 51]

The adjustment section 51 adjusts at least one selected
10 from the group consisting of a temperature and a humidity of the first gas contained in the target sample receiving section 50. The adjustment section 51 that adjusts the temperature is, for example, a heater or a cooler. In this case, the adjustment section 51 may be configured to cover the entire
15 target sample receiving section 50. The adjustment section 51 that adjusts the humidity is, for example, a humidifier or a dehumidifier. The adjustment section 51 may adjust, for each type of the first gas, at least one selected from the group consisting of the temperature and the humidity, or may
20 change, every certain time period during measurement of an identical first gas, at least one selected from the group consisting of the temperature and the humidity.

[0094]

The adjustment section 51 adjusting at least one
25 selected from the group consisting of the temperature and the

humidity of the first gas in the target sample receiving section 50 enables the odor measuring device 100 to, for example, use a condition in accordance with a type(s) (gas weight, volatility, etc.) of the first gas to send the first gas to the sensor chamber 60. Further, this enables the odor measuring device 100 to send, to the sensor chamber 60, the first gas having a stable concentration. This results in improved measurement accuracy.

[0095]

10 [Sensor chamber 60]

The sensor chamber 60 is a space in which the sensor element 31 for measuring an odor substance is stored. The sensor chamber 60 is connected with the second port 502 of the target sample receiving section 50. Specifically, the sensor chamber 60 includes a gas supply port 601 and a gas discharge port 602, and the second port 502 of the target sample receiving section 50 and the gas supply port 601 are connected.

[0096]

20 The sensor chamber 60 includes a sensor element 31A that is capable of outputting a measurement result in accordance with an odor substance contained in the first gas. The sensor element 31A may be one sensor element or may be a plurality of sensor elements. In a case where the sensor element 31A is a plurality of sensor elements, the plurality of

25

sensor elements may be sensor elements 31 each including a different resin composition as a substance receiving layer. That is, the plurality of sensor elements 31A may differ in sensitivity and specificity to an odor substance of each of the sensor elements 31. For example, the sensor chamber 60 of Fig. 1 includes the sensor element 31 and the sensor element 31b. However, the present invention is not limited to this. Further, the sensor chamber 60 of Fig. 1 includes a sensor element 31c that includes, as a substance receiving layer, a resin composition which differs from the resin compositions included in the sensor elements 31 and 31b. The sensor element 31 and the sensor element 31b are each capable of outputting a measurement result in accordance with an identical odor substance contained in the first gas, but output respective different measurement results. A measurement result in accordance with an odor substance is, for example, a measurement result in accordance with a concentration of the odor substance. Note that, in the following description, the sensor elements 31, 31b, 31c and a sensor element 31d described later that are not particularly distinguished from each other are each referred to collectively as a "sensor element 31".

[0097]

In the sensor chamber 60, any combination of sensor elements 31 each including a different resin composition as a

substance receiving layer may be provided in any arrangement. In addition, a plurality of sensor elements 31 each including an identical resin composition as a substance receiving layer may be provided in the sensor chamber 60.

5 [0098]

Here, the sensor element 31 and the sensor element 31b each may be a sensor element that is capable of outputting a measurement result in accordance with a different odor substance. For example, a sensor element 31 that is capable
10 of outputting a measurement result in accordance with an odor substance contained in the first gas and a sensor element 31b that is capable of outputting a measurement result in accordance with a second odor substance which differs from the odor substance contained in the first gas may be disposed
15 in the sensor chamber 60. For example, the odor sensor 30 may include sensor elements 31 and 31b that are different from each other in resin composition used for an odor substance receiving layer 315.

[0099]

20 By including a plurality of sensor elements 31 in which resin compositions having different characteristics of adsorbing an odor substance are used for odor substance receiving layers 315, the odor measuring device 100 can simultaneously estimate a plurality of odor substances. Note
25 that in addition to a sensor element 31 in accordance with an

embodiment of the present invention, a sensor element 31 containing no surfactant (C) in an odor substance receiving layer 315 may be used in combination.

[0100]

5 Further, using the odor measuring device 100 makes it possible to obtain, for each of known odor substances, a first change pattern indicating a change in electrical conductivity of the sensor element 31 and a second change pattern indicating a change in electrical conductivity of the sensor
10 element 31b. An estimation model 22 may be generated by machine learning with use of both the first change pattern and the second change pattern. The odor measuring device 100 uses the estimation model 22 thus generated to estimate an odor substance. This makes it possible to more precisely
15 identify each odor substance.

[0101]

 For example, the sensor chamber 60 of Fig. 1 includes a plurality of sensor elements 31A in the arrangement of four sensor elements by four columns. The number of sensor
20 elements 31A and the manner of arrangement of the sensor elements 31A are not limited. The total number of sensor elements 31A included in the sensor chamber 60 is not particularly limited, and may be, for example, 2, 16, or 64.

[0102]

25 As in the case of the target sample receiving section 50,

a material of an inner surface of the sensor chamber 60 is preferably a material that is inert to an odor substance. Examples of the material that is inert to an odor substance include glass, metal, and resin. In a case where metal is employed, stainless steel (SUS) is preferable. In a case where resin is employed, a fluorine-based resin, polypropylene (PP), polyethylene (PE), an ABS resin, or polyethylene terephthalate (PET) is preferable. In a case where the material of the inner surface of the sensor chamber 60 is a material that adsorbs an odor substance contained in the first gas, adsorption of an odor substance on the sensor chamber reduces an amount of change in output from a sensor element 31 in a later measurement. This may prevent the odor measuring device 100 from accurately carrying out measurement.

[0103]

[Sensor elements 31A]

The sensor elements 31A each may include a thin film. For example, the odor substance receiving layer 315 in each of Figs. 2 and 3 is a thin film.

[0104]

Examples of an aspect in which the first gas containing an odor substance is sent into the sensor chamber 60 are considered to include an aspect in which an odor substance is sent from the gas supply port 601 side of the sensor chamber 60 to the sensor chamber 60A by providing a vacuum

pump on the gas discharge port 602 side of the sensor chamber 60 and using the vacuum pump to draw a gas. However, in a case where the sensor elements 31 and 31b each include a thin film, and the sensor chamber 60 has an internal negative pressure, expansion of the film may prevent the sensor elements 31 and 31b from outputting a stable measurement result. According to the odor measuring device 100 in accordance with the present example embodiment, since the first gas is sent to the sensor chamber 60 by the gas supply section 80 sends pushing a gas from the first port 501 side of the target sample receiving section 50 and the sensor chamber 60, the sensor chamber 60 has a positive internal pressure. For this reason, the odor measuring device 100 can obtain a stable measurement result even in a case where the plurality of sensor elements 31A each include a thin film.

[0105]

[Gas supply section 80]

The gas supply section 80 is connected with the first port 501 of the target sample receiving section 50 and sends the second gas to inside the target sample receiving section 50 so as to send the first gas from inside the target sample receiving section 50 to the sensor chamber 60.

[0106]

A valve 81 may be provided between the gas supply section 80 and the target sample receiving section 50.

Opening and closing of the valve 81 may adjust the start and stop of gas supply from the gas supply section 80.

[0107]

Since the first gas is thus sent to the sensor chamber 60 by the gas supply section 80 pushing a gas from the first port 501 side of the target sample receiving section 50, the sensor chamber 60 has a positive internal pressure. This enables the odor measuring device 100 to obtain a stable measurement result. Further, since opening and closing of the valve 81 makes it possible to send the second gas, the odor measuring device 100 can send the first gas from inside the target sample receiving section 50 to the sensor chamber 60 at any timing. According to this, the odor measuring device 100 that uses the sensor element group 31A to repeatedly carry out measurements with respect to an odor substance contained in the first gas makes it possible to improve reproducibility of the shape of a waveform output by each sensor element 31.

[0108]

The second gas may be an inert gas or air. Examples of the inert gas include argon and nitrogen. In a case where the second gas is an inert gas, the gas supply section 80 may be a gas cylinder.

[0109]

Further, in a case where the second gas is air, the gas

supply section 80 may be a pump. In this case, in order to remove a component that reacts with the first gas contained in the target sample receiving section 50, the odor measuring device 100 may include, for example, an activated carbon
5 filter on the first port 501 side of the target sample receiving section 50.

[0110]

The odor measuring device 100 may further include a massflow controller on the first port 501 side of the target
10 sample receiving section 50, more specifically, between the valve 81 and the gas supply section 80. The odor measuring device 100 that employs this configuration can send the first gas from the target sample receiving section 50 to the sensor chamber 60 at a constant flow rate. This enables the plurality
15 of sensor elements 31A to stably carry out output.

[0111]

Note that, although Fig. 1 illustrates the configuration in which the first gas and the second gas that have exited from inside the target sample receiving section 50 pass through the
20 pipe 93 and the sensor chamber 60, the present invention is not limited to this configuration. Since the target sample receiving section 50 of the odor measuring device 100 has a large volume relative to the sensor chamber 60, it is not necessary to send the total amount of the first gas inside the
25 target sample receiving section 50 to the sensor chamber 60

during the measurement. Further, after the measurement, in a case where purging of the inside of the target sample receiving section 50 is carried out with use of the second gas, the target sample receiving section 50 and the sensor chamber 60 need not be connected. Therefore, the odor measurement device 100 may be configured such that a valve (not illustrated) is disposed in the pipe 93 so that the first gas and the second gas which have exited from inside the target sample reception section 50 can be exhausted without passing through the sensor chamber 60.

[0112]

First, the following description will discuss a configuration of the odor measuring device 100 in accordance with an embodiment of the present invention with reference to Fig. 1. Fig. 1 is a block diagram illustrating an example configuration of the odor measuring device 100.

[0113]

As illustrated in Fig. 1, the odor measuring device 100 includes an estimation device 10 and the odor sensor 30.

[0114]

[Estimation device 10]

The estimation device 10 is a device that estimates an odor substance detected by the odor sensor 30. The estimation device 10 is, for example, a computer and includes a CPU (not illustrated) and a memory (not illustrated). The estimation

device 10 is connected with the odor sensor 30 so as to be capable of communicating with the odor sensor 30. Specifically, the estimation device 10 estimates the odor substance by analyzing a measured value obtained from the odor sensor 30. In a case where the sensor chamber 60 further includes a sensor element 31c in which a resin composition different from those used in the sensor element 31 and the sensor element 31b is used for a substance receiving layer 315, the estimation device 10 may further acquire and analyze a measured value that is measured by a voltmeter by supplying a constant voltage to the sensor element 31c. Further, the estimation device 10 may display the measured value itself, a waveform obtained by plotting the measured value, and an estimation result for an unknown odor substance which estimation result is based on an estimation model. Further, the estimation device 10 may display, for example, a numerical value and a graph each indicating a change in proportion of presence of each odor substance to a gas containing a plurality of odor substances. Further, the estimation device 10 may generate an estimation model 22 that is used to estimate the odor substance.

[0115]

<Generation of estimation model 22>

Next, the following description will discuss, with reference to Figs. 5 and 6, (i) a configuration of the odor

measuring device 100 that carries out a process for generating the estimation model 22 which is used to estimate an odor substance and (ii) the process for generating the estimation model 22.

5 [0116]

The estimation model 22 is generated by machine learning with use of learning data including a combination of (i) a measured value that is measured by the voltmeter 33 in a case where each of a plurality of odor substances is
10 adsorbed on at least one sensor element and (ii) identification information specific to an odor substance to which the measured value has been given. Note here that examples of the identification information specific to an odor substance include the name, the CAS number, a chemical formula, and
15 the like of the odor substance.

[0117]

(Configuration of estimation device 10 (generation of estimation model 22))

Fig. 5 is a functional block diagram illustrating an
20 example configuration of the odor measuring device 100. Note that for convenience, members having functions identical to those of the respective members described with reference to Fig. 1 are given respective identical reference numerals, and a description of those members is omitted.

25 [0118]

As illustrated in Fig. 5, the estimation device 10 includes an input section 15, a control section 1, and a storage section 2.

[0119]

5 The input section 15 is for accepting various input operations from a user, and may be, for example, a keyboard, a mouse, or a touch screen.

[0120]

10 The control section 1 includes a measured value acquiring section 11 (acquisition section), a change pattern analyzing section 12 (analysis section), a learning control section 13, and an estimation model generating section 14.

[0121]

15 The measured value acquiring section 11 acquires a measured value from the voltmeter 33. Further, the measured value acquiring section 11 uses the acquired measured value to calculate a value (for example, a resistance value, an impedance, and the like) indicating electrical conductivity of the sensor element 31. The measured value acquiring section
20 11 may acquire the measured value from the voltmeter 33 at a predetermined time interval (for example, an interval of 0.1 seconds).

[0122]

25 The change pattern analyzing section 12 analyzes a change over time in electrical conductivity of at least one

sensor element 31. The change pattern analyzing section 12 uses the resistance value calculated by the measured value acquiring section 11 to calculate a value indicating an amount of change in electrical conductivity of the sensor element 31 due to adsorption of an odor substance. The change pattern analyzing section 12 generates data indicating a change pattern indicating a change over time in calculated amount of change in electrical conductivity. In a case where a generated change pattern is a known odor substance, the change pattern analyzing section 12 may store the generated change pattern in a change pattern database 21 (learning data) in association with identification information specific to the known odor substance.

[0123]

The learning control section 13 reads the change pattern database 21 from the storage section 2 to control generation of the estimation model 22 by machine learning. Note here that the change pattern database 21 is a database including a combination of (i) a measured value that is measured in a case where a plurality of odor substances are adsorbed on the sensor element 31 and (ii) identification information specific to a known odor substance to which the measured value has been given. The learning control section 13 inputs, to the estimation model generating section 14, the change pattern read from the change pattern database 21.

Further, the learning control section 13 compares identification information of an odor substance corresponding to the change pattern input to the estimation model generating section 14 with an estimation result output from the estimation model generating section 14, and outputs, to the estimation model generating section 14, a correction instruction in accordance with a comparison result.

[0124]

The estimation model generating section 14 generates the estimation model 22 by a machine learning algorithm in which the change pattern stored in the change pattern database 21 is used. The estimation model generating section 14 may be configured to generate the estimation model 22 with use of a known supervised machine learning algorithm. Examples of the machine learning algorithm that is applicable to the estimation model generating section 14 include a k-nearest neighbor method, a logistic regression, a support vector machine, a random forest, and a neural network. Details of the machine learning algorithm will be described later.

[0125]

(Process for generating estimation model 22)

The following description will discuss, with reference to Fig. 6, a specific process carried out by each section of the control section 1. Fig. 6 is a flowchart showing an example

flow of a process in which the estimation device 10 generates the estimation model 22 of the odor measuring device 100. The estimation model 22 is generated by machine learning with use of learning data including a combination of (i) a measured value that is measured by the voltmeter 33 in a case where each of a plurality of odor substances is adsorbed on at least one sensor element 31 and (ii) identification information specific to an odor substance to which the measured value has been given. Note here that examples of the identification information specific to an odor substance include the name, the CAS number, a chemical formula, and the like of the odor substance.

[0126]

First, the measured value acquiring section 11 acquires a voltage value V_0 measured in the odor sensor 30 in which an odor substance has not been introduced into the target sample receiving section 50, and calculates a resistance value R_0 (step S1). The resistance value R_0 is $200\ \Omega$ to $1000\ \Omega$, more preferably $250\ \Omega$ to $900\ \Omega$, and particularly preferably $300\ \Omega$ to $800\ \Omega$. After that, an odor substance is introduced into the target sample receiving section 50 (step S1).

[0127]

Meanwhile, the input section 15 accepts input of, for example, the name of a known odor substance which has been introduced into the target sample receiving section 50 (step

S2). The process in step S2 may be alternatively carried out before step S1.

[0128]

Next, the measured value acquiring section 11 acquires
5 a change amount (ΔV) data (a waveform or a pattern of change over time) of the voltage value V in stages from before adsorption of the odor substance on the sensor element 31 to after desorption of the odor substance from the sensor element 31 (step S3).

10 [0129]

Next, the change pattern analyzing section 12 stores, in the change pattern database, (i) the change amount (ΔV) data (a waveform or a pattern of change over time) of the voltage value V in the stages from before adsorption of the odor
15 substance to after desorption of the odor substance and (ii) the name of the input known odor substance in such a manner that the change amount data and the name of the input known odor substance are associated with each other (step S4).

[0130]

20 In a case where a change pattern has not been stored for an existing odor substance of a predetermined type (NO in step S5), that is, in a case where data for use in machine learning is still insufficient, the process returns to step S1.

[0131]

25 In a case where a change pattern has been stored for an

existing odor substance of a predetermined type (YES in step S5), the learning control section 13 reads the change pattern, stored in the change pattern database 21, for the known odor substance, and inputs the read change pattern to the estimation model generating section 14. The estimation model generating section 14 generates the estimation model 22 by a machine learning algorithm in which the change pattern stored in the change pattern database 21 is used (step S6).

[0132]

The estimation model generating section 14 stores, in the storage section 2, the estimation model 22 that has been generated by predetermined machine learning (step S7).

[0133]

In the examples illustrated in Figs. 5 and 6, the estimation device 10 generates the estimation model 22. Note, however, that a method in which the estimation model 22 is generated is not limited to this. For example, a computer which is an external computer different from the estimation device 10 and which has functions identical to those of the learning control section 13 and the estimation model generating section 14 may be provided with data identical to that stored in the change pattern database 21 to prepare the estimation model 22.

[0134]

The process for generating the estimation model 22 may

include pre-processing of data and feature amount extraction. In addition, a machine learning algorithm may be used for machine learning for generating the estimation model 22.

[0135]

5 (Feature amount extraction)

The learning data for generating the estimation model 22 by machine learning may be a measured value itself or may be a feature amount extracted from the measured value. The feature amount may be, for example, a statistic, differential and integral values, a peak detection value, or an autocorrelation value. Examples of the statistic include an average value, a variance value, a maximum value, a minimum value, a difference between the maximum value and the minimum value, and a standard deviation. Examples of the differential and integral values include a differential value (a slope of a graph showing, for example, a change over time in a measured value) and an integral value (an area of a region defined by (i) a curve showing a change in a measured value in a graph showing, for example, a change over time in a measured value and (ii) a horizontal axis (e.g., a time axis)). Examples of the peak detection value include the number of peaks and the height of a peak in a change in a measured value (e.g., a change over time). Examples of the autocorrelation value include a difference in a change in a measured value (e.g., a change over time). The extraction of

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these feature amounts from measured values can be carried out based on a known method.

[0136]

(Pre-processing method)

5 The learning data for generating the estimation model
22 by machine learning may be used for machine learning
without performing pre-processing or may be used after
predetermined pre-processing has been performed as
necessary. Further, in a case where pre-processing is
10 performed, the pre-processing may be performed before the
feature amount extraction is performed, after the feature
amount extraction has been performed, or both before the
feature amount extraction and after the feature amount
extraction. The pre-processing may be performed by a known
15 method. Examples of the known method include methods such
as correction, noise removal, standardization, conversion of
data, smoothing, and data expansion. Examples of the
correction include integration, addition, subtraction, and
division using output ratios, independent component analysis
20 (ICA), or statistics based on a measurement result of a
standard gas by a plurality of sensor elements or a
commercially available sensor (e.g., a temperature sensor, a
humidity sensor, or the like). Examples of the noise removal
include removal of an outlier or noise such as white noise.
25 Examples of the standardization include normalization and

regularization of a feature amount. Examples of the conversion of data include removal of trend of data, frequency conversion, and logarithmic transformation. Examples of the smoothing include acquisition of a moving average of data and acquisition of a difference. Examples of the data extension include addition of the same sample data (e.g., data addition assuming a normal distribution) and addition of new sample data (e.g., addition of data related to a mixing ratio of vectors). [0137]

10 (Machine learning algorithm)

Examples of the machine learning algorithm applicable to the estimation model generation section 14 include regression analysis, classification, tree, time series analysis, neural network, and clustering. Examples of the regression analysis include logistic regression, Lasso regression, elastic regression, support vector regression (SVR), linear regression, Ridge regression, and ensemble regression. Examples of the classification include a k-nearest neighbor method, support vector classification (SVC), simple Bayesian classification (Naive Bayes classifier), stochastic gradient descent method (SGD), and kernel approximation. Examples of the tree include a decision tree, a regression tree, a random forest, boosting (lightGBM, XGboost), and stacking. Examples of the time series include AR, MA, ARIMA, and state space. Examples of the neural network include a multilayer perceptron (MLP),

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20
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a convolutional neural network (CNN), a recurrent neural network (RNN), a residual neural network (ResNet), a transformer, and a graph neural network (GNN). Examples of the clustering include a Gaussian mixture model (GMM), a k-average method (k-means), mini k-means, a variational Gaussian mixture model (VBGMM), and kernel approximation.
[0138]

<Estimation of odor substance>

Next, the following description will discuss, with reference to Figs. 7 and 8, (i) a configuration of an odor measuring device 100a that uses the estimation model 22 to estimate an odor substance and (ii) an estimation process.

[0139]

(Configuration of estimation device 10a (execution of estimation process))

Fig. 7 is a functional block diagram illustrating an example configuration of the odor measuring device 100a. Note that for convenience, members having functions identical to those of the respective members described with reference to Figs. 1 and 5 are given respective identical reference numerals, and a description of those members is omitted.

[0140]

As illustrated in Fig. 7, the estimation device 10a includes a control section 1a, a storage section 2a, and an output section 18. Note here that Fig. 7 illustrates an example

configuration in a case where the estimation device 10 illustrated in Fig. 5 is used for a process for estimating an odor substance. That is, the estimation device 10 illustrated in Fig. 5 and the estimation device 10a illustrated in Fig. 7 may be computers including identical hardware configurations.

[0141]

The output section 18 is for presenting an estimation result to a user, and may be, for example, a display, a speaker, a lamp, or the like.

[0142]

The control section 1a includes the measured value acquiring section 11 (acquisition section), the change pattern analyzing section 12 (analysis section), an estimation section 16, and an output control section 17.

[0143]

The estimation section 16 uses the estimation model 22 to estimate an odor substance from an analysis result obtained by analyzing a measured value acquired from the odor sensor 30.

[0144]

The output control section 17 controls the output section 18 so as to output an estimation result.

[0145]

(Estimation process)

The following description will discuss, with reference to Fig. 8, a specific process carried out by each section of the control section 1a. Fig. 8 is a flowchart showing an example flow of a process in which the estimation device 10a estimates an odor substance.

[0146]

First, the measured value acquiring section 11 acquires the voltage value V_0 measured in the odor sensor 30 in which the odor substance has not been introduced into the target sample receiving section 50, and calculates the resistance value R_0 . After that, an unknown odor substance (properties are not limited) is introduced into the target sample receiving section 50 (step S11).

[0147]

Next, the measured value acquiring section 11 acquires a change amount (ΔV) data (a waveform or a pattern of change over time) of the voltage value V in stages from before adsorption of the unknown odor substance (i.e., an odor substance to be estimated) on the sensor element 31 to after desorption of the unknown odor substance from the sensor element 31 (step S12).

[0148]

Next, the estimation section 16 estimates the unknown odor substance from the pattern of change over time (or a feature amount extracted from a change pattern) on the basis

of the estimation model 22 (step S13).

[0149]

The output control section 17 controls the output section so as to output an estimation result (step S14).

[0150]

In the foregoing embodiment, (i) the estimation device 10 which generates the estimation model 22 and (ii) the estimation device 10a which estimates an odor substance with use of the estimation model 22 have been described. Note that the estimation device 10 and the estimation device 10a may be separate devices or may be one device.

[0151]

<Example configuration of sensor element 31c>

Fig. 9 is a top view illustrating an example configuration of a sensor element 31c included in the sensor element group 31A. The sensor element 31c includes the electrode 313, which is a metal wire, disposed on the substrate 311 and a circular odor substance receiving layer 315c formed on the electrode 313. The electrode 313 includes a first metal wire 313C and a second metal wire 313D. The first metal wire 313C and the second metal wire 313D are each a metal wire functioning as an electrode for measuring a change in electrical conductivity of the odor substance receiving layer 315c. The diameter R of the odor substance receiving layer 315c is not less than 0.2 mm and not more than 5 mm. In Fig.

9, the odor substance receiving layer 315c included in the sensor element 31c has, for example, an elliptical shape, but a shape of the odor substance receiving layer 315c is not limited to this. In a case where the shape of the odor substance receiving layer 315c is an ellipse, an average of a minor axis and a major axis of the ellipse may be not less than 0.2 mm and not more than 5 mm. Alternatively, the shape of the odor substance receiving layer 315c may be a perfect circle.

[0152]

Fig. 10 is a top view illustrating an example configuration of a sensor element 31d included in the sensor element group 31A. The sensor element 31d includes the electrode 313 (the first metal wire 313C and the second metal wire 313D) disposed on the substrate 311 and a belt-shaped odor substance receiving layer 315d formed on the electrode 313. The odor substance receiving layer 315d has a width W of not less than 0.2 mm and not more than 5 mm in the short direction. Note that, in the following description, the odor substance receiving layer 315c and the odor substance receiving layer 315d that are not particularly distinguished from each other are each referred to collectively as an "odor substance receiving layer 315".

[0153]

The sensor elements 31 included in the sensor element

group 31A each have a first electrode and a second electrode, and the first electrode and the second electrode may be disposed so as to be in the shape of parallel lines, in the shape of parallel curves, in a comb shape, or in a concentric shape.

5 The first electrode and the second electrode that have any of the above-listed shapes are preferably disposed so as to have line symmetry or point symmetry. The first electrode and the second electrode that are thus disposed enable the odor measuring device 100 to measure, with high accuracy, an odor
10 substance contained in a gas.

[0154]

The sensor element 31c of Fig. 9 has the first metal wire 313C and the second metal wire 313D. For example, the first metal wire 313C is a first electrode that is constituted by a
15 metal wire 313a and a metal wire 313b, and the two metal wires are arranged in a T-shape so as to be perpendicular to each other. The second metal wire 313D is a second electrode that is constituted by two metal wires 313c and 313d as in the case of the first metal wire 313C, and the two metal wires
20 are configured to be arranged in a T-shape so as to be perpendicular to each other. Further, the first metal wire 313C and the second metal wire 313D are disposed in the shape of parallel lines such that the metal wire 313a and the metal wire 313c face each other.

25 [0155]

The first metal wire 313C and the second metal wire 313D can be placed at a suitable distance particularly because the first metal wire 313C and the second metal wire 313D are each disposed in a T-shape. This makes it possible to stabilize an electrode resistance value. For example, electrodes that are disposed in a comb shape may result in a too low electrode resistance value due to a short distance between the electrodes. Further, the first metal wire 313C and the second metal wire 313D each being disposed in a T-shape allows a slurry to easily spread in an application step of a method for manufacturing a sensor element 31 (described later). This is because a region in which the slurry spreads has no electrode unevenness part that can prevent the slurry from spreading. Further, the slurry easily spreading brings about an effect such that the odor substance receiving layer 315 after drying has a constant thickness.

[0156]

Fig. 11 is a perspective view illustrating an example configuration of a sensor element 31c included in the sensor element group 31A. As illustrated in Fig. 11, in the sensor element 31c, the first metal wire 313C and the second metal wire 313D are connected to corresponding pins 316 at their respective end portions where the first metal wire 313C and the second metal wire 313D face away from each other. The pin 316 is a conductive member for electrically connecting the

first metal wire 313C and the second metal wire 313D and the other members of the odor sensor 30. Although not illustrated, the sensor element 31c and the sensor element 31d illustrated in Figs. 9 and 10 also each include the pin 316 illustrated in
5 Fig. 11.

[0157]

<Method for manufacturing sensor element>

The following description will discuss a method for manufacturing a plurality of types of sensor elements 31 used in the odor measuring device 100. Slurries having various
10 makeups can be used as a raw material of the respective odor substance receiving layers 315 of the sensor elements 31.

[0158]

(Slurry preparing step)

15 First, a plurality of types of slurries having different mixing ratios of an electrically conductive carbon material and a resin composition are prepared. Mixing ratios of the electrically conductive carbon material and the resin composition need only be set, as appropriate, by desired
20 sensitivity and desired detection specificity of an odor substance receiving layer 315. The slurry may contain a solvent, an additive, and a surfactant other than the electrically conductive carbon material and the resin composition.

25 [0159]

(Electrode disposing step)

Next, an electrode is disposed on a substrate. The electrode may include a first electrode and a second electrode. The first electrode and the second electrode may be disposed so as to be in any of the following shapes: the shape of parallel straight lines, the shape of parallel curves, a comb shape, and a concentric shape. Further, the first electrode and the second electrode that have any of the above-listed shapes are preferably disposed so as to have line symmetry or point symmetry. Further, the first electrode and the second electrode are more preferably disposed so as to be in the shape of parallel straight lines or in the shape of parallel curves. It is particularly preferable that the first electrode and the second electrode be disposed so as to be in the shapes as illustrated in Figs. 9 and 10. Specifically, the first metal wire 313C is constituted by two metal wires (the metal wire 313a and the metal wire 313c) that are arranged in a T-shape so as to be perpendicular to each other. The second metal wire 313D is constituted by two metal wires (the metal wire 313c and the metal wire 313d) that are arranged in a T-shape so as to be perpendicular to each other. The first metal wire 313C and the second metal wire 313D are disposed in the shape of parallel lines such that the metal wire 313a and the metal wire 313c face each other. The first metal wire and the second metal wire that are thus disposed enable the odor measuring

device 100 to measure, with high accuracy, an odor substance contained in a gas.

[0160]

For example, in Figs. 9 and 10, a set of electrodes (the first metal wire 313C and the second metal wire 313D) is disposed on a single substrate 311. Alternatively, a plurality of sets of electrodes may be disposed side by side on a single substrate.

[0161]

(Region defining step)

Subsequently, an application region to which each of a plurality of types of slurries is applied is defined on the substrate on which the electrode is disposed. The application region may be defined, for example, by being provided with a resist. Further, in the application step, the application region may be defined in accordance with a nozzle diameter in a case where a slurry is dripped via a nozzle. The resist M is provided so as to define an application region 330. The application region 330 is in a state in which the substrate 311 is bare.

[0162]

An area of the application region 330 may be defined so as to be identical for each of the plurality of types of slurries. That is, even in the case of slurries having different mixing ratios of the electrically conductive carbon material and the resin composition, the application region 330 to which the

slurries are to be applied may have a uniform area. This reduces a variation in area of a plurality of types of odor substance receiving layers 315 after drying even in a case where a plurality of types of slurries having different mixing ratios are used.

[0163]

The application region 330 has, for example, a shape of a circle. Note, however, that the shape of the application region 330 is not limited to this. The application region 330 may have a shape of a circle or a belt. Thus, an odor substance receiving layer 315 having the shape of a circle or a belt is formed.

[0164]

In a case where the application region 330 has the shape of a circle, a diameter of the circle may be not less than 0.2 mm and not more than 5 mm. In a case where the application region 330 has the shape of a belt, a length in a short direction of the belt may be not less than 0.2 mm and not more than 5 mm. Thus, the following odor substance receiving layers are formed: an odor substance receiving layer 315c which has the shape of a circle and the diameter of the circle of which is not less than 0.2 mm and not more than 5 mm; and an odor substance receiving layer 315d which has the shape of a circle and the length of the belt in the short direction of which is not less than 0.2 mm and not more than

5 mm.

[0165]

A method by which the resist M is provided is not particularly limited. Examples of the method include the following methods: a method in which a solder resist is silk-screen printed in a defined region and then UV-cured; a method in which a resist film is attached to a substrate; and a method in which only a resist in a defined region is cured and an uncured part is removed.

[0166]

(Application step)

Subsequently, each of the plurality of types of slurries is applied to the application region 330. To a method by which the slurry is applied, a method that is conventionally known in the art is applicable. The slurry may be dripped, sprayed, or spin-coated via a nozzle. The method by which the slurry is applied is particularly preferably a method in which the slurry is dripped via a nozzle. For example, with use of IMAGE MASTER 350PC Smart (manufactured by Musashi Engineering, Inc.) equipped with a SUS metal needle nozzle (inner diameter of $\Phi 0.1$ mm; outer dimension of 0.23 mm), a desired application shape can be obtained.

[0167]

(Drying step)

Finally, the slurry applied to the application region 330

is dried to form an odor substance receiving layer 315. A method of drying the slurry is not particularly limited and can be, for example, a method in which the slurry is heated at 100°C for one hour under normal pressure and then heated at 100°C for one hour under reduced pressure in a vacuum dryer.

[0168]

<Software implementation example>

Control blocks (in particular, the control section 1) of the estimation devices 10 and 10a can be realized by a logic circuit (hardware) provided in an integrated circuit (IC chip) or the like or can be alternatively realized by software.

[0169]

In the latter case, the estimation devices 10 and 10a each include a computer that executes instructions of a program that is software realizing the foregoing functions. The computer not only includes, for example, at least one processor but also includes a computer-readable storage medium in which the program is stored. An object of the present invention can be achieved by the processor reading and executing, in the computer, the program stored in the storage medium. Examples of the processor include a central processing unit (CPU). Examples of the storage medium include "non-transitory tangible media" such as read only memories (ROMs), tapes, disks, cards, semiconductor

memories, and programmable logic circuits. The computer may further include a random access memory (RAM) or the like in which the program is loaded. The program can be made available to the computer via any transmission medium (such as a communication network or a broadcast wave) which allows the program to be transmitted. Note that an aspect of the present invention can also be achieved in the form of a computer data signal in which the program is embodied via electronic transmission and which is embedded in a carrier wave.

[0170]

The present invention is not limited to the embodiments, but can be altered by a skilled person in the art within the scope of the claims. The present invention also encompasses, in its technical scope, any embodiment derived by combining technical means disclosed in differing embodiments.

<Others>

The present invention includes the following configurations:

<1> An odor substance receiving layer containing a resin composition that contains a polyesteramide (A) and a filler (B).

<2> The odor substance receiving layer described in <1>, wherein the polyesteramide (A) has an acid value of 0.3

mg KOH/g to 50.0 mg KOH/g.

<3> The odor substance receiving layer described in <1> or <2>, wherein the filler (B) is an electrically conductive carbon material.

5 <4> The odor substance receiving layer described in any one of <1> to <3>, wherein the filler has a fibrous or particulate shape.

 <5> The odor substance receiving layer described in any one of <1> to <3>, wherein the polyesteramide (A) is a resin
10 having a structure in which the polyesteramide (A) has polyallylamine in a main chain thereof and has a polyester chain in a side chain thereof.

 <6> The odor substance receiving layer described in any one of <1> to <5>, wherein the polyesteramide (A) has a
15 number-average molecular weight of 600 to 50000.

 <7> The odor substance receiving layer described in any one of <1> to <4>, wherein the filler (B) is contained in an amount of 5% by weight to 50% by weight, where 100% by weight represents a total amount of the polyesteramide (A) and
20 the filler (B).

 <8> A sensor element including: the odor substance receiving layer described in any one of <1> to <7>; a first metal wire; and a second metal wire, wherein the first metal wire and the second metal wire are spaced apart from each other,
25 and the odor substance receiving layer is in contact with at

least part of the first metal wire and at least part of the second metal wire.

<9> An odor sensor including: the at least one sensor element described in <8>; a power source for supplying electric power to the sensor element; and a measuring instrument that outputs a measured value indicating electrical conductivity of the odor substance receiving layer of the sensor element to which the electric power is supplied by the power source.

<10> The odor sensor described in <9>, wherein the power source supplies a constant current or applies a constant voltage to the at least one sensor element.

<11> An odor measuring device including the odor sensor described in <9> or <10> and an estimation device, the estimation device including: an acquisition section that acquires a measured value from a measuring instrument; an analysis section that analyzes a change over time in electrical conductivity of at least one sensor element; and an estimation section that estimates an odor substance on a basis of an estimation model, the estimation model being generated by machine learning using learning data including a combination of (i) a measured value that is measured by the measuring instrument in a case where each of a plurality of odor substances is adsorbed on the at least one sensor element and (ii) identification information specific to an odor substance to

which the measured value has been given.

<12> A control program for causing a computer to function as the odor measuring device described in <11>, the control program causing the computer to function as the acquisition section, the analysis section, and the estimation section.

Examples

[0171]

The following description will further discuss the present invention with reference to Examples and Comparative Examples. Note, however, that the present invention is not limited to these. In the following description, "%" refers to "% by weight", and "part" refers to "part by weight", unless otherwise specified.

[0172]

<Conditions for measurement of number-average molecular weight (also referred to as Mn) of polyesteramide (A) and polyester resin>

In the present specification, Mn of the polyesteramide (A) can be measured under the following conditions using gel permeation chromatography (GPC) (HLC-802A (manufactured by Tosoh Corporation)).

Columns: G44000PWXL (manufactured by Tosoh Corporation) and G5000PWXL (manufactured by Tosoh Corporation) (these two columns were placed in series)

Mobile phase: 20% acetonitrile (containing 50 mM lithium chloride)

Flow rate: 0.8 mL/min

Column temperature: 40°C

5 Pump: L-6200 (manufactured by Hitachi, Ltd.)

Detectors: L-3300 (RI: differential refractometer; manufactured by Hitachi, Ltd.) and L-4200 (UV-VIS: ultraviolet-visible absorption spectrometer; manufactured by Hitachi, Ltd.)

10 Sample solution: 0.5% by weight of acetonitrile solution

Sample injection volume: 200 μ L

A calibration curve for calculating the molecular weight was created using standard polyethylene oxide (manufactured by Tosoh Corporation; Mn was the following six types: 15 2.40×10^4 , 5.00×10^4 , 1.0×10^5 , 1.40×10^5 , 2.5×10^5 , and 5.4×10^5).

[0173]

<Method for measuring acid values of polyester resin, polyamide resin, and polyesteramide>

20 The acid values of a polyester resin, a polyamide resin, and a polyesteramide were measured in accordance with JIS K 0070:1992.

[0174]

The following will provide Production Examples of 25 polyester resins and a polyamide resin.

[0175]

<Production Example 1>

[Preparation of polyester resin (PE-1)]

5 58.2 parts of 12-hydroxystearic acid and 441.8 parts of
ε-caprolactone were introduced into a reaction tank equipped
with a cooling pipe, a heating/cooling device, a thermometer,
a stirrer, and a nitrogen introduction pipe, heated up to 140°C
over 4 hours in a nitrogen atmosphere, and then reacted for 2
10 hours. A resulting resin was taken out at a point in time when
a remaining amount of ε-caprolactone became not more than
1%. The resin which had been taken out was cooled to room
temperature and then pulverized into particles to obtain a
polyester resin (PE-1). The polyester resin (PE-1) had a
number-average molecular weight (Mn) of 2600 and an acid
15 value of 21.6 mg KOH/g.

[0176]

<Production Example 2>

[Preparation of polyester resin (PE-2)]

20 A polyester resin (PE-2) was obtained in the same
manner as in Production Example 1 except that 152.5 parts
of 12-hydroxystearic acid was introduced instead of 58.2 parts
of 12-hydroxystearic acid, and 347.5 parts of ε-caprolactone
was introduced instead of 441.8 parts of ε-caprolactone. The
polyester resin (PE-2) had a number-average molecular weight
25 (Mn) of 1000 and an acid value of 56.9 mg KOH/g.

[0177]

<Production Example 3>

[Preparation of polyester resin (PE-3)]

30.0 parts of xylene, 300.0 parts of 12-hydroxystearic
5 acid, and 0.1 parts of tetrabutyl titanate as a condensation
catalyst were introduced into a reaction tank equipped with a
cooling pipe, a water separation pipe, a heating/cooling
device, a thermometer, a stirrer, and a nitrogen introduction
10 pipe and heated up to 140°C over 4 hours in a nitrogen
atmosphere. Next, the xylene was distilled off by heating at
140°C for 4 hours. After that, a resulting resin was taken out.
Note that water generated during a heating reaction was
separated from the xylene in a distillate and discharged to the
outside of the reaction tank, and the xylene was returned to
15 the reaction solution. The resin which had been taken out was
cooled to room temperature and then pulverized into particles
to obtain a polyester resin (PE-3). The polyester resin (PE-3)
had a number-average molecular weight (Mn) of 2550 and an
acid value of 22.0 mg KOH/g.

20 [0178]

<Production Example 4>

[Preparation of polyester resin (PE-4)]

28.8 parts of xylene, 89.4 parts of ethylene glycol, 210.6
parts of adipic acid, and 0.1 parts of tetrabutyl titanate as a
25 condensation catalyst were introduced into the same reaction

tank as that described in Production Example 3 and heated up to 140°C over 4 hours in a nitrogen atmosphere. Next, the xylene was distilled off by heating at 160°C for 2 hours. After that, a resulting resin was taken out. The resin which had been taken out was cooled to room temperature and then pulverized into particles to obtain a polyester resin (PE-4). The polyester resin (PE-4) had a number-average molecular weight (Mn) of 2600 and an acid value of 21.6 mg KOH/g.

[0179]

<Production Example 5>

[Preparation of polyester resin (PE-5)]

A polyester resin (PE-5) was obtained in the same manner as in Production Example 1 except that 21.7 parts of 12-hydroxystearic acid was introduced instead of 58.2 parts of 12-hydroxystearic acid, and 478.3 parts of ϵ -caprolactone was introduced instead of 441.8 parts of ϵ -caprolactone. The polyester resin (PE-5) had a number-average molecular weight (Mn) of 9700 and an acid value of 5.8 mg KOH/g.

[0180]

<Production Example 6>

[Preparation of polyamide resin (PA-1)]

10.2 parts of xylene, 44.3 parts of hexamethylenediamine, and 55.7 parts of adipic acid were introduced into the same reaction tank as that described in Production Example 3 and heated up to 160°C over 4 hours in

a nitrogen atmosphere. Next, the xylene was distilled off by heating at 160°C for 0.5 hours. After that, a resulting resin was taken out. The resin which had been taken out was cooled to room temperature and then pulverized into particles to obtain a polyamide resin (PA-1). The polyamide resin (PA-1) had a number-average molecular weight (Mn) of 600 and an acid value of 93.5 mg KOH/g.

[0181]

The following will provide Production Examples of polyesteramides.

[0182]

<Production Example 7>

[Preparation of polyesteramide (A-1)]

150 parts of xylene and 125.2 parts of a 20% aqueous solution of polyallylamine ("PAA-03" manufactured by Nittobo Medical Co., Ltd.; average molecular weight of approximately 3,000) were introduced into the same reaction tank as that described in Production Example 3 and heated up to 160°C. Water was distilled off with use of the water separation pipe. In this case, the xylene which had been separated from water was returned to the reaction solution. After that, a product obtained by heating 75.0 parts of the polyester resin (PE-1), which had been obtained in Production Example 1, up to 160°C was introduced, and a reaction was performed at 160°C for 2 hours. Next, the xylene was distilled off by heating at

160°C for 0.5 hours. After that, a resulting resin was taken out. The resin which had been taken out was cooled to room temperature and then pulverized into particles to obtain a polyesteramide resin (A-1). The polyesteramide resin (A-1) had a number-average molecular weight (Mn) of 10,800 and an acid value of 0.5 mg KOH/g.

[0183]

<Production Examples 8 to 18>

[Preparation of polyesteramides (A-2) to (A-12)]

The same operation as that described in Production Example 7 was performed in accordance with the formulations shown in Table 1 to produce polyesteramides (A-2) to (A-12). Note that, in Table 1, a polyester amount (part) means the amount of polyester introduced. However, polyallylamine PAA-01 in Table 1 indicates a 15% aqueous solution of polyallylamine ("PAA-01" manufactured by Nittobo Medical Co., Ltd.; average molecular weight of approximately 1,600), and polyallylamine PAA-15C in Table 1 indicates a 15% aqueous solution of polyallylamine ("PAA-15C" manufactured by Nittobo Medical Co., Ltd.; average molecular weight of approximately 15,000).

[0184]

[Table 1]

		Production Example					
		7	8	9	10	11	12
Polyesteramide (A)		A-1	A-2	A-3	A-4	A-5	A-6
Polyallylamine	Product name	PAA-03	PAA-03	PAA-03	PAA-03	PAA-03	PAA-03
	Average molecular weight	3000	3000	3000	3000	3000	3000
	Concentration of aqueous solution (wt%)	20	20	20	20	20	20
	Amount of aqueous solution of polyallylamine (part)	125.2	93.0	90.6	82.3	145.0	138.7
Polyester	Product name	PE-1	PE-1	PE-1	PE-1	PE-2	PE-2
	Number-average molecular weight	2600	2600	2600	2600	1000	1000
	Amount of polyester (part)	75.0	81.4	81.9	83.5	71.0	72.3
Polyesteramide	Acid value (mg KOH/g)	0.5	10.1	11.3	14.9	22.4	27.5
	Number-average molecular weight	10800	10500	10500	10200	6500	6400

(Continued)

		Production Example					
		13	14	15	16	17	18
Polyesteramide (A)		A-7	A-8	A-9	A-10	A-11	A-12
Polyallylamine	Product name	PAA-03	PAA-03	PAA-03	PAA-03	PAA-01	PAA-15C
	Average molecular weight	3000	3000	3000	3000	1600	15000
	Concentration of aqueous solution (wt%)	20	20	20	20	15	15
	Amount of aqueous solution of polyallylamine (part)	129.8	120.1	83.8	82.3	163.4	141.6
Polyester	Product name	PE-2	PE-2	PE-3	PE-4	PE-2	PE-5
	Number-average molecular weight	1000	1000	2550	2600	1000	6900
	Amount of polyester (part)	74.0	76.0	83.2	83.5	75.5	78.8
Polyesteramide	Acid value (mg KOH/g)	34.8	45.2	15.0	14.8	15.1	6.6
	Number-average molecular weight	6000	5800	10400	10500	4700	35000

<Production Example 19>

[Preparation of polyesteramide (A-13)]

150 parts of xylene, 42.6 parts of polyester resin (PE-2), 51.1 parts of polyamide resin (PA-1), 10.6 parts of 1,4-butanediol, and 0.1 parts of tetrabutyl titanate as a condensation catalyst were introduced into the same reaction tank as that described in Production Example 3 and heated up to 160°C over 4 hours in a nitrogen atmosphere. Next, the xylene was distilled off by heating at 160°C for 2 hours. After that, a resulting resin was taken out. The resin which had been taken out was cooled to room temperature and then pulverized into particles to obtain a polyesteramide (A-13). The polyesteramide (A-13) had a number-average molecular weight (Mn) of 9,350 and an acid value of 12.0 mg KOH/g.

[0185]

<Production Example 20>

[Preparation of polyesteramide (A-14)]

150 parts of xylene, 24.7 parts of hexamethylenediamine, 13.3 parts of ethylene glycol, 62.1 parts of adipic acid, and 0.1 parts of tetrabutyl titanate as a condensation catalyst were introduced into the same reaction tank as that described in Production Example 3 and heated up to 160°C over 4 hours in a nitrogen atmosphere. Next, the xylene was distilled off by heating at 160°C for 4 hours. After that, a resulting resin was taken out. The resin which had

been taken out was cooled to room temperature and then pulverized into particles to obtain a polyesteramide (A-14). The polyesteramide (A-14) had a number-average molecular weight (Mn) of 10,000 and an acid value of 11.2 mg KOH/g.

5 [0186]

The following will provide Production Examples of resin compositions and Comparative Production Examples thereof.

[0187]

10 The following will provide a description of various materials used in Production Examples of resin compositions and Comparative Production Examples thereof.

<Filler (B)>

15 B-1: carbon black (manufactured by Denka Company Limited; "DENKA BLACK"; primary particle size of 48 nm; DBP oil absorption amount of 177 cm³/100 g)

B-2: carbon black (manufactured by MTI Corporation; "Super C65"; primary particle size of 50 nm; DBP oil absorption amount of 254 cm³/100 g)

20 B-3: carbon nanotube (manufactured by Showa Denko K.K.; "VGCF-H")

B-4: silica (manufactured by Nissan Chemical Industries, Ltd.; "IPA-ST-ZL")

<Solvent (D)>

D-1: N-methyl-2-pyrrolidone

25 D-2: isopropyl alcohol

D-3: toluene

<Resin (P)>

P-1: butyral resin (manufactured by Sekisui Chemical Co., Ltd.; "S-LEC BM-1")

5 P-2: cellulose acetate (manufactured by FUJIFILM Wako Pure Chemical Corporation)

P-3: polymethyl methacrylate (manufactured by FUJIFILM Wako Pure Chemical Corporation)

10 P-4: polyvinyl chloride (manufactured by FUJIFILM Wako Pure Chemical Corporation)

P-5: fluorine resin (manufactured by Sigma-Aldrich; "Polyvinylidene fluoride")

<Dispersing agent (Q)>

15 Q-1: polyethylene glycol (number-average molecular weight of 3,400) (manufactured by Sanyo Chemical Industries, Ltd.; "PEG-4000S")

Q-2: long-chain aminoamide, phosphoric acid, and amine (active ingredient of 45%) (manufactured by Kusumoto Chemicals, Ltd.; "DISPARLON 1850")

20 Q-3: sodium deoxycholate (manufactured by Sigma-Aldrich)

Q-4: polyacrylic acid-based polymer (solid content of 40%) (manufactured by Toagosei Co., Ltd.; "SD-10")

<Resin composition 1>

25 The following components were measured out in the following amounts into a sample bottle to obtain a mixture.

[0188]

60 parts by weight of polyesteramide (A-1)

40 parts by weight of filler (B-1)

400 parts by weight of solvent (D-1)

5 A planetary centrifugal mixer (ARE-310 manufactured
by THINKY CORPORATION) was used to stir the mixture at
2,000 revolutions/minute for 20 minutes to obtain a slurry.
Thus, a resin composition 1 was obtained as the slurry.

[0189]

10 <Resin compositions 2 to 20>

The same operation as in the production of the resin
composition 1 was carried out in accordance with the
formulations shown in Tables 2 and 3 to obtain the resin
compositions 2 to 20.

15

[Table 2]

[illegible]

[Table 3]

[illegible]

<Comparative resin composition r1>

The following components were measured out in the following amounts into a sample bottle to obtain a mixture.

[0190]

5 60 parts by weight of dispersing agent (Q-1)

40 parts by weight of filler (B-1)

400 parts by weight of solvent (D-1)

A planetary centrifugal mixer (ARE-310 manufactured by THINKY CORPORATION) was used to stir the mixture at
10 2,000 revolutions/minute for 20 minutes to obtain a slurry.
Thus, a comparative resin composition r1 was obtained as the slurry.

<Comparative resin composition r2>

A comparative resin composition 2 was prepared as in
15 the case of the comparative resin composition r1 except that
133 parts of dispersing agent (Q-2) was used instead of 60
parts of dispersing agent (Q-1), and 327 parts of solvent (D-
1) was used instead of 400 parts of solvent (D-1).

<Comparative resin composition r3>

20 A comparative resin composition r3 was prepared as in
the case of the comparative resin composition r1 except that
the dispersing agent (Q-3) was used instead of the dispersing
agent (Q-1), and the filler (B-3) was used instead of the filler
(B-1).

25 <Comparative resin composition r4>

A comparative resin composition 4 was prepared as in the case of the comparative resin composition r1 except that 150 parts of dispersing agent (Q-4) was used instead of 60 parts of dispersing agent (Q-1), the filler (B-3) was used instead of the filler (B-1), and 310 parts of solvent (D-1) was used instead of 400 parts of solvent (D-1).

[0191]

The following will provide Examples of sensor elements and Comparative Examples thereof.

[0192]

<Manufacture of sensor substrate K-1>

[Manufacture of substrate]

Figs. 12 and 13 are each a schematic diagram for describing a method for manufacturing a sensor substrate K-1 used in Examples. In the present example, with use of a glass cloth-based epoxy resin copper-clad laminate FR-4.0 (manufactured by Panasonic Electric Works Co., Ltd.) having a length of 150 mm, a width of 100 mm, and a thickness of 1.0 mm, sensor substrates designed on the laminate were manufactured in 16 rows in the longitudinal direction and 16 columns in the lateral direction (256 sensor substrates in total) by the method described later, as illustrated in Figs. 12 and 13. At this time, a margin of 11 mm was left in each of upper and lower parts of the laminate, and a margin of 10 mm was left in each of left-side and right-side parts of the

laminate.

[0193]

[Design of wiring pattern]

Figs. 14 and 15 are each a view schematically illustrating a configuration of the sensor substrate K-1 used in Examples. Fig. 14 illustrates a front surface (a surface where the metal wire 313 and the odor substance receiving layer 315 are disposed in Fig. 10) of a sensor element (corresponding to the sensor element 31 in the embodiment), and Fig. 15 illustrates a back surface (a surface opposite to the front surface) of the sensor element. As illustrated in Fig. 12, designed on the foregoing laminate were a total of 256 wiring patterns each having a substrate size of a length of 8 mm and a width 5 mm, being shaped such that T-shaped electrodes illustrated in Fig. 9 faced each other, and having metal wires 313a and 313c each being 2.5 mm long and metal wires 313b and 313d each being 2 mm long, having an interval of 1.5 mm between the metal wires 313a and 313c, and having a width of 0.3 mm in each electrode. Further, as illustrated in Figs. 14 and 15, designed as portions for inserting pins, which are conductive members for providing electrical connection with the other members of the odor sensor were (i) circular conduction portions each having a diameter of 1 mm and being provided at the end portions of the first metal wire 313C and the second metal wire 313D facing away from each other and

(ii) circular conduction portions each having a diameter of 1 mm and being provided similarly at the same positions on the back surface.

[0194]

5 [Through hole creating step]

In order to mount pins (corresponding to the pins 316 in the embodiment) on each sensor substrate, through holes each having a copper plating layer with a thickness of 25 μm were created by boring holes for the through holes at the circular conduction portions each having a diameter of 1 mm using an NC drill machine, first applying electroless copper plating, and then applying copper sulfate plating.

[0195]

[Pattern forming step]

15 A photosensitive dry film resist (product name "Photec RD-3025"; film thickness of 25 μm ; manufactured by Showa Denko Materials Co., Ltd.) was attached onto both surfaces of a sensor substrate with use of a roll laminator (pressure of 0.4 MPa; temperature of 110°C; lamination speed of 0.4 m/min). After that, the photosensitive dry film resist side was irradiated with ultraviolet light (wavelength of 355 nm) at 85 mJ/cm² through a negative photomask for the front surface and a negative photomask for the back surface by an ultraviolet exposure machine, and the photosensitive dry film resist in an unexposed area was removed with use of a 5% by

20

25

weight aqueous solution of sodium carbonate of 35°C. After that, with use of an aqueous ferric chloride solution, the copper foil in a bare area after the removal of the photosensitive dry film resist was removed by etching, and the
5 photosensitive dry film resist in an exposed area was removed with use of a 10% by weight aqueous solution of sodium hydroxide of 35°C.

[0196]

For the negative photomask for the front surface used
10 in this case, a pattern was used in which designed sensor substrates were arranged in 16 rows, each measuring 8 mm, in the longitudinal direction and in 16 columns, each measuring 5 mm, in the lateral direction. For the negative photomask for the back surface, a pattern was used in which
15 circular parts with a diameter of 1 mm were arranged at positions coinciding with circular parts of the negative photomask for the front surface.

[0197]

[Solder resist step]

20 Two-component alkali development type solder resist ink (manufactured by Taiyo Ink Mfg. Co., Ltd.; product name "PSR-4000 AUS320/CA-40 AUS320") was pattern-printed on the front surface side except for the copper foil portion, the through hole portion, and the strip-shaped odor substance
25 receiving layer 315d portion (portion indicated by diagonal

lines in Fig. 14) and pattern-printed on the back surface side except for the copper foil portion and the through hole portion, and temporarily dried by heating at 80°C for 30 minutes. Then, irradiation with ultraviolet light (wavelength
5 of 355 nm) at 600 mJ/cm² was carried out, and an unexposed area was removed with use of a 1% by weight aqueous solution of sodium carbonate of 35°C. After that, by heating at 150°C for 60 minutes, the solder resist ink was hardened.

[0198]

10 [Surface treatment step]

The sensor substrate was degreased, soft-etched, acid-washed, and immersed in a catalyst application solution (manufactured by Okuno Chemical Industries Co., Ltd.; product name "ICP Accera COA") at 25°C for 5 minutes. After
15 that, the sensor substrate was washed with water, immersed in an electroless Ni plating solution of 90°C (made up of 100 ml of product name "Top Nicoron SA-98-MLF" and 55 ml of product name "Top Nicoron SA-98-1LF" both manufactured by Okuno Chemical Industries Co., Ltd.) for 6 minutes to form a
20 Ni coating with a thickness of 3 μm, and then washed with pure water.

[0199]

Next, the sensor substrate was immersed in a displacement type gold plating solution (manufactured by
25 Kojima Chemicals Co., Ltd.; product name "OL 2300") at 85°C

for 5 minutes to form a displacement gold coating with a thickness of 0.05 μm on the Ni coating, and a substrate was obtained in which the copper foil portion was covered with nickel and gold plating.

5 [0200]

[V-cutting of substrate]

With use of a V-cutting machine, V-cutting was performed for each sensor substrate in size of 8 mm long and 5 mm wide so that each sensor substrate could be separated.

10 [0201]

[Mounting of pins]

IC terminals (manufactured by Mac Eight Co., Ltd.; product name "Terminal for Hybrid IC"; $\phi 0.6$ mm; length of 5 mm) were soldered to the through holes that had been created.

15 In this way, a total of 256 sensor substrates K-1 illustrated in Figs. 14 and 15 were produced.

[0202]

[Manufacture of sensor substrate K-2]

20 A seal substrate including a set of two metal wires was cut from a seal substrate (ICB-073; manufactured by Sunhayato Corp.) including a plurality of metal wires having a pitch of 500 μm . The cut seal substrate was further cut so that the metal wires had a length of 3.5 cm.

[0203]

25 The cut seal substrate was attached with a double-sided

tape to a glass plate so that the metal wires were on an upper side. Further, an excess part of the metal wires was masked with a vinyl tape so that an exposed part of the metal wires had a length of 3.0 cm.

5 [0204]

In this way, the sensor substrate K-2 was produced.

[0205]

<Sensor element>

10 With use of IMAGE MASTER 350PC Smart
(manufactured by Musashi Engineering, Inc.) equipped with a
SUS metal needle nozzle (inner diameter of $\Phi 0.1$ mm; outer
dimension of 0.23 mm), each of the resin compositions 1 to 19
was dripped onto the produced sensor substrate K-1 to apply
each of the resin compositions 1 to 19 to the area where the
15 metal wires were provided. The application was followed by
drying for 3 hours with use of a circulation dryer heated to
100°C. The drying was followed by cooling to room
temperature to produce sensor elements (E1-1) to (E1-19).
Note that the same operation was repeated 10 times in total
20 to produce 10 pieces for each sensor element. For the resin
composition 4, the same operation was further repeated 50
times.

[0206]

25 19 parts of (D-2) and 1 part of (P-1) were introduced
into a vessel equipped with a stirrer, and a resulting mixture

was stirred to dissolve (P-1). With use of the above-described application device, the produced solution of (P-1) was applied onto the part where the resin composition 4 had been applied in the sensor element that had undergone application of the resin composition 4 and drying. The application was followed by drying for 1 hour with use of a circulation dryer heated to 100°C. The drying was followed by cooling to room temperature to produce a sensor element (E1-20). The same operation was repeated 10 times in total to produce 10 pieces.

[0207]

Ten sensor elements (E1-21) were produced by carrying out the same operation except that (D-1) was introduced instead of (D-2), and (P-2) was introduced instead of (P-1).

[0208]

Ten sensor elements (E1-22) were produced by carrying out the same operation except that (D-3) was introduced instead of (D-2), and (P-3) was introduced instead of (P-1).

[0209]

Ten sensor elements (E1-23) were produced by carrying out the same operation except that (D-1) was introduced instead of (D-2), and (P-4) was introduced instead of (P-1).

[0210]

Ten sensor elements (E1-24) were produced by carrying out the same operation except that (D-1) was introduced instead of (D-2), and (P-5) was introduced instead of (P-1).

[0211]

In the produced sensor substrate K-2, each of the resin compositions 4, 5, 20, and 21 was applied to the exposed part of the metal wires with use of a bar coater (No. 4). The application was followed by drying for 3 hours with use of a circulation dryer heated to 100°C. The drying was followed by cooling to room temperature, and then the metal wires including an odor substance receiving layer 315 were separated from the glass plate to produce sensor elements (E2-1) to (E2-4). Note that the same operation was repeated 10 times to produce 10 pieces for each sensor element.

[0212]

<Construction of odor sensors 1 to 12>

Produced was a housing including (i) a target sample receiving section that includes an inlet through which a specimen (odor substance) is to be introduced and an aluminum block thermostatic tank for temperature adjustment and (ii) a nitrogen gas cylinder for gas supply, a mass flow controller, and a sensor chamber. At this time, the volume of the target sample receiving section was designed to be 5 times the volume of the sensor chamber.

[0213]

A lead wire for taking out a terminal of a sensor to the outside of the sensor chamber was soldered onto each of ten sensor elements (E1-1), and the ten sensor elements (E1-1)

were placed in the sensor chamber. For each of the sensor elements (E1-1), a constant voltage power source of 5 V and a fixed resistor of 300 Ω were connected in series to an end of the lead wire taken out outside the sensor chamber, and a
5 voltmeter for measuring a voltage applied to both terminals of the sensor element was connected to the end of the lead wire taken out to the outside of the sensor chamber. Thus, an odor sensor 1 having the ten sensor elements (E1-1) was configured.

10 [0214]

Odor sensors 2 to 26 and c1 and c8 were configured as in the case of the odor sensor 1 except that sensor elements (E1-2) to (E1-24) and (E2-1) to (E2-2) and comparative sensor elements (E'1-1) to (E'1-4) and (E'2-1) to (E'2-4) were used
15 instead of the sensor element (E1-1).

[0215]

Odor sensors 27, 29, and c9 were constructed as in the case of the odor sensor 1 except that sensor elements (E2-3), (E2-4), and (E'2-5) were used instead of the sensor element
20 (E1-1), a membrane-type surface stress sensor (MSS) system was further used, an SD-MSS sensor probe (manufactured by NIMS) was used, and an electromotive force from a sensor element was amplified by an amplifier to acquire an output voltage.

25 [0216]

Odor sensors 28, 30, and c10 were constructed as in the case of the odor sensor 1 except that the sensor elements (E2-3), (E2-4), and (E'2-5) were used instead of the sensor element (E1-1), a quartz crystal microbalance (QCM) system was used, a QA-A9M-AU (manufactured by SEIKO EG&G CO., LTD.) was used, and a resonance frequency was measured by a frequency counter to acquire a frequency change.

[0217]

[Evaluation]

<Measurements of voltage change amount (ΔV) and ΔV variation coefficient>

For each of the odor sensors 1 to 30 and c1 to c10, 5 ml of ethanol as a specimen was poured into a target sample receiving section. Thereafter, the gas flow regulator was used to allow nitrogen as a carrier gas to flow at a flow rate of 1 L/min from the carrier gas introducing part into the chamber in which the sensor elements were provided, so that the nitrogen was discharged outside. During this period, a measured value of the voltmeter connected to each of the sensor elements was recorded by a computer. Thus, a voltage value of each of the ten sensor elements of each of the odor sensors was measured. For each of the sensor elements of each of the odor sensors, a maximum value ΔV of a difference between an output voltage V_0 before introduction of the specimen and a voltage V after introduction of the specimen

was calculated. Then, a standard deviation σ and an average value μ of data of ten maximum values ΔV obtained in each of the odor sensors were calculated to determine a ΔV variation coefficient ($=\sigma/\mu$) of a resin composition forming the sensor elements. For the odor sensors 27, 29, and c9, V0 and V were obtained for output power obtained from MSS sensor elements. For the odor sensors 28, 30, and c10, F0 and F were obtained for frequencies obtained from QCM sensor elements, and calculation was carried out for each of F0 and F as in the case of obtainment of V0 and V to obtain an average value and a variation coefficient.

[0218]

Tables 4 to 6 show makeups and sensor evaluation results of resin compositions of the odor sensors 1 to 30 of Examples 1 to 30 and the odor sensors c1 to c10 of Comparative Examples 1 to 10.

[Table 4]

	Odor sensor No.	Sensor system	Sensor element No.	Substrate type	Resin composition No.	Polyesteramide (A)	
						Type	Acid value (mg KOH/g)
Example 1	1	Resistance type	E1-1	K-1	1	A-1	0.5
Example 2	2	Resistance type	E1-2	K-1	2	A-2	10.1
Example 3	3	Resistance type	E1-3	K-1	3	A-3	11.3
Example 4	4	Resistance type	E1-4	K-1	4	A-4	14.9
Example 5	5	Resistance type	E1-5	K-1	5	A-5	22.4
Example 6	6	Resistance type	E1-6	K-1	6	A-6	27.5
Example 7	7	Resistance type	E1-7	K-1	7	A-7	34.8
Example 8	8	Resistance type	E1-8	K-1	8	A-8	45.2
Example 9	9	Resistance type	E1-9	K-1	9	A-9	15.0
Example 10	10	Resistance type	E1-10	K-1	10	A-10	14.8
Example 11	11	Resistance type	E1-11	K-1	11	A-11	15.1
Example 12	12	Resistance type	E1-12	K-1	12	A-12	6.6
Example 13	13	Resistance type	E1-13	K-1	13	A-13	12.0
Example 14	14	Resistance type	E1-14	K-1	14	A-14	11.2
Example 15	15	Resistance type	E1-15	K-1	15	A-4	14.9
Example 16	16	Resistance type	E1-16	K-1	16	A-4	14.9
Example 17	17	Resistance type	E1-17	K-1	17	A-4	14.9
Example18	18	Resistance type	E1-18	K-1	18	A-4	14.9
Example19	19	Resistance type	E1-19	K-1	19	A-4	14.9

(Continued)

	Filler (B)	Weight ratio	Sensor structure	Resin (P)	ΔV	
		(A):(B)			Average value (V)	Variation coefficient
Example 1	B-1	60:40	Single layer	—	1.1	0.15
Example 2	B-1	60:40	Single layer	—	1.22	0.1
Example 3	B-1	60:40	Single layer	—	1.32	0.07
Example 4	B-1	60:40	Single layer	—	1.47	0.03
Example 5	B-1	60:40	Single layer	—	1.48	0.03
Example 6	B-1	60:40	Single layer	—	1.35	0.05
Example 7	B-1	60:40	Single layer	—	1.23	0.09
Example 8	B-1	60:40	Single layer	—	1.08	0.15
Example 9	B-1	60:40	Single layer	—	1.33	0.07
Example 10	B-1	60:40	Single layer	—	1.26	0.08
Example 11	B-1	60:40	Single layer	—	1.39	0.06
Example 12	B-1	60:40	Single layer	—	1.37	0.08
Example 13	B-1	60:40	Single layer	—	0.92	0.17
Example 14	B-1	60:40	Single layer	—	0.78	0.18
Example 15	B-1	75:25	Single layer	—	1.44	0.08
Example 16	B-1	85:15	Single layer	—	1.46	0.12
Example 17	B-1	93:7	Single layer	—	1.47	0.18
Example18	B-2	60:40	Single layer	—	1.44	0.03
Example19	B-3	70:30	Single layer	—	1.44	0.09

[Table 5]

	Odor sensor No.	Sensor system	Sensor element No.	Substrate type	Resin composition No.	Polyesteramide (A)	
						Type	Acid value (mg KOH/g)
Example 20	20	Resistance type	E1-20	K-1	4	A-4	14.9
Example 21	21	Resistance type	E1-21	K-1	4	A-4	14.9
Example 22	22	Resistance type	E1-22	K-1	4	A-4	14.9
Example 23	23	Resistance type	E1-23	K-1	4	A-4	14.9
Example 24	24	Resistance type	E1-24	K-1	4	A-4	14.9
Example 25	25	Resistance type	E2-1	K-2	4	A-4	14.9
Example 26	26	Resistance type	E2-2	K-2	5	A-5	22.4
Example 27	27	MSS	E2-3	K-2	20	A-4	14.9
Example 28	28	QCM	E2-3	K-2	20	A-4	14.9
Example 29	29	MSS	E2-4	K-2	21	A-4	14.9
Example 30	30	QCM	E2-4	K-2	21	A-4	14.9

(Continued)

	Filler (B)	Weight ratio	Sensor structure	Resin (P)	ΔV	
		(A):(B)			Average value (V)	Variation coefficient
Example 20	B-1	60:40	Two layers	P-1	1.46	0.03
Example 21	B-1	60:40	Two layers	P-2	1.42	0.04
Example 22	B-1	60:40	Two layers	P-3	1.41	0.03
Example 23	B-1	60:40	Two layers	P-4	1.41	0.04
Example 24	B-1	60:40	Two layers	P-5	1.4	0.04
Example 25	B-1	60:40	Single layer	—	1.46	0.03
Example 26	B-1	60:40	Single layer	—	1.47	0.04
Example 27	B-4	70:30	Single layer	—	0.75	0.18
Example 28	B-4	70:30	Single layer	—	210 Hz	0.19
Example 29	B-4	80:20	Single layer	—	0.77	0.19
Example 30	B-4	80:20	Single layer	—	240 Hz	0.2

[Table 6]

	Odor sensor No.	Sensor system	Sensor element No.	Substrate type	Resin composition No.	Polyesteramide (A)	
						Type	Acid value (mg KOH/g)
Comparative Example 1	c1	Resistance type	E'1-1	K-1	r1	—	—
Comparative Example 2	c2	Resistance type	E'1-2	K-1	r2	—	—
Comparative Example 3	c3	Resistance type	E'1-3	K-1	r3	—	—
Comparative Example 4	c4	Resistance type	E'1-4	K-1	r4	A-4	14.9
Comparative Example 5	c5	Resistance type	E'2-1	K-2	r1	—	—
Comparative Example 6	c6	Resistance type	E'2-2	K-2	r2	—	—
Comparative Example 7	c7	Resistance type	E'2-3	K-2	r3	—	—
Comparative Example 8	c8	Resistance type	E'2-4	K-2	r4	A-4	14.9
Comparative Example 9	c9	MSS	E'2-5	K-2	r5	—	—
Comparative Example 10	c10	QCM	E'2-5	K-2	r5	—	—

(Continued)

	Dispersing agent (Q)	Filler (B)	Weight ratio (A):(B)	ΔV	
				Average value (V)	Variation coefficient
Comparative Example 1	Q-1	B-1	60:40	0.03	0.35
Comparative Example 2	Q-2	B-1	60:40	0.04	0.28
Comparative Example 3	Q-3	B-3	70:30	0.05	0.3
Comparative Example 4	—	—	—	0.01	0.44
Comparative Example 5	Q-1	B-1	60:40	0.05	0.36
Comparative Example 6	Q-2	B-1	60:40	0.05	0.29
Comparative Example 7	Q-3	B-3	70:30	0.06	0.3
Comparative Example 8	—	—	—	0.01	0.45
Comparative Example 9	Q-4	B-4	70:30	0.12	0.45
Comparative Example 10	Q-4	B-4	70:30	10 Hz	0.44

In Tables 4 to 6, the average value of ΔV is preferably higher from the viewpoint of the sensitivity of the odor sensor. On the other hand, the ΔV variation coefficient is preferably lower from the viewpoint of reducing the variation.

5 [0219]

<Consideration>

As shown in Tables 4 and 5, the odor sensors 1 to 30 each exhibit a higher average value of ΔV and a lower ΔV variation coefficient than the odor sensors c1 to c10, which are Comparative Examples.

10 [0220]

A comparison between (a) Examples 1 to 30 and (b) Comparative Examples 1 to 3, 5 to 7, 9, and 10 has shown that the odor sensors c1 to c3, c5 to c7, c9, and c10, which include any of the resin composition r1 to r3 and r5 not containing the polyesteramide, have a low average value of ΔV and a high ΔV variation coefficient.

15 [0221]

A comparison between Examples 1 to 30 and Comparative Examples 4 and 8 has shown that the odor sensors c4 and c8, which include the resin composition r4 not containing the filler, have a low average value of ΔV and a high ΔV variation coefficient.

[0222]

25 According to a comparison among Examples 1 to 8, an

average value of ΔV and a ΔV variation coefficient that have no practical problem are obtained regardless of the acid value of the polyesteramide (A). In particular, the odor sensors 4 and 5, which include the polyesteramides having an acid value of 14.9 and 22.4, respectively, and the fillers that is an electrically conductive carbon material at a weight ratio of 60:40, had a high average value of ΔV and the lowest value of the ΔV variation coefficient.

[0223]

According to a comparison between Example 4 and Examples 13 and 14, an average value of ΔV and a ΔV variation coefficient that have no practical problem are obtained regardless of the molecular structure of the polyesteramide (A). In particular, the odor sensor 4, which includes the polyesteramide (A-4) that is a resin having a structure in which the polyesteramide (A-4) has polyallylamine in a main chain thereof and has a polyester chain in a side chain thereof, had the highest average value of ΔV and the lowest value of the ΔV variation coefficient.

[0224]

According to a comparison among Examples 25 to 30, a ΔV variation coefficient that has no practical problem is obtained even in cases differing in sensor system.

[0225]

According to a comparison between Example 4 and

Examples 18 and 19, an average value of ΔV and a ΔV variation coefficient that have no practical problem are obtained even in cases differing in type of the filler (B).

[0226]

5 According to a comparison between Example 4 and Examples 15 to 17, an average value of ΔV and a ΔV variation coefficient that have no practical problem are obtained even in cases differing in weight ratio of the polyesteramide (A) and the filler (B). In particular, the odor sensor 4, which includes
10 the resin composition 4 of (A):(B)=60:40, had the highest average value of ΔV and the lowest value of the ΔV variation coefficient.

[0227]

15 Thus, an odor sensor that includes an odor substance receiving layer which includes a resin composition containing the polyesteramide (A) and the filler (B) has been found to exhibit an average value of ΔV and a ΔV variation coefficient that have no practical problem. That is, an odor measuring device including such an odor sensor has high detection
20 sensitivity to an odor and is capable of outputting a stable measurement result, and thus can be said to have high odor identification performance.

Industrial Applicability

25 [0228]

The present invention is useful as an odor identification sensor for medical use, for gas detection, for agricultural use, and for other uses in industry and life. For example, farmers can use an odor sensor to determine a state of maturation of scented crops to manage optimal harvesting timing. Further, an odor sensor can be used to convert an odor of a product such as food or cosmetics into data so as to support improvement in efficiency of product development and quality stabilization.

Reference Signs List

[0229]

10, 10a: estimation device

11: measured value acquiring section (acquisition section)

12: change pattern analyzing section (analysis section)

16: estimation section

30: odor sensor

31A: a plurality of sensor elements (sensor element group)

31, 31b, 31c: sensor element

32, 32b: constant voltage power source (power source)

33, 33b: voltmeter (measuring instrument)

100, 100a: odor measuring device

313A, 313C: first metal wire

313B, 313D: second metal wire

315, 315c, 315d: odor substance receiving layer

50: target sample receiving section

51: adjustment section

60: sensor chamber

80: gas supply section

5 91, 92, 93, 94: pipe

501: first port

502: second port

503: sample inlet

Claims

[Claim 1]

5 An odor substance receiving layer comprising a resin composition that contains a polyesteramide (A) and a filler (B).

[Claim 2]

10 The odor substance receiving layer according to claim 1, wherein the polyesteramide (A) has an acid value of 0.3 mg KOH/g to 50.0 mg KOH/g.

[Claim 3]

15 The odor substance receiving layer according to claim 1 or 2, wherein the filler (B) is an electrically conductive carbon material.

[Claim 4]

20 The odor substance receiving layer according to claim 3, wherein the filler has a fibrous or particulate shape.

[Claim 5]

25 The odor substance receiving layer according to any one of claims 1 to 4, wherein the polyesteramide (A) is a resin having a structure in which the polyesteramide (A) has polyallylamine in a main chain thereof and has a polyester

chain in a side chain thereof.

[Claim 6]

5 The odor substance receiving layer according to any one of claims 1 to 5, wherein the polyesteramide (A) has a number-average molecular weight of 600 to 50000.

[Claim 7]

10 The odor substance receiving layer according to any one of claims 1 to 6, wherein the filler (B) is contained in an amount of 5% by weight to 50% by weight, where 100% by weight represents a total amount of the polyesteramide (A) and the filler (B).

15 [Claim 8]

A sensor element comprising: the odor substance receiving layer recited in any one of claims 1 to 7; a first metal wire; and a second metal wire, wherein

20 the first metal wire and the second metal wire are spaced apart from each other, and

the odor substance receiving layer is in contact with at least part of the first metal wire and at least part of the second metal wire.

[Claim 9]

An odor sensor comprising:

the at least one sensor element recited in claim 8;

a power source for supplying electric power to the
5 sensor element; and

a measuring instrument that outputs a measured value
indicating electrical conductivity of the odor substance
receiving layer of the sensor element to which the electric
power is supplied by the power source.

10

[Claim 10]

The odor sensor according to claim 9, wherein the power
source supplies a constant current or applies a constant
voltage to the at least one sensor element.

15

[Claim 11]

An odor measuring device comprising the odor sensor
recited in claim 10 and an estimation device,

the estimation device comprising:

20 an acquisition section that acquires a measured value
from a measuring instrument;

an analysis section that analyzes a change over time in
electrical conductivity of at least one sensor element; and

25 an estimation section that estimates an odor substance
on a basis of an estimation model,

the estimation model being generated by machine learning using learning data including a combination of (i) a measured value that is measured by the measuring instrument in a case where each of a plurality of odor substances is adsorbed on the at least one sensor element and (ii) identification information specific to an odor substance to which the measured value has been given.

[Claim 12]

A non-transitory computer-readable storage medium storing instructions executable by a computer, wherein execution of the instructions by the computer realizes:

(1) an acquiring step of acquiring a measured value which is output from a measuring instrument, the measured value indicating electrical conductivity of the odor substance receiving layer of the at least one sensor element recited in claim 8 to which electric power is supplied:

(2) an analyzing step of analyzing a change over time in electrical conductivity of the at least one sensor element; and

(3) an estimating step of estimating an odor substance on a basis of an estimation model,

the estimation model being generated by machine learning using learning data including a combination of (i) a measured value that is measured by the measuring instrument in a case where each of a plurality of odor

substances is adsorbed on the at least one sensor element and
(ii) identification information specific to an odor substance to
which the measured value has been given.