

Resistance Thermometer

This invention relates to a resistance thermometer with a measuring resistor in the form of a resistive layer with a thickness of 0.1 to 10 μm substantially consisting of a metal of the platinum group, which is applied to an electrically insulating surface of a carrier base with a thermal expansion coefficient within the range of 8.5 to 10.5 ppm/K and which is provided with an electrically insulating cover layer.

From DE 24 50 551 a resistance thermometer with a platinum resistive layer is known which is applied to a base consisting of an aluminium oxide carrier base with a thin intermediate layer laid out on it. This intermediate layer consists of oxides of the group of lanthanum, yttrium, cer, titanium and iron and/or mixtures of the above named metal oxides having the function to adjust the mismatching in thermal expansion between the aluminium oxide carrier base and the platinum resistive layer. There is, however, the problem that under-stoichiometric or

over-stoichiometric oxides lose their electrically insulating properties in the presence of high temperatures affecting the values measured with the resistance thermometer.

Furthermore, a method is known from DE 25 27 739 to manufacture an electrical measuring resistor for a resistance thermometer, where the measuring resistor on a carrier base out of ceramic material comprises a platinum thin-film produced by sputtering in the predetermined form containing a predefined temperature coefficient. In this method such a ceramic is used as a carrier base the mean thermal expansion coefficient of which differs from that of the thermometer platinum by less than $\pm 30\%$. This ceramic basic material for substrates covered by a platinum thin-film resistance layer produced by vapour deposition is heated in an oxygenous atmosphere to such degrees that the substrate contains less than 15 ppm chromium, less than 30 ppm iron, less than 45 ppm lead and less than 700 ppm silicon in a form which is reactive with platinum. With simultaneous presence of all the above listed metals the sum of contaminations due to these metals does not exceed 20 ppm, whereby the substrate coated with platinum of a thickness of 0.1 to 10 μm is heated at a temperature within the range of 1000 $^{\circ}\text{C}$ to 1400 $^{\circ}\text{C}$ for at least 60 minutes in an oxygenous atmosphere. The substrate either consists of aluminium oxide, beryllium oxide, thorium oxide, magnesium oxide or of a magnesium silicate. During coating the substrate is subject to a temperature within the range of 500 $^{\circ}\text{C}$ to 900 $^{\circ}\text{C}$. Preferably,

aluminium oxide ceramic is used as substrate, the platinum layer presenting a thickness of 1 to 5 μm .

In DE 40 26 061 the manufacture of an electrical measuring resistor with predetermined temperature coefficients especially for resistance thermometers is disclosed, a platinum thin-film as resistive layer being sputtered or being applied by vapour deposition onto a substrate on which a preparation containing rhodium sulphoresinate is applied in using the screen printing process and burned, so that the rhodium penetrates in even distribution into the platinum resistive layer. When using a metal substrate the platinum thin-film sided substrate is provided with an electrically insulating intermediate layer out of glass-ceramic.

From DE 43 00 084 is known a resistance thermometer with a platinum measuring resistor with a thickness of 0.1 to 10 μm . The resistance layer is applied onto an electrically insulating surface of a carrier base comprising a thermal expansion coefficient within the range of 8.5 to 10.5 ppm/K aiming at avoiding mechanical tensions of the applied sensitive resistive layer so that resistance characteristics result as in the case of a suspended measuring resistor. This measuring resistor is to be used as temperature sensor within the range of $-200\text{ }^{\circ}\text{C}$ to $+500\text{ }^{\circ}\text{C}$ with high accuracy whereby a difference as small as possible to the predefined reference value characteristic according to DIN IEC 751 is achieved. During this process the electrically insulating surface is either formed by the surface of an

electrically insulating substrate or by the electrically insulating surface of a glass or ceramic layer. In a preferred embodiment the use of a titanium substrate with an electrically insulating glass layer is described. Furthermore, it is described to electrically insulate the metal substrate from a layer out of silicon oxide, silicon nitride, aluminium oxide, titanium oxide, magnesium oxide or magnesium aluminium spinel at the surface.

A disadvantage of this method on the one hand is the expensive process (e.g. precleaning of the metal substrates and/or burning-in of the glass layer under nitrogen) during manufacture and, on the other hand, the maximum application temperature is limited to 500 °C, as due to the thin intermediate layer contaminations from the below metallic substrate can easily reach the sensitive platinum layer. However, also in the case of the known ceramic substrates there is the danger of "poisoning" of the platinum layer, as contaminations (e.g. from the housing material) can reach the platinum layer in connection with a reducing atmosphere within a thermometer housing and may react there (by catalysis) with the platinum, so that the resistance characteristics would be strongly altered. In this case, the usefulness of such resistance thermometers can no longer be guaranteed.

It is an object of the present invention to provide a resistance thermometer enabling long-time stability even in the higher temperature ranges, i.e. above 500 °C by simultaneously maintaining the advantages of

the known embodiments. The resistance characteristic for platinum measuring resistors according to DIN IEC 751 is to be reproduced as exactly as possible within the range of -200°C to $+850^{\circ}\text{C}$. Furthermore, a possibility of using commercially available substrates is to be described.

In accordance with the present invention the problem is solved in that a material is selected as a substrate for the platinum measuring resistor essentially consisting of magnesium titanate. This material is adapted in an optimized way to the expansion coefficient of platinum with its mean thermal expansion coefficient of 8.9 ppm/K . Thereby the tensions developing during heating up and cooling down are minimized so that a characteristic will be reproduced as predetermined in accordance with DIN IEC 751 between -200°C and $+850^{\circ}\text{C}$. This characteristic is also reproduced following permanent storage at temperatures above 500°C . Moreover, magnesium titanate is a commercially available material which, however, is usually used for high-frequency components or ceramic condensators and which has not been known as substrate material for resistance thermometers up to now. It meets all the requirements (strength, dimensions, process temperatures etc.) of the manufacturing process parameters when producing platinum thin-film measuring resistors.

With regard to an intermediate layer the problem of this invention is solved by the characteristic

features of claim 2. It has proved to be advantageous to apply an intermediate layer of Al_2O_3 or MgO onto the described substrate out of magnesium titanate, if, for example, the surface quality of the offered substrate is not sufficient for the subsequent platinum film application technique (evaporation, sputtering). Furthermore, an improved adhesion for the resistive layer to be applied to the intermediate layer is achieved. The resistive layer is preferably composed of platinum.

Due to these two measures (selection of a suitable substrate and, if necessary, application of an intermediate layer) an optimized protection of the sensitive platinum layer against contaminations from the base and an adaptation in the thermal expansion behavior is guaranteed in addition to the other effects described.

In order to keep away further detrimental influences from the platinum thin-film, for example, caused by materials of the outer thermometer casing, this platinum layer is provided with a cover layer. Just like the base for the platinum layer this cover, as well, is to approximate as closely as possible to the thermal expansion characteristic of platinum in its thermal expansion behavior, so that a change of the resistance characteristics caused by this compound is kept as small as possible.

Advantageously, a borosilicate glass is used for the cover layer which is applied by means of the screen printing process and is burned-in. The thickness of

this glass cover layer is within the range of 10 μm to 100 μm . Typically, layer thicknesses of 30 μm are achieved.

To guarantee an especially intensive protection a ceramic lamina with a thickness between 0.1 mm and 1 mm is applied to the platinum resistive layer as a cover, and is attached by means of a coldcuring ceramic bonding agent or a glass solder. The described borosilicate glass, for example, can be used as a glass solder. Advantageously, the ceramic lamina is composed of the same material as the substrate, that is to say, magnesium titanate.

In the following the subject of the invention is described in detail by means of figures 1 and 2:

Figure 1 shows a measuring resistor for resistance thermometers at which the resistive layer is applied directly to the surface of an electrically insulating substrate.

Figure 2 shows a measuring resistor with an intermediate layer between resistive layer and substrate.

In accordance with figure 1 a cuboid-formed body 1 with a surface 2 which is adapted to the form of the measuring resistor 4 to be applied is used as a substrate. In the present embodiment the surface 2 is formed with a roughness height of 20 nm to 200 nm. The substrate 1 consists of magnesium titanate MgTiO_3 . It is, however, possible, as well, to apply

aluminium oxide as material. The resistive layer 4 consisting of a part of the platinum group, preferably platinum, is applied to the surface 2 of the substrate 1. The resistive layer 4 is applied by means of cathode sputtering and/or evaporation resulting in a structure in the form of a meander. The relatively sensitive (and catalytically active) platinum layer 4 is protected by a cover layer 5.

For high-temperature applications a ceramic lamina with a thickness of 0.1 mm to 1 mm is used as cover layer 5. In this case, the ceramic lamina has a thickness of 0.3 mm and consists of magnesium titanate. The ceramic lamina is attached to the substrate layer 4 and/or the substrate 1 by means of a hard glass solder. With applications up to a temperature of 500° C the cover lamina 5 can also be attached by means of a glass solder with a low melting point or a ceramic bonding agent.

In the place of the ceramic lamina the cover layer 5 can also be formed out of a borosilicate glass, which is applied by means of the screen printing process. After burning-in the borosilicate glass layer has a thickness of 30 μm .

At one side of the substrate 1 contact surfaces 8,9 are arranged in connection with the meandered resistive layer 4. These contact surfaces 8,9 can also be described as thick-layer pads and are applied to the connecting contacts 6,7 of the resistive layer 4. At the contact surfaces 8,9 the outer connecting

leads 10,11 are applied by welding or bonding. The connecting area is electrically insulated and strain-relieved by an outer cover layer 14 out of glass-ceramics material which is applied to the contact surfaces 8,9 and partially to the cover layer 5. Borosilicate glass has proved to be a suitable glass-ceramics material. Its thickness is found to be within the range of 0.5 mm to 3 mm. For application in the high-temperature area ($>600^{\circ}\text{C}$) a cover lamina 12 in the area of the contact surfaces 8,9 is applied in addition to the cover layer 14. This process is carried out by means of a hard glass solder which can be identical with the borosilicate glass of the cover layer 14.

In accordance with figure 2 an electrically insulating intermediate layer 3 is applied to the surface 2 of the substrate 1. This intermediate layer 3 is applied by the cathode sputtering method. It is, however, also possible to apply it by evaporation or thick-film technique (screen printing of resins). The intermediate layer 3 adjusts surface defects of the substrate 1 and, additionally, is adapted in its expansion behavior to the resistive layer 4 to be applied to it. The intermediate layer consists of aluminium oxide or magnesium oxide. It can also be used as an adhesion agent between the substrate 1 and the resistive layer 4 to be applied. When using a substrate out of magnesium titanate it has proven especially convenient to apply aluminium oxide as an intermediate layer.

The further construction of the resistance thermometer corresponds to the embodiment described in figure 1 relating to cover layer 5, connecting contact surfaces 6,7, contact surfaces 8,9 connecting leads 10,11, contact surface cover layer 14 and cover lamina 12.

This Sheet Has Been Replaced



THIS SHEET HAS BEEN
REPLACED

11



Patent Claims

1. A resistance thermometer with a measuring resistor in the form of a resistive layer with a thickness of 0.1 to 10 μm substantially consisting of a metal of the platinum group, which is applied to an electrically insulating surface of a carrier base with a thermal expansion coefficient within the range of 8.5 to 10.5 ppm/K and which is provided with an electrically insulating cover layer, characterized in that a substrate (1) substantially out of magnesium titanate is intended to be used as a carrier base.

2. A resistance thermometer according to claim 1 characterized in that an intermediate layer (3) preferably out of aluminium oxide or magnesium oxide is applied between the substrate (1) and the resistive layer (4).



3. A resistance thermometer according to claim 1 or 2 characterized in that the cover layer (5) consists of a borosilicate glass.
4. A resistance thermometer according to claim 3 characterized in that the borosilicate glass has a thickness within the range of 10 μm to 100 μm .
5. A resistance thermometer according to claim 1 or 2 characterized in that the cover layer (5) is a ceramic lamina out of the material of the substrate (1).
6. A resistance thermometer according to claim 5 characterized in that the ceramic lamina has a thickness of 0.1 to 1 mm.
7. A resistance thermometer according to claim 5 or 6 characterized in that the ceramic lamina, as a cover layer (5), is attached onto the resistive layer (4) and the substrate (1) by means of a ceramic bonding agent or a glass solder.

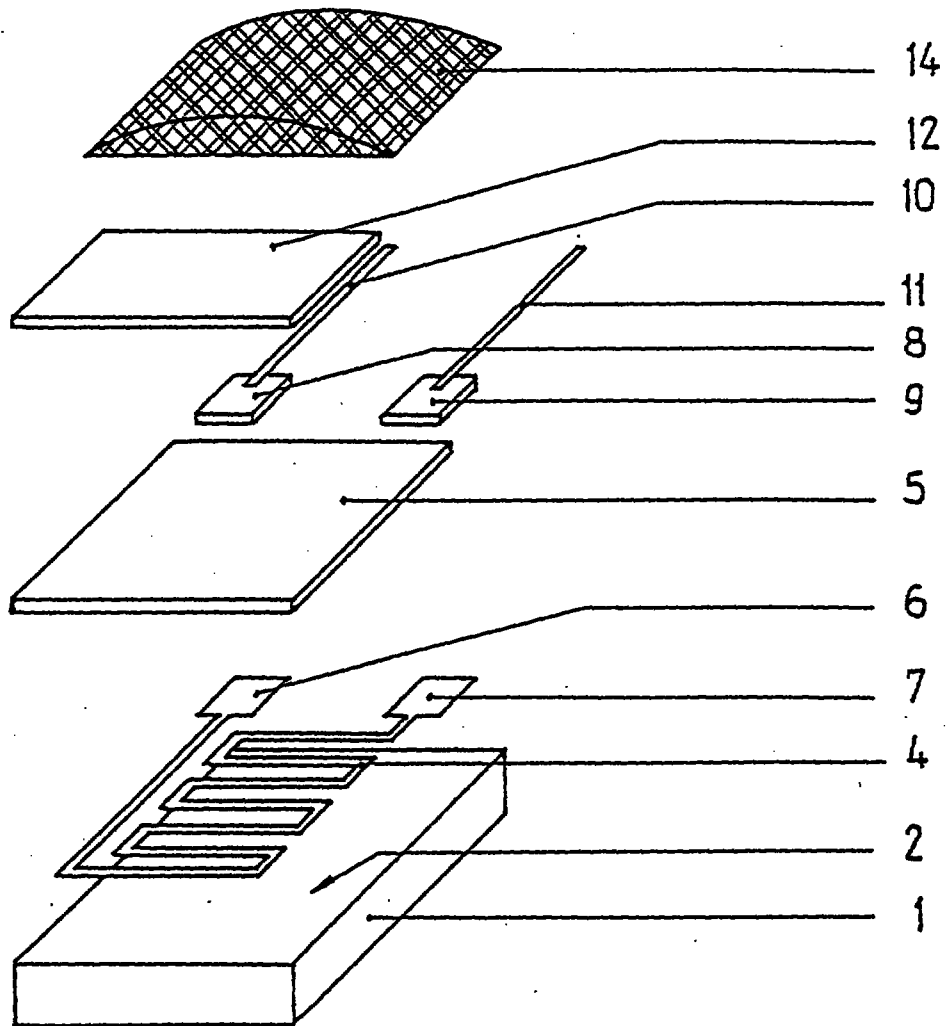


Figure 1

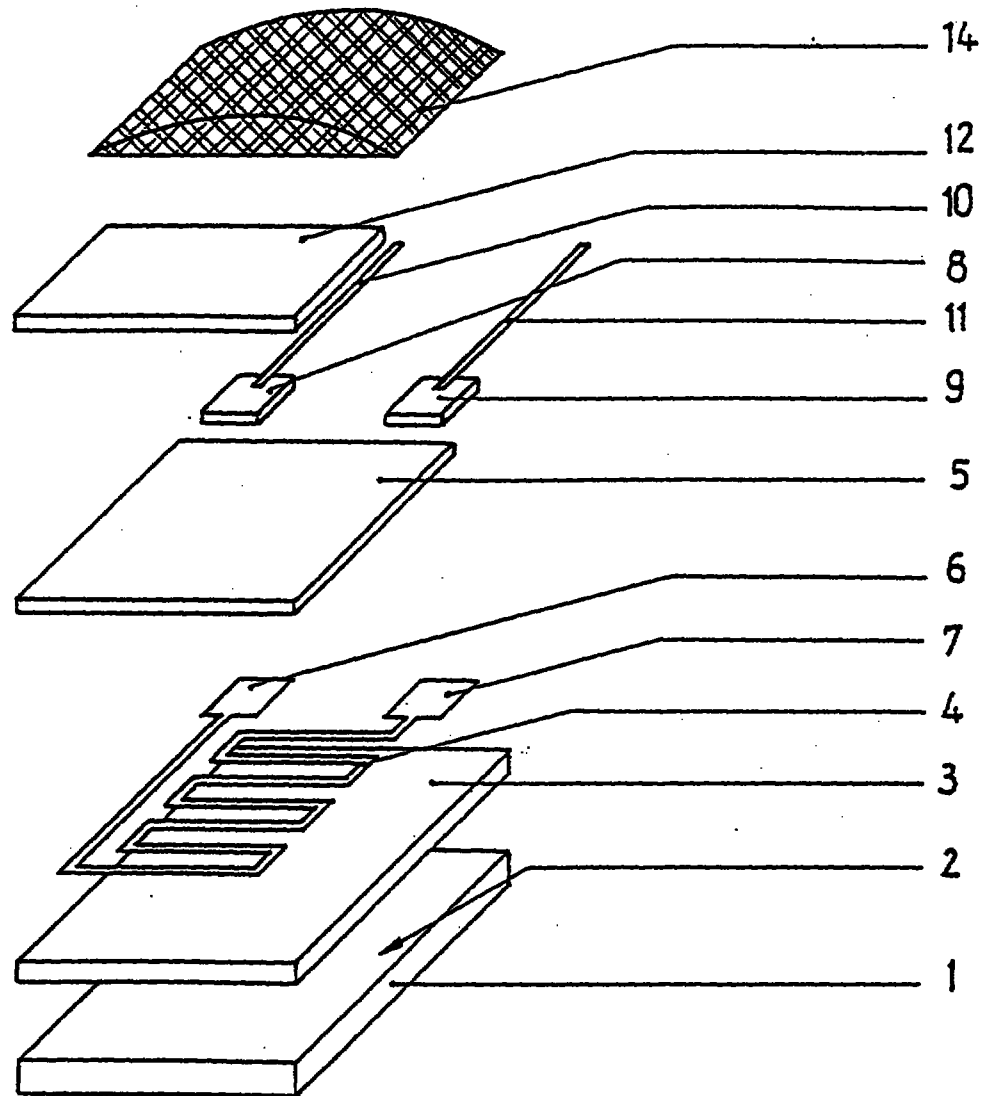


Figure 2

ABSTRACT

Resistance Thermometer

The invention refers to a resistance thermometer with a measuring resistor in form of a resistive layer, substantially consisting of a metal of the platinum group, preferably platinum, which is applied to an electrically insulating surface of a carrier base with a thermal expansion coefficient within the range of 8.5 to 10.5 ppm/K and which is provided with an electrically insulating cover layer. The carrier base for the resistive layer can be formed as follows:

- a) as a substrate, which substantially consist of magnesium titanate
or
- b) as an intermediate layer out of alumina or magnesium oxide covering said substrate.

This resistance thermometer enables a high long-term stability in the higher temperature range (above 500°C).

(Figure 2)

5786708



- 11 -

REPLACEMENT SHEET

Date : 0.3 DEC 1997.....

Patent Claims

1. A resistance thermometer with a measuring resistor in the form of a resistive layer with a thickness of 0.1 to 10 μm substantially consisting of a metal of the platinum group, which is applied to an electrically insulating surface of a carrier base with a thermal expansion coefficient within the range of 8.5 to 10.5 ppm/K and which is provided with an electrically insulating cover layer, characterized in that a substrate of magnesium titanate is used as a carrier base.
2. A resistance thermometer according to claim 1 characterized in that an intermediate layer is applied between the substrate and the resistive layer.
3. A resistance thermometer according to claim 2 wherein the intermediate layer consists of aluminium oxide or magnesium oxide.
4. A resistance thermometer according to any one of claims 1 to 3 characterized in that the cover layer consists of a borosilicate glass.



Substitute sheet - 1 December 1997

- 12 -

REPLACEMENT SHEET

Date : 03 DEC 1997

5. A resistance thermometer according to claim 4 characterized in that the borosilicate glass has a thickness within the range of 10 μm to 100 μm .
6. A resistance thermometer according to any one of claims 1 to 3 characterized in that the cover layer is a ceramic lamina of magnesium titanate.
7. A resistance thermometer according to claim 6 characterized in that the ceramic lamina has a thickness of 0.1 to 1 mm.
8. A resistance thermometer according to claim 6 or claim 7 characterized in that the ceramic lamina is attached onto the resistive layer and the substrate by means of a ceramic bonding agent or a glass solder.