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"HUMIDITY SENSOR"

The present invention relates to a humidity sensor.

Areas in which humidity measurement and humidity control are required have recently been increasing and the importance of a humidity sensor has been recognized.

There are various humidity sensors for detecting humidity as a result of a change in the electrical characteristic of an element in consequence of a change in the humidity of the environment around the sensor. Thus there are, for example, electrolytic, metallic, polymeric and ceramic humidity sensors, and all these humidity sensors have been closely studied. Among these sensors, polymeric humidity sensors and ceramic humidity sensors have been put to practical use. Each of these sensors utilizes the fact that the resistance or electrostatic capacity of an element changes when the element absorbs or desorbs moisture. A humidity sensor for detecting humidity by a change in the resistance of an element which corresponds to the humidity of the environment is called a resistance-change type humidity sensor and a humidity sensor for detecting humidity by a change in the electrostatic capacity of an element which corresponds to the humidity of the environment is called a capacitance-change type humidity sensor.

Many of the prior resistance-change type humidity sensors have such a high resistance at a low humidity that it is impossible to measure a low humidity with high accuracy. In order to obtain a humidity sensor

which is capable of measuring such a high resistance with high accuracy, special circuitry and a special mounting technique is required, which has the disadvantage of involving a high manufacturing cost. In a general resistance-change type humidity sensor, the logarithm of the resistance changes linearly with respect to a change in relative humidity. If the linearity is good, a logarithmic amplifier is capable of compensating the linearity. In a prior humidity sensor, however, the linearity is bad and in order to produce a highly accurate hygrometer, a complicated linearity compensation circuit is required. It is often said that in a resistance-change type humidity sensor, the larger the rate of change in the resistance between a low humidity and a high humidity, the higher the sensitivity. However, when a hygrometer is produced, since it is difficult to achieve the dynamic range of a measuring circuit if the rate of change in the resistance between a low humidity and a high humidity is too large, the desirable rate of change in the resistance at a relative humidity of 0 to 100% is about one to three figures. In a prior humidity sensor, however, the rate of change is large, and in order to produce a highly accurate hygrometer, special circuitry and a special mounting technique is required. In a capacitance-change type humidity sensor, the linearity of a change in electrostatic capacity with respect to relative humidity is bad, and in order to produce a highly accurate hygrometer, a complicated linearity compensation circuit is required. Many capacitance-change type humidity sensors have a poor stability at a high humidity, so that it is impossible to measure a high humidity with high accuracy.

In a prior humidity sensor, the temperature

dependence of the moisture sensitivity is so large that a temperature compensation circuit is required. If the temperature dependence of the moisture sensitivity is represented by a simple function, the temperature compensation circuit is not so complicated. In a prior humidity sensor, however, the temperature dependence of the moisture sensitivity is not represented by a simple function and a complicated temperature compensation circuit is therefore required in order to produce a highly accurate hygrometer. However complicated the temperature compensation circuit may be, complete temperature compensation is impossible in a place at which the change in temperature is large due to a difference in thermal response between the humidity sensor and the temperature sensor or a difference in the locations of the humidity sensor and the temperature sensor. That is, so long as there is a temperature dependence of the moisture sensitivity of a humidity sensor, accurate humidity measurement is impossible.

As described above, in the prior art, in order to produce a highly accurate hygrometer, special circuitry and a special mounting technique is required, and since high skill and a long time are also required for inspection and control of the humidity sensor, a prior humidity sensor cannot be easily produced, resulting in an expensive humidity sensor. In addition, the electric power used for the circuit is so large that it is impossible to produce a long-life humidity sensor driven by a battery.

In many polymeric humidity sensors, the reliability deteriorates at a high temperature and a high humidity. The deterioration is particularly marked with respect to an organic solvent. Some ceramic humidity sensors are provided with heating means for

restoring the properties of the sensor by heating it several hundred degrees (about 300 to 800°C) every predetermined period. The heating means can reduce a change in the characteristics with time, but such a humidity sensor cannot be used in an environment in which a combustible gas or dust exists because when the sensor is heated to a high temperature, there is a danger of an explosion or a fire. In this way, it is no exaggeration to say that there is no humidity sensor having satisfactory properties in the present state of the art.

According to the present invention, there is therefore provided a humidity sensor comprising a support of insulating material; electrodes provided on said support; and a porous silica film with carbon particles dispersed therein which is provided on the support so as to be provided about at least a portion of the electrodes.

A further silica film may, if desired, be provided on the said porous silica film.

The support may be constituted by an insulating substrate.

Alternatively, the support may comprise an insulating substrate having a support film of silica thereon, the electrodes and the porous silica film being mounted directly on the support film.

The insulating substrate may be made of alumina, glass or a refractory brick.

The electrodes may comprise a pair of comb electrodes.

The electrodes may be made,at least in part, of Au, Ag, Pt, Pd, Cr, or an alloy thereof.

Alternatively, the electrodes may be made of RuO_2.

The electrodes may have multi-layered lead

portions for connection to lead wires. Thus at least one layer of each lead portion may be formed from Au, Ag, Pt, Pd, Cr or an alloy thereof, the remaining part of each electrode being made of Cr.

The present invention enables the production of a humidity sensor having high accuracy and high reliability which is capable of measuring humidity in a wide range with high accuracy and the characteristics of which do not deteriorate even in a severe environment.

As the insulating substrate, an alumina substrate, a glass substrate and a refractory brick substrate are preferable from the point of view of reliability and mass productivity. In the case of using a glass substrate, a silica glass substrate may be used when particularly high reliability is required.

The pair of electrodes are preferably comb electrodes each of which is designed as if to have teeth of a comb in order to reduce the resistance of the humidity sensor. As indicated above, the material of each electrode is preferably a metal selected from the group consisting of Au, Ag, Pt, Pd and Cr, an alloy containing at least one element selected therefrom, or RuO_2. In order to improve the adhesions between the insulating substrate, or the silica support film provided on the insulating substrate, and the electrodes, a multi-layered electrode may be provided by, for example, forming a Cr electrode on the insulating substrate or the silica support film, and then forming an Au electrode on the Cr electrode.

In the pair of electrodes, if a comb electrode of Cr is used at least for the portion at which the porous silica film with carbon particles dispersed therein is formed, it is possible to improve the adhesion between each electrode and the porous silica film with carbon

particles dispersed therein, and if a multi-layered electrode produced by providing at least one layer of an electrode of a metal selected from the group consisting of Au, Ag, Pt, Pd and Cr or an alloy containing at least one element selected therefrom on a Cr electrode is used at the portion to which a lead wire is connected, the connection of the lead wire is facilitated and the reliability is improved.

A humidity sensor of the present invention enables the conductivity to freely vary by varying the content of the carbon particles dispersed in the porous silica film or the thickness of the porous film. The linearity of a change in resistance with respect to a change in relative humidity therefore becomes good, and since it is easy to measure a low humidity which raises the resistance of the humidity sensor, it is possible to measure humidity in a wide range with high accuracy. Although the relationship between the relative humidity and the logarithm of the resistance is linear in a prior resistance-change type humidity sensor, in the case of the present invention it is also possible to produce a humidity sensor having a linear relationship between the relative humidity and the resistance by controlling the content of the carbon particles and the thickness of the porous silica film containing carbon particles, thereby dispensing with a logarithmic amplifier. In addition, since the temperature dependence of the moisture sensitivity is low, a temperature compensation circuit may be dispensed with. Since the carbon particles and the silica film are chemically stable, the characteristics of the humidity sensor do not deteriorate even in a severe environment. Thus, a humidity sensor of the present invention is usable as a high-accuracy and high-reliability humidity sensor.

The content of the carbon particles in the porous silica film, as indicated above, may be 10 to 50 wt% and is preferably 15 to 45 wt%. If it is less than 10 wt%, the resistance becomes very high. On the other hand, if it exceeds 50 wt% the sensitivity becomes very low.

The thickness of the porous silica film with carbon particles dispersed therein, as indicated above, may be 1 to 300 μm, and is preferably 5 to 250 μm. If it is less than 1 μm, the resistance becomes very high. On the other hand, if it exceeds 300 μm, the sensitivity becomes very low.

The silica support film formed on the insulating substrate serves to improve the adhesion between the insulating substrate and the porous silica film with carbon particles dispersed therein. The further silica film formed on the porous silica film with carbon particles dispersed therein functions as a protective film for the porous silica film with carbon particles dispersed therein, thereby enhancing the mechanical strength of the porous silica film with carbon particles dispersed therein and improving the durability and the reliability of the humidity sensor.

The porous silica film with carbon particles dispersed therein is easily produced by forming, as indicated above, a silica sol with carbon particles dispersed therein into a film and by heat treating the thus-obtained film. The silica sol with carbon particles dispersed therein is easily produced by dispersing, as indicated above, silica particles and carbon particles in a hydrolyzed solution of a silicon alkoxide. It is therefore easy to control the content of the carbon particles dispersed in the porous silica film by the amount of carbon particles dispersed in the silica sol.

The silica support film is easily produced by forming, as indicated above, a silica sol into a film and heat treating the thus-obtained film. The silica sol is easily produced by dispersing silica particles in a hydrolyzed solution of a silicon alkoxide.

The silica particles and the carbon particles may be dispersed either before or after the hydrolysis of the silicon alkoxide.

Preferably, a method of synthesizing a ceramic material from a liquid phase of a metal alkoxide as used in the present invention is called a sol gel method and can produce a ceramic material at a lower temperature than a conventional method and, in addition, can produce a ceramic composite which is impossible by a conventional method. In the case of the present invention, it is possible to produce a silica film or a porous silica film with carbon particles dispersed therein at a temperature not higher than 500°C, which is much lower than in a conventional method of producing a ceramic material. Accordingly, the manufacturing cost is reduced, thereby enabling the manufacture of a cheap humidity sensor. In addition, the production of a composite of silica and carbon which is difficult in a conventional method is facilitated.

When the above-described sol is formed into a film, a method such as dip coating, spin coating, roll coating and screen printing may be adopted in accordance with the viscosity of the sol and the necessary film thickness.

As described above, since it is easy to manufacture a humidity sensor of the present invention, the mass productivity is good, and since the raw materials are cheap and the manufacturing cost is low, it is possible to manufacture a cheap humidity

sensor.

Thus, it is possible to manufacture a humidity sensor having a high accuracy and a high reliability at a low cost with good mass productivity.

The invention is illustrated, merely by way of example in the accompanying drawings, in which:-

Figures 1, 4, 10 and 14 are sectional views of embodiments of a humidity sensor according to the present invention;

Figure 1a is a perspective view of the humidity sensor shown in Figure 1 with a porous silica film thereof removed;

Figure 1b is a view similar to Figure 1a but showing the porous silica film in position;

Figures 2, 5, 7, 8, 9, 11, 12, 13 and 15 show characteristic curves of the moisture sensitivity of the embodiments of humidity sensor according to the present invention; and

Figures 3 and 6 show the response curves of embodiments of a humidity sensor according to the present invention.

The invention is illustrated by the following Examples.

Example 1

A pair of comb electrodes 3 (Figures 1,1a,1b) were provided on an insulating substrate 1 of alumina by sputtering Cr on the substrate 1. Layers 3a, 3b, 3c of Au, NiCr and Au respectively were then sputtered ~~in that order~~ on the comb electrodes 3 at the portions thereof 6 to which lead wires (not shown) were connected. That is, the comb portions of the electrodes 3 are composed only of Cr, while the four-layered portions of the electrodes 3 composed of Cr, Au, NiCr and Au in that order were located at the portions 6 to which lead wires were

connected. A porous silica film 4 having carbon particles dispersed therein was formed on the substrate 1 so as to be provided about a portion of the electrodes 3 whilst not surrounding the portions 6.

The porous silica film 4 was produced as follows. Tetraethoxysilane ($Si(OC_2H_5)_4$) was hydrolyzed by adding 25 mℓ of ethanol and 4 mℓ of 0.02 N hydrochloric acid to 50 mℓ of tetraethoxysilane and by stirring the mixture for 1 hour. 10 mℓ of glycerin and 13.5 g of fine silica powder were added to the hydrolyzed mixture and the resultant mixture was stirred for 30 minutes. 5.4 g of activated carbon and 2.7 g of carbon black were then further added thereto and the mixture was stirred for 30 minutes to produce a silica sol with carbon particles dispersed therein. The alumina substrate 1 with the electrodes 3 provided thereon was dip coated with the silica sol, dried at 100°C for 10 minutes and sintered at 430°C for 30 minutes, thereby forming the porous silica film 4 with carbon particles dispersed therein. The content of the carbon particles in the porous silica film 4 was 23 wt% and the thickness of the porous silica film 4 was 15 μm.

The thus-obtained humidity sensor is shown in the sectional view in Figure 1. The moisture sensitivity of the humidity sensor of Figure 1 is shown in the graph of Figure 2 in which the abscissa represents relative humidity and the ordinate represents resistance (in ohms) on a logarithmic scale.

From Figure 2, it is clear that the linearity of the logarithm of resistance with respect to relative humidity is good, and that since the resistance is easy to measure even at a low humidity, a complicated linearity compensation circuit and a high resistance measuring circuit are unnecessary. Since the

temperature dependence of the moisture sensitivity is small, the humidity sensor of Figure 1 does not require a temperature compensation circuit.

The response characteristics of the humidity sensor of Figure 1 is shown in the graphs of Figure 3 in which the abscissa represents time (in seconds) and the ordinate represents resistance (in ohms) on a logarithmic scale. It is clear from Figure 3 that the humidity sensor is quick in response. The moisture sensitivity was measured after the humidity sensor was left to stand in a thermo-hydrostat at a temperature of 60°C and a relative humidity of 95% for 1000 hours in order to examine the durability and the reliability of the humidity sensor. The results were the same as in Figure 2 within the margin of error. Accordingly, the humidity sensor of Figure 1 proved to have high durability and high reliability. In this way by using such a humidity sensor, it is possible to produce at a low cost a hygrometer and a humidity detector having simple circuitry, economical in power consumption and having high accuracy, high-speed responsiveness and high reliability.

Similar humidity sensors were produced by using Ag, Cu, Pt, an Ag-Pt alloy and a Pt-Pd alloy, respectively, in place of Au at the portions to which the lead wires were connected.

Example 2.

Tetraethoxysilane was hydrolyzed by adding 35 mℓ of ethanol and 16 mℓ of 0.02 N hydrochloric acid to 50 mℓ of tetraethoxysilane and by stirring the mixture for 1 hour. 20 mℓ of ethylene glycol, 5g of activated carbon and 9.5 g of carbon black were added thereto and the mixture was stirred for 30 minutes. Further, 20 g of fine silica powder was added thereto and the resultant

mixture was stirred for 30 minutes to produce a silica sol with carbon particles dispersed therein.

An alumina substrate 1a (Figure 4) with Pt-Pd comb electrodes 3a provided thereon by screen printing was spin coated with the silica sol, dried at 150°C for 1 hour, and sintered at 380°C for 1 hour, thereby forming a porous silica film 4a with carbon particles dispersed therein. The content of the carbon particles in the porous silica film 4a was 30 wt% and the thickness of the porous silica film 4a was 30 μm.

Tetraethoxysilane was then hydrolyzed by adding 35 mℓ of ethanol and 4 mℓ of 0.02 N hydrochloric acid to 50 mℓ of tetraethoxysilane and by stirring the mixture for 1 hour. 10 g of fine silica powder was added thereto and the mixture was stirred for 30 minutes to obtain a silica sol. The porous silica film 4a with carbon particles dispersed therein was spin coated with the thus-obtained silica sol, dried at 120°C for 30 minutes and sintered at 400°C for 20 minutes, thereby producing a silica film 5a.

The thus-obtained humidity sensor is shown in the sectional view in Figure 4. The moisture sensitivity of the humidity sensor of Figure 4 is shown in Figure 5 in which the abscissa represents relative humidity and the ordinate represents resistance (in ohms) on a logarithmic scale. From Figure 5, it is clear that the linearity of the logarithm of resistance with respect to relative humidity is good, and that since the resistance is easy to measure even at a low humidity, a complicated linearity compensation circuit and a high resistance measuring circuit are unnecessary. Since the temperature dependence of the moisture sensitivity is small, the humidity sensor of Figure 4 does not require a temperature compensation circuit.

The response characteristic of the humidity sensor is shown in Figure 6 in which the abscissa represents time (in seconds) and the ordinate represents resistance (in ohms) on a logarithmic scale. It is clear from Figure 6 that the humidity sensor of Figure 4 is quick in response. The moisture sensitivity was measured after the humidity sensor of Figure 4 was left to stand in an atmosphere saturated with water and ethanol steam at 60°C for 1000 hours in order to examine the durability and the reliability of the humidity sensor. The results were the same as in Figure 5 within the margin of error. Accordingly, the characteristics of the humidity sensor of Figure 4 proved to be stable even in a very severe environment.

A similar humidity sensor was produced by using Pt as the material for the comb electrode in place of a Pt-Pd alloy.

Example 3

A further humidity sensor as shown in Figure 4 was produced as follows.

Tetraethoxysilane was hydrolyzed by adding 50 mℓ of ethanol, 8 mℓ of 0.02 N hydrochloric acid and 10 g of fine silica powder to 50 mℓ of tetraethoxysilane and by stirring the mixture for 1 hour. 5 mℓ of monoolein and 18 g of activated carbon were added thereto and the mixture was stirred for 30 minutes to produce a silica sol with carbon particles dispersed therein.

A refractory brick substrate 1a with RuO_2 comb electrodes 3a provided thereon by screen printing was roll coated with the silica sol, dried at 60°C for 24 hours and sintered at 450°C for 20 minutes, thereby forming a porous silica film 4a with carbon particles dispersed therein. The content of the carbon particles in the porous silica film 4a was 43 wt% and the

thickness of the porous silica film 4a was 250 μm.

Tetraethoxysilane was then hydrolyzed by adding 50 mℓ of ethanol, 8 mℓ of 0.02 N hydrochloric acid and 20 g of fine silica powder to 50 mℓ of tetraethoxysilane and by stirring the mixture for 1 hour, thereby producing a silica sol. The porous silica film 4a with carbon particles dispersed therein was roll coated with the thus-obtained silica sol, dried at 80°C for 5 hours and sintered at 480°C for 10 minutes, thereby producing a silica film 5a.

The thus-obtained humidity sensor is shown in the sectional view of Figure 4. The moisture sensitivity of this humidity sensor is shown in Figure 7 in which the abscissa represents relative humidity and the ordinate represents resistance (in kilo-ohms). From Figure 7, it is clear that there is a linear relationship between relative humidity and resistance. Accordingly, this humidity sensor does not require a logarithmic amplifier and is capable of measuring humidity in a wide range by means of a very simple circuit and with high accuracy. In this way, it is possible to produce a humidity sensor having a linear relationship between relative humidity and resistance by controlling the content of the carbon particles and the thickness of the porous silica film. The moisture sensitivity was measured after the humidity sensor was boiled in boiling water for 1 hour and dried at 100°C for 1 hour in order to examine the durability and the reliability of the humidity sensor. The results were the same as in Figure 7 within the margin of error. Accordingly, the characteristics of this humidity sensor proved to be stable even in a very severe environment.

Example 4.

Samples A and B were produced in the same way as in Example 3 except that the amount of activated carbon

used was changed to 22g and 25g, respectively. The contents of the carbon particles in the porous silica film 4a of the samples A and B were 48 wt% and 52 wt%, respectively. The moisture sensitivities of the respective humidity sensors are shown in Figure 8 in which the abscissa represents relative humidity and the ordinate represents resistance (in kilo-ohms).

In Figure 8, the curves A and B represent the moisture sensitivities of the humidity sensors in which the contents of the carbon particles in the porous silica film 4a were 48 wt% and 52 wt%, respectively. It is clear from Figure 8 that when the content of the carbon particles in the porous silica film 4a exceeds 45 wt%, the sensitivity is lowered at a low humidity, and when it exceeds 50 wt%, the sensitivity is lowered at all humidities. Accordingly, a humidity sensor having good characteristics is obtained when the content of the carbon particles in the porous silica film 4a is not more than 50 wt% and preferably is not more than 45 wt%.

Example 5.

Samples C and D were produced in the same way as in Example 3 except that the thickness of the porous silica film 4a with carbon particles dispersed therein was changed to 300 μm and 350 μm, respectively. The moisture sensitivities of the respective humidity sensors are shown in the graphs of Figure 9 in which the abscissa represents relative humidity and the ordinate represents resistance (in kilo-ohms).

In Figure 9, the curves C and D represent the moisture sensitivities of the humidity sensors in which the thicknesses of the porous silica film 4a with carbon particles dispersed therein were 300 μm and 350 μm, respectively. It is clear from Figure 9 that when the thickness of the porous silica film 4a with carbon

particles dispersed therein exceeds 250 μm, the sensitivity (i.e. the rate of change in the resistance between a low humidity and a high humidity) is lowered at a low humidity, and when it exceeds 300 μm, the sensitivity is lowered at all humidities. Accordingly, a humidity sensor having good characteristics is obtained when the thickness of the porous film with carbon particles dispersed therein is not more than 300 μm, and preferably not more than 250 μm.

Example 6

Tetraethoxysilane was hydrolyzed by adding 40 mℓ of 0.02 N hydrochloric acid and 25 g of fine silica powder to 50 mℓ of tetraethoxysilane and by stirring the mixture for 1 hour, thereby producing a silica sol. The thus-obtained silica sol was screen printed on a glass substrate 1b (Figure 10) and sintered at 300°C for 1 hour, thereby forming a silica film 2b. Cr and Au were deposited on the silica film 2b in that order to provide comb electrodes 3b.

Tetraethoxysilane was then hydrolyzed by adding 50 mℓ of 0.02 N hydrochloric acid, 25g of fine silica powder and 7.3g of carbon black to 50 mℓ of tetraethoxysilane and by stirring the mixture for 1 hour, thereby producing a silica sol with carbon particles dispersed therein. The thus-obtained silica sol was screen printed on the silica film 2b and the comb electrodes 3b provided thereon, sintered at 350°C for 10 hours, thereby producing a porous silica film 4b with carbon particles dispersed therein. The content of the carbon particles in the porous silica film 4b was 16 wt% and the thickness of the porous silica film was 5 μm.

The thus-obtained humidity sensor is shown in the sectional view of Figure 10 and the moisture sensitivity

of this humidity sensor is shown in Figure 11 in which the abscissa represents relative humidity and the ordinate represents resistance (in ohms) on a logarithmic scale.

Example 7

Samples E and F were produced in the same way as in Example 6 except that the amount of carbon black used was changed to 5.3g and 3.3g, respectively. The contents of the carbon particles in the porous silica film 4b were 12 wt% and 8 wt%, respectively. The moisture sensitivities of the respective humidity sensors are shown in the graphs of Figure 12 in which the abscissa represents relative humidity and the ordinate represents resistance (in ohms) on a logarithmic scale. In Figure 12, the curves E and F represent the moisture sensitivities of the humidity sensors in which the contents of the carbon particles in the porous silica film 4b were 12 wt% and 8 wt%, respectively. It is clear from Figure 12 that when the content of the carbon particles in the porous silica film is less than 15 wt%, the resistance becomes high at a low humidity, and when it is less than 10 wt%, the resistance becomes very high. Accordingly, a humidity sensor having good characteristics is obtained when the content of the carbon particles in the porous silica film 4b is not less than 10 wt%, and preferably not less than 15 wt%.

Example 8

Samples G and H were produced in the same way as in Example 6 except that the thickness of the porous silica film 4b with carbon particles dispersed therein were changed to 1 μm and 0.5 μm, respectively. The moisture sensitivities of the respective humidity sensors are shown in Figure 13 in which the abscissa

represents relative humidity and the ordinate represents resistance (in ohms) on a logarithmic scale. In Figure 13, the curves G and H represent the moisture sensitivities of the humidity sensors in which the thicknesses of the porous silica film 4b with carbon particles dispersed therein were 1 μm and 0.5 μm, respectively. It is clear from Figure 13 that when the thickness of the porous silica film 4b with carbon particles dispersed therein is less than 5 μm, the resistance becomes high at a low humidity, and when it is less than 1 μm, the resistance becomes very high. Accordingly, a humidity sensor having good characteristics is obtained when the thickness of the porous silica film 4b with carbon particles dispersed therein is not less than 1 μm, and preferably not less than 5 μm.

Example 9

Tetraethoxysilane was hydrolyzed by adding 25 mℓ of ethanol, 16 mℓ of 0.02 N hydrochloric acid and 13.5g of fine silica powder to 50 mℓ of tetraethoxysilane and by stirring the mixture for 1 hour, thereby producing a silica sol (hereinunder referred to as "sol A"). A silica glass substrate 1c (Figure 14) was dip coated with the thus-obtained sol A, dried at 50°C for 10 minutes and sintered at 500°C for 30 minutes, thereby forming a silica film 2c. Comb electrodes 3c of an Ag-Pd alloy were produced on the silica film 2c by screen printing.

Tetraethoxysilane was then hydrolyzed by adding 15 mℓ of ethanol, 2 mℓ of 0.02 N hydrochloric acid, 8.7g of activated carbon and 8.7g of carbon black to 50 mℓ of tetraethoxysilane and by stirring the mixture for 1 hour. 50 mℓ of polyethylene glycol and 15 g of fine silica powder were added thereto and the resultant

mixture was stirred for 30 minutes, thereby producing a silica sol with carbon particles dispersed therein. The silica film 2c and the comb electrodes 3c provided thereon was dip coated with the thus-obtained silica sol, dried at 200°C for 5 minutes and sintered at 400°C for 1 hour, thereby producing a porous silica film 4c with carbon particles dispersed therein. The content of the carbon particles in the porous silica film 4c was 38 wt% and the thickness of the porous silica film 4c was 100 μm.

The thus-obtained porous silica film 4c with carbon particles dispersed therein was dip coated with sol A, dried at 50°C for 10 minutes and sintered at 380°C for 5 hours to produce a silica film 5c.

The thus-produced humidity sensor is shown in the sectional view of Figure 14. The moisture sensitivity of this humidity sensor is shown in Figure 15 in which the abscissa represents relative humidity and the ordinate represents resistance (in ohms) on a logarithmic scale. From Figure 15, it is clear that the linearity of the logarithm of resistance with respect to relative humidity is good, and that since the resistance is easy to measure even at a low humidity, this humidity sensor is highly accurate. The moisture sensitivity was measured after the humidity sensor of Figure 14 was washed in acetone at an ultrasonic frequency for 10 minutes in order to examine the durability and the reliability of the humidity sensor. The results were the same as in Figure 15 within the margin of error. Accordingly, the characteristics of the humidity sensor of Figure 14 proved to be stable even in a very severe environment.

A similar humidity sensor was produced by using Ag as the material for the comb electrodes 3c in place of

an Ag-Pd alloy.

As described above, in a humidity sensor of the present invention, it is possible to freely vary the conductivity by controlling the content of the carbon particles in the porous silica film.

It is therefore possible to produce a humidity sensor which has a good linearity of the change in resistance with respect to change in relative humidity, and a resistance which is easy to measure at a low humidity at which the resistance becomes high, whereby it is capable of measuring humidity in a wide range by a simple circuit with high accuracy. It is also possible to produce a humidity sensor which has a linear relationship between relative humidity and resistance, thereby obviating the need for a logarithmic amplifier. In addition, since the temperature dependence of the moisture sensitivity is small, a temperature compensation circuit can be dispensed with. In this way, it is possible to simplify the humidity measuring circuit and to produce a humidity measuring apparatus at a low cost which is capable of measuring humidity with high accuracy and economical power.

Since carbon particles and a silica film are chemically stable, they do not deteriorate even in a severe environment. Therefore, their properties do not need to be restored by heat treatment and the humidity sensor can be used in an environment in which combustible gas or dust exists. Furthermore, since the response to a change in humidity is quick and a change in characteristics with time is small,the humidity sensor is usable for a humidity control apparatus having high accuracy.

Since the humidity sensor of the present invention is easily produced, it can be easily made by mass

production, and since the raw materials are cheap and the manufacturing cost is low, it is possible to manufacture a cheap humidity sensor.

As described above, the humidity sensor according to the present invention is applicable as a highly accurate and highly reliable humidity sensor in a wide field where humidity measurement and humidity control are required.

* C L M S *

CLAIMS

1. A humidity sensor comprising a support of insulating material; electrodes provided on said support; and a porous silica film with carbon particles dispersed therein which is provided on the support so as to be provided about at least a portion of the electrodes.

2. A humidity sensor as claimed in claim 1 in which a further silica film is provided on the said porous silica film.

3. A humidity sensor as claimed in claim 1 or 2 in which the support is constituted by an insulating substrate.

4. A humidity sensor as claimed in claim 1 or 2 in which the support comprises an insulating substrate having a support film of silica thereon, the electrodes and the porous silica film being mounted directly on the support film.

5. A humidity sensor as claimed in claim 3 or 4 in which the insulating substrate is made of alumina, glass, or a refractory brick.

6. A humidity sensor as claimed in any preceding claim in which the electrodes comprise a pair of comb electrodes.

7. A humidity sensor as claimed in any preceding claim in which the electrodes are made, at least in part, of Au, Ag, Pt, Pd, Cr, or an alloy thereof.

8. A humidity sensor as claimed in any of claims 1-6 in which the electrodes are made of RuO_2.

9. A humidity sensor as claimed in any preceding

claim in which the electrodes have multi-layered lead portions for connection to lead wires.

10. A humidity sensor as claimed in claim 9 in which at least one layer of each lead portion is formed from Au, Ag, Pt, Pd, Cr or an alloy thereof, the remaining part of each electrode being made of Cr.

11. A humidity sensor as claimed in any preceding claim in which the said porous silica film with carbon particles dispersed therein contains 10 to 50 wt% of said carbon particles.

12. A humidity sensor as claimed in any preceding claim in which the said porous silica film with carbon particles dispersed therein has a thickness of 1 to 300 μm.

13. A humidity sensor as claimed in any preceding claim in which the said porous silica film with carbon particles dispersed therein is produced by forming a silica sol with carbon particles dispersed therein into a film, and by heat treating said film.

14. A humidity sensor according to claim 13 in which the said silica sol with carbon particles dispersed therein is produced by dispersing silica particles and carbon particles in a hydrolyzed solution of a silicon alkoxide.

15. A humidity sensor as claimed in claim 2 or claim 4 or in any claim dependent thereon in which the further silica film or the support film is produced by forming a silica sol into a film and by heat treating said film.

16. A humidity sensor as claimed in claim 15 in which said silica sol is produced by dispersing silica particles in a hydrolyzed solution of a silicon alkoxide.

17. A humidity sensor substantially as

hereinbefore described with reference to and as shown in any of Figures 1, 4, 10 or 14 of the accompanying drawings.