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U1S S1437 S1438

(56) Documents Cited
GB 2209630 A **EP 0461102 A2** **EP 0309664 A2**
US 5181007 A **US 5172466 A**

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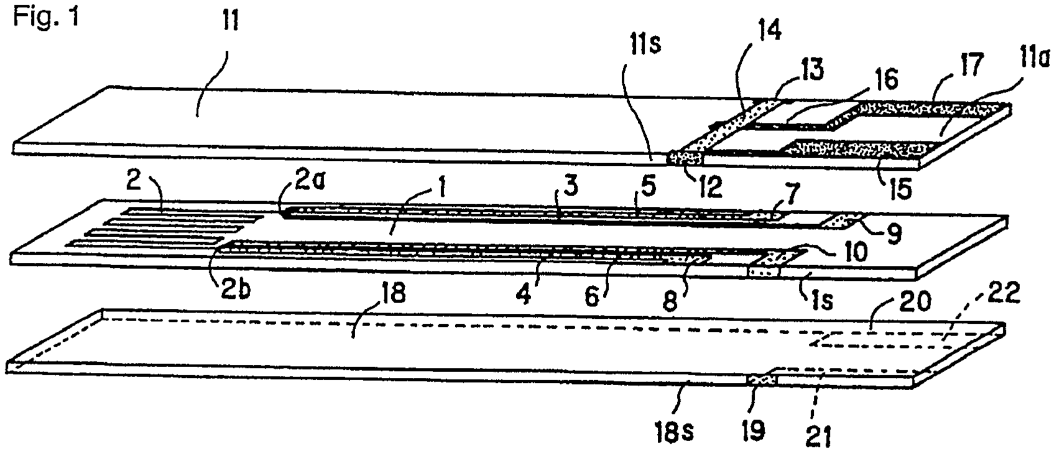
UK CL (Edition N) **G1N NAFB NAGB2 NAGC2 NAGD2 NAHAT**
INT CL^6 **G01K 7/16 7/18 7/21 15/00**

(54) **Temperature sensor**

(57) A temperature sensor includes a ceramic substrate (1, 11, 18), a sensing resistor (2) of positive temperature coefficient and e.g. containing platinum embedded in the ceramic substrate, and a further resistor (14) connected to the resistor (2) and used to adjust the resistance of the device. The sensor described is for use in exhaust gas and the two resistors (2, 14) are at opposite ends of the substrate whereby the resistor (2) is not affected by heat during laser trimming of the resistor (14) and the latter need not be exposed to the gas in service. As shown the resistor (2) is printed together with current leads (3, 4) and voltage leads (5, 6) onto a green ceramic sheet (1). The sheet is then sandwiched between further sheets (11, 18) carrying the resistor (14) and pads (15, 17) and (21, 22) for the voltage and current connections respectively, and the assembly is pressed together and fired. The two resistors are electrically in parallel, the resistor (14) acting as a voltage divider. The resistor (14) may be protected by a glass layer after trimming.

Fig. 1



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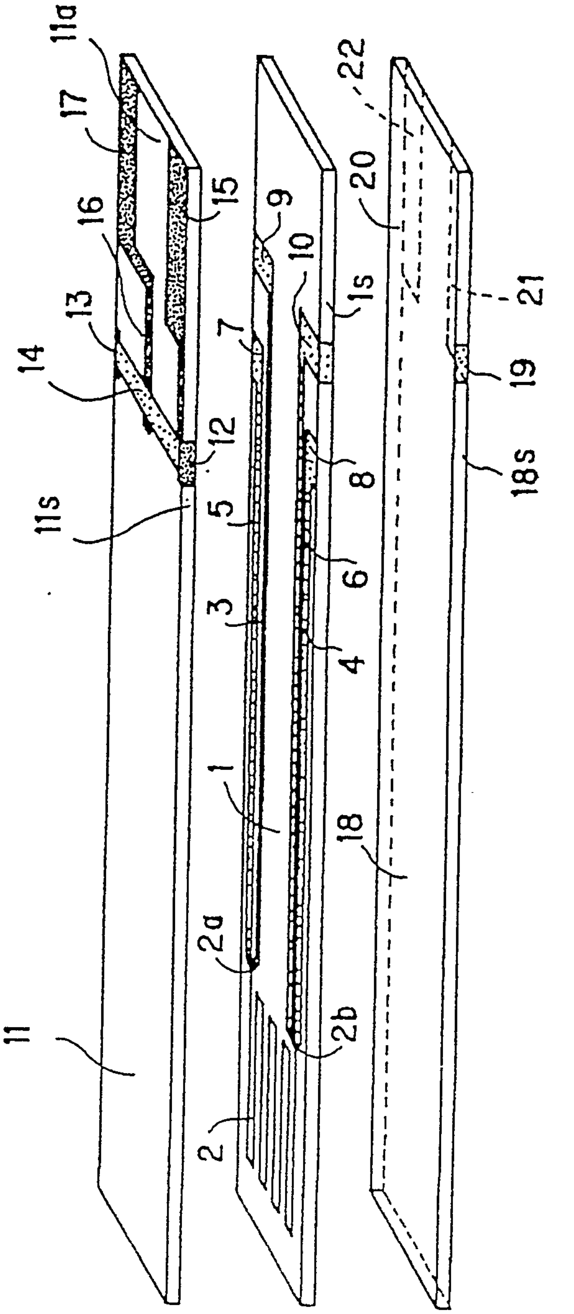
11a
17
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1s
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2a
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11
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Fig. 1

Fig. 2

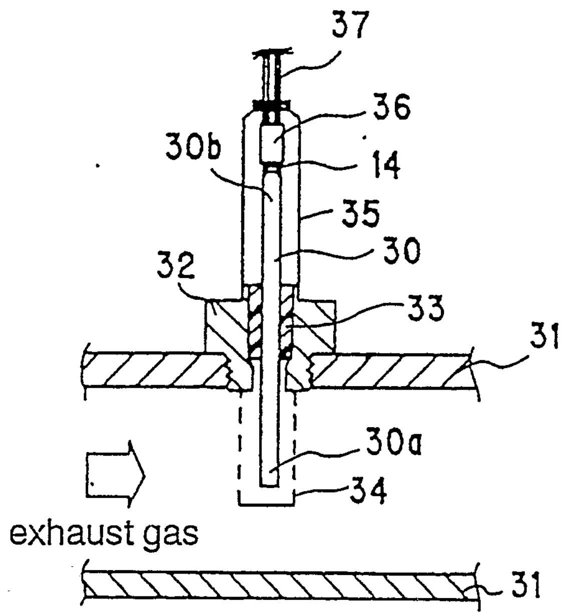


Fig. 3

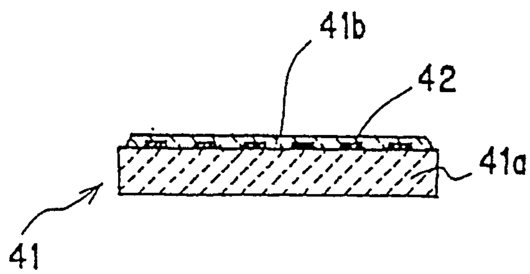


Fig. 4

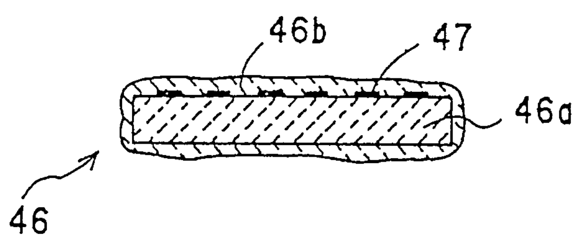


Fig. 5

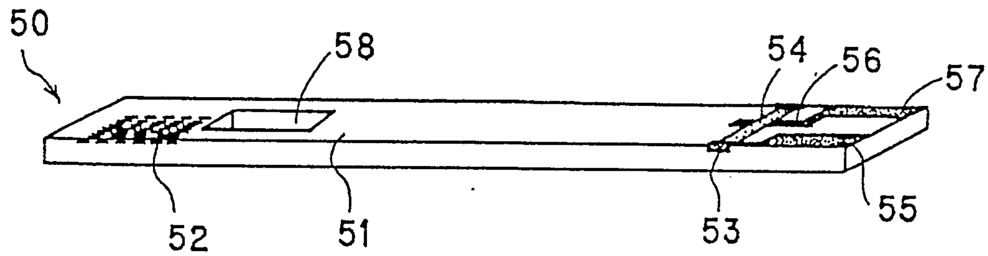


Fig. 6

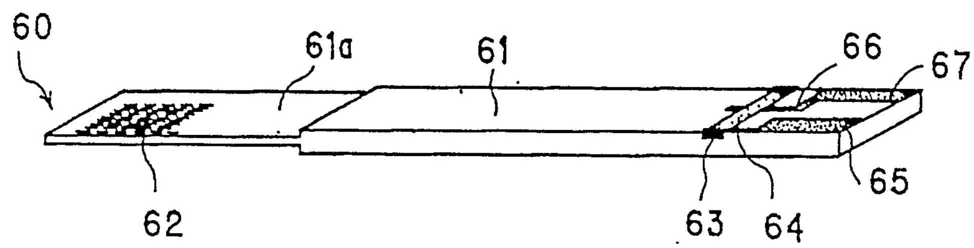


Fig. 7

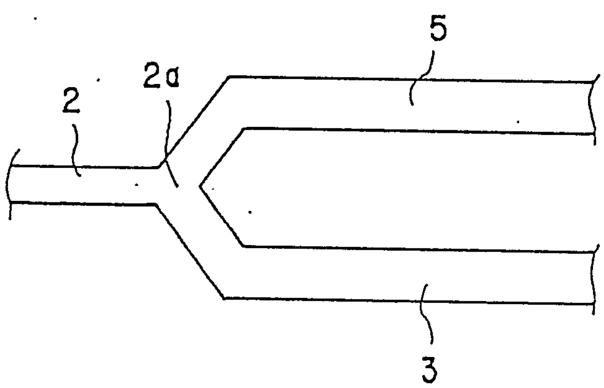
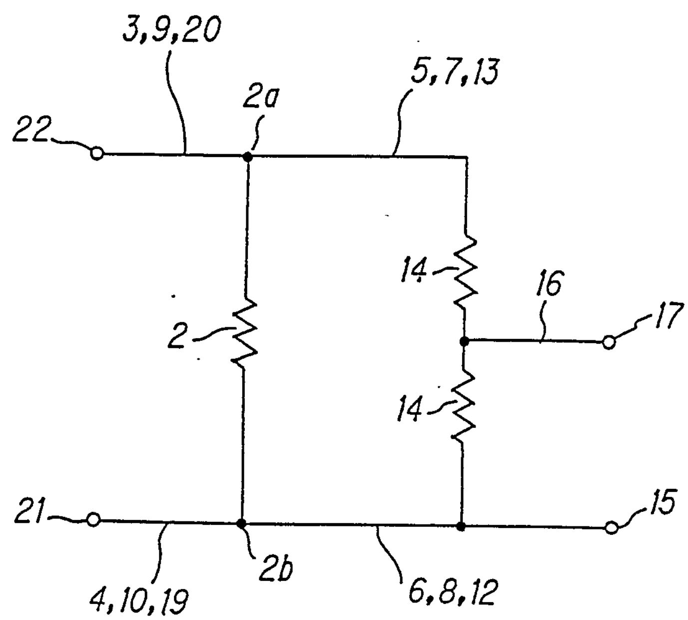


Fig. 8



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TEMPERATURE SENSOR

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a temperature sensor or a resistance thermometer using platinum or a cermet of platinum and a metal as a resistor. The temperature sensor of the present invention improves reliability at high temperatures and precision.

2. Description of Related Art

A temperature sensor or a resistance thermometer has a sensing resistor having an electrical resistance varying with temperature. The temperature sensor is driven by a constant current source in order to develop voltages across the changing resistance of the sensing resistor. A temperature sensor having a platinum film is disclosed in a preprint "Platinum Film Temperature Sensors" by G. S. Iles for Automotive Engineering Congress and Exposition, Detroit, Michigan, February 24–28, 1975, held by Society of Automotive Engineers.

Japanese Patent Application Laid–Open No. 4–279831 discloses a temperature sensor including a ceramic substrate, a platinum resistor coated thereon, and a glass layer coated onto the platinum resistor. Before coated by the glass layer, the platinum resistor on the substrate is trimmed by laser irradiation so as to have electrical resistance of a predetermined value.

However, in the step of trimming the platinum resistor, the laser irradiation heats the resistor thereby changing its electrical resistance. Consequently, it is not easy to improve precision in an ohmic resistance value of the resistor, and variance of the ohmic resistance value tends to increase. Moreover, the glass layer may not withstand high temperatures, and the temperature sensor may not be used in the high temperatures.

In some of applications, the temperature sensor is used under demanding conditions, for example, at high temperatures as well as in an oxidizing atmosphere, a reducing atmosphere, and an atmosphere containing a corrosive gas. For example, temperatures of an exhaust gas from an internal combustion engine and an exhaust gas from a plant may need to be monitored. Under these conditions, the resistor of the temperature sensor may gradually change its electrical resistance value over a long period.

SUMMARY OF THE INVENTION

An object of the present invention is to solve the aforementioned problem. The present invention provides a temperature sensor comprising a ceramic substrate; a sensing resistor, being embedded in the ceramic substrate, having a positive temperature coefficient of resistance; a first lead connected to the sensing resistor, wherein electric current can be applied to the sensing resistor through the first lead; a second lead connected to the sensing resistor, wherein a voltage of the sensing resistor can be detected through the second lead; a second resistor electrically connected to the sensing resistor, the second resistor has an electrical resistance value such that upon applying electric current having a certain value the sensing resistor has output voltage having a predetermined value.

In the temperature sensor of the present invention, a sensing resistor is embedded in a ceramic substrate so that the sensing resistor avoids contact with an atmosphere to be sensed thereby the sensing resistor does not deteriorate. Consequently, the temperature sensor of the present invention remains stable and reliable even under demanding conditions, such as an oxidizing atmosphere at high temperatures, a reducing atmosphere at high temperatures, an atmosphere containing a corrosive gas, etc.

A ceramic material for the ceramic substrate preferably insulates electricity. The ceramic material preferably has low thermal conductivity so as to decrease a heat flow between the sensing resistor and another resistor through the ceramic substrate, thereby improving the precision of the temperature sensor. The ceramic substrate may be composed of, for example, alumina, stearite, mullite, etc. Preferably, the entirety of the ceramic substrate may consist of the same ceramic material. However, part of the ceramic substrate may be composed of a different ceramic material from the other parts of the ceramic substrate. The ceramic substrate may be dense so as to prevent gas molecules from permeating therethrough.

The ceramic substrate may have a planar shape. However, the ceramic substrate may have any shape including a tubular shape and a cylindrical shape. The ceramic substrate favorably has a shape such that heat that is experienced at the sensing resistor does not affect temperature of the voltage–dividing resistor.

The sensing resistor contains a metal having a positive temperature coefficient of resistance. The positive temperature coefficient of resistance is preferably large. The metal may include, for example, platinum, rhodium, nickel, tungsten, etc., and especially platinum is favorable. The sensing resistor may be composed of any of these metals, an alloy including any of these metals, or a cermet consisting of a ceramic material and any of these metals. The temperature sensor of the present invention can measure temperature by properties that the sensing resistor changes its electrical resistance depending on temperature.

A resistor for dividing voltage is electrically connected to the sensing resistor by means of, for example, a pair of leads. In contrast to the sensing resistor, the voltage–dividing resistor preferably has a small temperature coefficient of resistance in terms of absolute value. In other words, upon varying temperatures, a voltage–dividing resistor preferably does not change its electrical resistance much. The voltage–dividing resistor may be made by printing a metal or metal oxide. Alternatively, the voltage–dividing resistor may be made of a glass matrix and particles dispersed therein, and the particles are made of a metal or a metal oxide. Alternatively, the voltage–dividing resistor may include a film made of a metal or metal oxide and a metal wire.

The voltage–dividing resistor may preferably be coated onto a surface of the ceramic substrate so that the voltage–dividing resistor is easily trimmed by laser irradiation so as to adjust output voltage. Upon applying electric current the output voltage is generated. During the laser irradiation, electric current having a certain value is applied to the sensing resistor and the voltage–dividing resistor at a certain temperature, for example, at 25° C while output voltage is detected. The voltage–dividing resistor is trimmed such that the backward voltage of the sensing resistor has a predetermined value, which corresponds to the electric current and an electric resistance value.

In the present invention, the output voltage of the temperature sensor has a small variance. In the present invention, the voltage–dividing resistor having a small temperature coefficient of resistance is trimmed by laser irradiation instead of the sensing resistor having a large temperature coefficient of resistance, and heat generated by the laser irradiation does not affect an electrical resistance value of the voltage–dividing resistor as much, thereby reducing error in the output voltage. In the present invention, the backward voltage of the sensing resistor is monitored during the trimming step so as to substantially decrease the effects of electrical resistance changes in the leads due to temperature changes, thereby decreasing a variance of the output voltage.

Preferably at 25° C the second resistor has electrical resistance larger than one hundred times as much as electrical resistance of the sensing resistor so as to improve the precision of the temperature sensor. Further preferably at 25° C the second resistor has electrical resistance larger than one thousand times as much as electrical resistance of the sensing resistor.

In the present invention, the voltage–dividing resistor may be disposed at a position that the voltage–dividing resistor is not exposed to an atmosphere to be sensed. In this arrangement, the voltage–dividing resistor remains reliable, and an electrical resistance value of the voltage–dividing resistor does not change much over a long period.

Preferably the ceramic substrate may have two ends, the sensing resistor may be disposed in one of the two ends, and the voltage–dividing resistor may be disposed in the other end.

The voltage–dividing resistor is preferably disposed at a position that has a certain distance from the sensing resistor so as to decrease a heat flow between the voltage–dividing resistor and the sensing resistor. This is especially the case when the temperature sensor detects high temperatures. While the sensing resistor is exposed to high temperatures, for example, at 1000° C, the voltage–dividing resistor is kept much lower temperatures, for example, at about 300° C, resulting a longer service life of the voltage–dividing resistor.

The voltage–dividing resistor is preferably coated with the glass layer so as to improve durability. In the embodiment that the voltage–dividing resistor has a certain distance from the sensing resistor to decrease heat conduction, the glass layer may withstand higher temperatures.

A method of coating the glass layer onto the voltage–dividing resistor may include the steps of making a slurry including glass (for example, borosilicate lead) powder, putting the slurry onto the surfaces of the voltage–dividing resistor, drying the slurry thereon, and firing the slurry thereon. The slurry–putting step can be carried out by immersion, blade coating, spray coating, etc.

In the temperature sensor of the present invention, upon applying electric current to the sensing resistor, the sensing resistor generates voltage, and the voltage signal is detected. The voltage signal may be then converted, for example, by a central processing unit to show temperature. Even when leads, terminal pads, side connections have some electrical resistance, the temperature sensor keeps the precision to detect temperatures. A lead may be used to transmit electric signals, such as voltage, from the sensing resistor, and the lead may be connected to the sensing resistor. Alternatively, electric power having a certain voltage may be applied to the sensing resistor while an electric current value is detected.

The sensing resistor, the second resistor, the leads, the terminal pads may preferably be printed so as to form a film. However, these elements may be formed by blade coating, spray coating, and so on.

BRIEF DESCRIPTION OF THE DRAWINGS

Further details are explained below with the help of the embodiments illustrated in the attached drawings.

Fig. 1 is a perspective view of the first embodiment of the temperature sensor of the present invention wherein the ceramic substrate is separated into three sheets.

Fig. 2 is a cross section showing a manner of using the temperature sensor.

Fig. 3 is a cross section of the second embodiment of the temperature sensor of the present invention.

Fig. 4 is a cross section of the third embodiment of the temperature sensor of the present invention.

Fig. 5 is a perspective view of the fourth embodiment of the temperature sensor of the present invention;

Fig. 6 is a perspective view of the fifth embodiment of the temperature sensor of the present invention.

Fig. 7 is an expansion of a part of Fig. 1.

Fig. 8 is a schematic circuit diagram of the first embodiment of the temperature sensor of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Fig. 1 shows the first embodiment of the temperature sensor of the present invention, and the ceramic substrate 1, 11, 18 is separated into three sheets for clarity. Fig. 1 can be seen as showing a process of making the first embodiment also.

In Fig. 1, a sensing resistor 2, which is composed of a paste mixture of platinum and alumina, is printed onto a surface of a ceramic sheet 1. During the printing step, the ceramic sheet is green alumina that is not fired yet.

A pair of current leads 3, 4 are also printed onto a surface of the ceramic sheet 1. One end of both of the current leads 3, 4 connects to the ends of the resistor 2. The other ends of the current leads 3, 4 connects to connecting pads 9, 10, respectively, for ensuring connection with a side surface 1s.

A pair of leads 5, 6 are printed onto the surface of the ceramic sheet 1 also. Voltage generated at the resistor 2 can be detected through the second leads 5, 6. One end of both of the leads 5, 6 connects to the ends of the resistor 2. The other ends of the second leads 5, 6 connects to connecting pads 7, 8, respectively, for ensuring connection with a side surface 1s. One end 2a of the resistor 2 diverges into the current lead 3 and the lead 5, while the other end 2b of the resistor 2 diverges into the current lead 4 and the lead 6.

Current leads 3, 4, leads 5, 6, and connecting pads 9, 10 may be composed of, for example, a paste mixture of platinum and alumina. They are preferably printed in the step of printing the resistor 2. However, materials for current leads 3, 4, leads 5, 6, and connecting pads 7,8 may not be the same as that for the resistor 2.

A ceramic substrate 11 is preferably made of the same material for the ceramic substrate 1. Side connections 12, 13 for electrically connecting the connecting pad 9, 10 are printed onto side surface 11s of the ceramic substrate 11.

The side connection 12 electrically connects to a terminal pad 15. A pad 16 for dividing voltage is printed between the side connections 12, 13. The pad 16 connects to another terminal pad 17. The terminal pad 15 does not cross the terminal pad 17.

The terminal pads 15, 17 and the pad 16 are printed onto a surface of an end 11a of the ceramic substrate. The terminal pads 15, 17 and the pad 16 may be composed of a paste mixture of platinum and alumina. However, materials for the terminal pads 15, 17 and the pad 16 may not be the same as that for the resistor 2.

A ceramic substrate 18 is preferably made of the same material for the ceramic substrate 1. Side connections 19, 20 extending to a back surface of the ceramic substrate are printed onto side surface 18s of the ceramic substrate 18. The side connections 19, 20 connect to terminal pads 21, 22, respectively printed onto a back surface of the ceramic substrate. The side connections 19, 20 and terminal pads 21, 22 may be composed of a paste mixture of platinum and alumina. However, materials for the side connections 19, 20 and terminal pads 21, 22 may not be the same as that for the resistor 2.

The three green ceramic substrates 1, 11, 18 are laminated together, pressed, and then fired at 1,600°C so as to form a unitary piece. When the resistor 2 contains tungsten or nickel, the atmosphere in the firing step may be a reducing atmosphere. When the resistor 2 contains platinum or rhodium, the atmosphere may be either a reducing atmosphere or an oxidizing atmosphere.

A resistor 14 for dividing voltage, which is composed of a mixture of ruthenium oxide and glass is printed and fired so as to connect side connections 12, 13. The resistor 14 coats at least a part of the pad 16 for dividing voltage so as to connect to the pad 16. For example, the resistor 14 may have electrical resistance of 50 kiloohms, and the sensing resistor may have electrical resistance of 20 ohms.

Electric current having a certain value is applied to the resistor 2 through the terminal pads 21, 22 while an output voltage from the resistor 2 is detected through the terminal pads 15, 17. Under these conditions, the resistor 14 for dividing voltage is trimmed by laser irradiation so as to give an output voltage having a certain value corresponding to the electric current. After trimming, the resistor 14 may be coated by a glass layer so as to protect the resistor.

In the trimming step, an infrared laser or an ultraviolet may be used. For example, a yttrium aluminum garnet laser generates a ray having a diameter of 50 μm onto the resistor 14 moving at a rate of 0.25 mm per second. The laser may have an oscillating frequency of one kilohertz and a power of 600 milliwatts.

The electrical circuit is illustrated in Fig. 8. The electrical circuit has temperature sensitive resistor 2 and voltage–dividing resistor 14, which are in parallel. Electric current is applied to the sensing resistor 2 by input terminals 21, 22. Voltage generated at the sensing resistor 2 is divided by the resistor 14 so as to give output voltage at output terminals 15, 17.

As temperature of the sensing resistor 2 varies, upon applying constant electric current, the electrical resistance of the sensing resistor 2 varies so as to change voltage generated at the sensing resistor 2, thereby output voltage at output terminals 15, 17 changes accordingly.

Fig. 2 shows a manner of using a temperature sensor 30 in the exhaust system of an automobile. The temperature sensor 30 is attached to an exhaust pipe 31 by means of a housing 32. One end 30a, which the resistor 2 is embedded in, is inserted into an inside the exhaust pipe 31, while the other end 30b having the resistor 14 is disposed in the outside the exhaust pipe 31. The housing 32 is threadedly engaged to the exhaust pipe 31, and a member 33 for absorbing shock is disposed between the housing 32 and the temperature sensor 30.

The end 30a is covered by a protection cover 34 so as to avoid an impact on the end since the ceramic substrate of the temperature sensor 30 may be vulnerable to the impact. The protection cover 34 is perforated so as to introduce an exhaust gas into an inside of the protection cover 34.

The other end 30b is connected to a connector 36 so that electric signals at terminal pads 15, 17, 21, 22 are transmitted to lines 37. The end 30b and the connector 36 are installed in a casing 35.

In a method of making the first embodiment, three green ceramic sheets 1, 11, 18 are laminated together, pressed, and then fired so as to form a unitary piece. However, three green ceramic sheets may not be required to make the first embodiment. For example, without the green ceramic sheet 18, terminal pads electrically connected to connection pads, 9, 10 may be printed onto a back surface of the green ceramic sheet 1, which is opposite to the surface that the resistor 2 is printed onto.

In Fig. 3, the second embodiment is similar to the first embodiment except that one end of the ceramic sheet 41a is coated by a coating layer 41b made of a ceramic material so that a sensing resistor 42 is embedded in the ceramic substrate 41 while the other end of the ceramic sheet 41a is not coated by the coating layer 41b. In the second embodiment, the ceramic substrate 41 has the ceramic sheet 41a and the coating layer 41b, and the sensing resistor 42 is disposed between the ceramic sheet 41a and the coating layer 41b. Leads are connected to the sensing resistor 42, and parts of the leads are coated by the coating layer 41b also. The other parts of the leads and a resistor for dividing voltage are coated by a glass layer.

In a method of making the second embodiment of the present invention, a ceramic paste is coated onto a surface of one end of the green ceramic sheet 1 so that the resistor 2 is coated by the ceramic paste. However, the other end is not coated by the ceramic paste. The green ceramic sheet is fired with the paste so as to form a unitary piece.

In Fig. 4, the third embodiment is similar to the first embodiment except that one end of the ceramic sheet 46a is coated by a coating layer 46b made of a ceramic material so that a sensing resistor 47 is embedded in the ceramic substrate 46 while the other end of the ceramic sheet 46a is not coated by the coating layer 46b. In the third embodiment, the coating layer 46b covers the whole surfaces of the one end of the ceramic sheet 46a having the resistor 47, while in the second embodiment the coating layer 42 covers only the surface having the resistor 42 thereon. Similar to the second embodiment, leads are connected to the sensing resistor, and parts of the leads are coated by the coating layer 46b also. The other parts of the leads and a resistor for dividing voltage are coated by a glass layer.

In a method of making the third embodiment of the present invention, one end of the green ceramic sheet 1 is dipped into a ceramic slurry so that the end having the resistor 2 is coated by the ceramic coating. The green ceramic sheet is fired with the ceramic coating so as to form a unitary piece.

In Fig. 5, the fourth embodiment of the present invention is similar to the first embodiment except that the ceramic substrate 51 is formed of a through hole 58 between a sensing resistor 52 in one end of the ceramic substrate and a resistor 54 for dividing voltage in the other end of the ceramic substrate so as to decrease a heat flow between the sensing resistor 52 and the voltage–dividing resistor 54 through the ceramic substrate. When the sensing resistor 52 is exposed to high temperatures, the voltage–dividing resistor 54 is kept much lower temperatures, resulting a longer service life of the resistor 54.

Preferably, the through hole 58 is formed close to the sensing resistor 52. The through hole 58 extends a thickness direction of the ceramic substrate 51. The resistor 52 is embedded in an end of the substrate 51.

In Fig. 6, the fifth embodiment of the present invention is similar to the first embodiment except that an end 61a of the ceramic substrate 61 is thinner than the other parts of the ceramic substrate 61 so as to decrease a heat flow between the sensing resistor 62 embedded in the thin end 61a and the voltage–dividing resistor 64 in the other end through the ceramic substrate 61. When the sensing resistor 62 is exposed to high temperatures, the voltage–dividing resistor 64 is kept much lower temperatures, resulting a longer service life of the resistor 64.

In the temperature sensor of the present invention, the sensing resistor is embedded in the ceramic substrate thereby the sensing resistor does not easily deteriorate. An electrical resistance value of the voltage–dividing resistor is adjusted so as to decrease variation in the output voltage of the temperature sensor. Moreover, where the voltage–dividing resistor has larger electrical resistance than the sensing resistor has, the temperature sensor has improved precision in determining temperatures.

CLAIMS

1. A temperature sensor comprising:

a ceramic substrate;

a sensing resistor, being embedded in said ceramic substrate, having a positive temperature coefficient of resistance;

a first lead connected to said sensing resistor, wherein electric current can be applied to said sensing resistor through said first lead;

a second lead connected to said sensing resistor, wherein voltage of said sensing resistor can be detected through said second lead;

a second resistor electrically connected to said sensing resistor; said second resistor having an electrical resistance value such that upon applying electric current having a certain value onto said sensing resistor output voltage having a predetermined value is generated.

2. A temperature sensor of claim 1, wherein said second resistor has a temperature coefficient of resistance, an absolute value of which is smaller than the positive temperature coefficient of resistance of said sensing resistor.

3. A temperature sensor of claim 1, wherein the absolute value of the temperature coefficient of resistance of the second resistor is not greater than half of the positive temperature coefficient of resistance of said sensing resistor.

4. A temperature sensor of claim 1, wherein at 25° C said second resistor has electrical resistance larger than said sensing resistor.

5. A temperature sensor of claim 1, wherein at 25° C said second resistor has electrical resistance larger than twice as much as electrical resistance of said sensing resistor.

6. A temperature sensor of claim 1, wherein said second resistor is connected to said

sensing resistor by means of said second lead.

7. A temperature sensor of claim 1, wherein said ceramic substrate has two ends, said sensing resistor is disposed in one of said two ends, and said second resistor is disposed in the other of said two ends.

8. A temperature sensor of claim 1, wherein said second resistor is coated onto a surface of said ceramic substrate, and said temperature sensor further comprises a glass layer wherein said second resistor is coated with said glass layer.

9. A temperature sensor of claim 1, wherein said sensing resistor, said second resistor, said first lead, and said second lead are printed so as to form a film.

10. A temperature sensor of claim 1, wherein said sensing resistor contains at least one of platinum, rhodium, nickel, and tungsten.

11. A temperature sensor of claim 1, wherein said sensing resistor consists essentially of a cermet containing a ceramic and at least one of platinum, rhodium, nickel, and tungsten.

12. A temperature sensor of claim 1, wherein said sensing resistor contains platinum.

13. A temperature sensor of claim 1, wherein said ceramic substrate is formed of a through hole between said sensing resistor and said second resistor so as to decrease a heat flow between said sensing resistor and said second resistor through said ceramic substrate.

14. A temperature sensor of claim 1, wherein said ceramic substrate has a planar shape having two ends, said sensing resistor is embedded in one of said two ends, said second resistor is disposed in the other end, the one end having said sensing resistor is thinner than the other end having said second resistor so as to decrease a heat flow between said sensing resistor and said second resistor through said ceramic substrate.

15. A temperature sensor substantially as herein described with reference to and as shown in Figs. 1 and 2, Fig. 3, Fig. 4, Fig. 5 or Fig. 6 of the accompanying drawings.

16. A method of making a temperature sensor according to any one of the preceding claims including the step of adjusting the resistance of said second resistor to obtain a predetermined output voltage of the sensor.

Patents Act 1977
Examiner's report to the Comptroller under Section 17
(The Search report)

16

Application number
GB 9425779.7

Relevant Technical Fields

(i) UK Cl (Ed.N) G1N (NAFB, NAGB2, NAGC2, NAGD2, NAHAT)

(ii) Int Cl (Ed.6) G01K 7/16, 7/18, 7/21, 15/00

Search Examiner
M G CLARKE

Date of completion of Search
8 MARCH 1995

Databases (see below)
(i) UK Patent Office collections of GB, EP, WO and US patent specifications.

(ii)

Documents considered relevant following a search in respect of Claims :-
1 to 16

Categories of documents

X: Document indicating lack of novelty or of inventive step.

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P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

&: Member of the same patent family; corresponding document.

Category	Identity of document and relevant passages		Relevant to claim(s)
A	GB 2209630 A	(MURATA MANUFACTURING CO.) whole document	1
A	EP 0461102 A2	(AUSTRIA EMAIL ETC.) see especially Figure 5	1
A	EP 0309664 A2	(RANCO INC.) see especially Figures 1-4	1, 16
A	US 5181007	(ass. to ROBERT BOSCH GmbH) whole document	1
A	US 5172466	(ass. to ROBERT BOSCH GmbH) whole document	1

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