(54) Title: TEMPERATURE SENSING DEVICE AND METHOD FOR MAKING SAME

(57) Abstract: A temperature sensing device for use with semiconductor processing. The device can include a substrate having a surface and a plurality of temperature sensors formed on the surface. Each of the plurality of temperature sensors can be formed from a thin film resistive trace made from an oxidation resistant material. Each trace can have first and second ends for permitting first and second electrical connections to the trace. A method for making the device is provided.
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TEMPERATURE SENSING DEVICE AND METHOD FOR MAKING SAME

BACKGROUND

Field of the Invention

[0001] The present invention relates to a temperature sensing device, and more particularly to a temperature sensing wafer.

Description of Related Art

[0002] Substrate temperature is often a critical variable in successful processing, especially in the processing of semiconductor wafers. Temperature monitoring, and calibration of processing equipment, may be critical to run processes with exacting requirements. Also, when a wafer process is not providing the desired results, it may be important to be assess the temperatures a wafer is achieving while being run on a heater, electrostatic chuck, or other similar device.

[0003] A known method for determining substrate temperatures during processing is to use what are commonly called TC wafers, or thermocouple wafers. As the name implies, TC wafers are silicon substrates, appropriately sized to match the substrates to be processed, with thermocouples embedded in the silicon wafer. The thermocouples are connected to a data processing machine, and the temperature of the wafer in the various locations of the thermocouples can be recorded during simulated processing.

[0004] TC wafers have a number of limitations which significantly impact their performance:

[0005] TC wafers cannot be operated in conjunction with plasma. Many thin film processes utilize plasma, and in these cases, the plasma can also affect the substrate temperature. Thermocouples utilize a very low voltage DC signal correlated with the TC temperature. This signal is so affected by plasma that it is unusable, making TC wafers applicable only in non-plasma environments.

[0006] TC wafers have high cost, and short lifetimes. The manufacturing processes utilized for TC wafers are largely manual, and therefore labor intensive. Yields are low,
requiring substantial rework. Wiring connections are fragile, allowing many opportunities for damage. And thermocouples themselves are made of metals which are subject to oxidation at elevated temperatures, thereby inducing a built-in mechanism for end-of-life. Typical lifetimes for a TC wafer in production use is on the order of one year.

[0007] TC wafers have limited numbers of sensing locations. The maximum number of sensors currently available on 300mm TC wafers is 34. It is not uncommon for hundreds of individual chips to be manufactured on a 300mm wafer. With only 34 temperature sensing locations, correlation between actual temperature data measured by TC wafers, and processing results is significantly limited.

[0008] What is needed is a temperature sensing substrate which can be operated in plasma, with many sensing points, with a robust mechanical design and good oxidation resistance for long lifetime.

**Brief Description of the Drawings**

[0009] FIG. 1 is a view of a temperature sensing device according to some embodiments of the present invention.

[0010] FIG. 2 is a view of a TCR-based temperature sensor according to some embodiments of the present invention.

[0011] FIG. 3 is a view of an embodiment of the TCR-based temperature sensor of FIG. 2 with certain dimensions noted thereon.

[0012] FIG. 4 is a view of a TCR-based temperature sensor according to some embodiments of the present invention.

[0013] FIG. 5 is a view of an embodiment of the TCR-based temperature sensor of FIG. 4 with certain dimensions noted thereon.

[0014] FIG. 6 is a view of a TCR-based temperature sensor according to some embodiments of the present invention.

[0015] FIG. 7 is a view of an embodiment of the TCR-based temperature sensor of FIG. 6 with certain dimensions noted thereon.
Detailed Description

[0016] In one embodiment, a temperature sensing wafer or device which allows for a large number of sensing positions on a single substrate is provided. The sensing positions, which in one embodiment can be temperature sensors, may be put onto a silicon wafer and may be of a high temperature coefficient material. Changes in resistance of the sensing positions or temperature sensors allow for determination of temperatures for the sensing positions or temperature sensors.

[0001] The embodiments of the invention set forth below are examples of the invention, and may in some instances be broader than the foregoing embodiment of the invention but are not intended to limit the breadth of the foregoing embodiment or the breadth of the invention. Additional features of the invention set forth in such embodiments are optional. A feature of any embodiment set forth below can be combined with the foregoing embodiment, with or without any other feature of any embodiment set forth below. All characteristics, steps, parameters and features of the methods below are not limited to the specific embodiments or specific parts set forth below, but instead are equally applicable to the foregoing embodiment of the invention and to all embodiments of the invention. Broad terms and descriptors are replaced with more specific terms and descriptors not to limit a disclosure to a specific term or descriptor but merely for ease of discussion and understanding.

[0017] In one embodiment of the invention, a temperature-testing wafer or device with a plurality of temperatures thereon is provided. The wafer can be of any suitable size and shape, for example the size and shape of a wafer to be processed in a semiconductor processing chamber. The temperature-testing wafer can be utilized to measure the temperature of a variety of locations on the top surface of a pedestal of a heater or electrostatic chuck provided in the chamber. In one embodiment, such temperature measurements can be used to characterize or calibrate a heater.

[0018] At least one temperature sensor, and in one embodiment a plurality of temperature sensors, can be provided on the temperature-testing wafer. When a plurality of temperature sensors are utilized, they can be arranged in any suitable pattern on the wafer. In one embodiment, such pattern can correspond in some manner to the heating elements provided in the heater pedestal. In one embodiment, a plurality of temperature sensors are spaced across the entire surface of the temperature-sensing wafer. In one embodiment, a plurality of temperature sensors are evenly spaced across the entire surface of the temperature-sensing
wafer. In one embodiment, a plurality of temperature sensors are spaced across the entire surface of the temperature sensing wafer to facilitate temperature readings across the entire surface of the pedestal. In one embodiment, one or more temperature sensors are provided on the top surface of the wafer, but is appreciated that the one or more temperature sensors can be provided on the bottom of the wafer or any combination of sensors on the top and bottom surface of the wafer. Each of the temperature sensors can be of any suitable type, and in one embodiment each of the temperature sensors is formed from a thin film resistive trace provided on the surface of the wafer. Each of the traces can be formed in any suitable pattern. In one embodiment, the thin film resistive trace of each sensor is identical. In one embodiment, a plurality of patterns of traces can be provided for the plurality of sensors. In one embodiment, each of the sensors can be formed from a distinct trace. In one embodiment, a plurality of patterns can be provided and one or more sensors can be formed from one of such plurality of patterns of traces. In one embodiment, each of the traces is formed from any suitable oxidation resistant material, and in one embodiment each of the traces is formed from the same oxidation resistant material.

[0019] As used herein, the term oxidation resistant material means a metallic material that resists chemical degradation caused by the action of air or other gaseous mediums utilized in semiconductor processing chambers. Such oxidation resistant materials include molybdenum, tungsten, silicon-germanium and manganite-silver.

[0020] In some embodiments of the present invention, as seen in FIG. 1, a temperature sensing wafer or device 11 is provided. The wafer or device 11 includes a wafer 12 be formed from any suitable material. In one embodiment, the wafer 12 of device 11 is formed from silicon. The wafer 12 can be circular in shape and provided with opposite top and bottom surfaces 13. In one embodiment, each of the surfaces 13 is planar. In one embodiment, the large gray circle represents a 300mm silicon wafer, a typical substrate used for temperature sensing devices. One or more temperature sensors 16 can be provided on one or both of surfaces 13 as discussed above. In one embodiment, a plurality of temperature sensors 16 are provided on the top surface 13 of the wafer 12. As discussed above, the plurality of temperature sensors can be arranged on surface 13 in any suitable pattern or configuration. In FIG. 1, for simplicity only a four temperature sensors 16 of a pattern are illustrated on wafer 12, it being appreciated that device 11 illustrated in FIG. 1 includes additional temperature sensors 16 on top surface 13 in such pattern of temperature sensors. Each of the temperature sensors 16 can be formed from a thin film resistive trace 17
deposited or otherwise formed on surface 13 in any suitable manner. As discussed above, each trace 17 can be formed in a pattern 18. In the embodiment of FIG. 1, each trace 17 is formed from the same pattern 18, although the pattern 18 of each trace 17 on wafer 12 can be different or one or more traces 17 can be formed form the same pattern 18. In the embodiment of FIG. 1, the black spirals of each trace 17 represent circuits of any suitable oxidation resistant material. In one embodiment, the oxidation-resistant material is a high TCR, oxidation-resistant material, such as molybdenum, tungsten, silicon-germanium or manganite-silver. As noted above, four such circuits are shown, but is can be seen that many of these circuits can be applied. With standard sputtering or electrochemical plating methods, it is possible to apply hundreds of such circuits, which would be sufficient for most applications, and lower cost than utilizing CVD and etch processes such as those used in semiconductor manufacturing.

[0021] The lines 21 connected to each end of the black spiral trace 17 at the top of the wafer represent sample electrical connections to the temperature sensing circuit of the temperature sensor 16. Soldering pads (not shown in FIG. 1) may be applied to each end of the temperature sensing circuits or pattern 18, and wires could be directly soldered to those pads. In one embodiment, connecting traces of near-zero TCR materials (such as NiCr or AgPt) could be applied in patterns complimentary to the spirals utilizing the same sputtering or plating methods utilized to apply the temperature sensing circuits. Those traces could be routed to locations on the substrate where making mechanical connections of signal wires is convenient. In one embodiment, connecting traces of copper may be used in conjunction with resistive trace elements of higher resistance.

[0022] In one embodiment, copper traces are used to route connection to the temperature sensors 18. In some aspects, a multi-layer trace approach may be used to create a temperature sensing wafer with a plurality of high TCR temperature sensing circuits interconnected with a plurality of copper traces.

[0023] FIGS. 2-7 illustrate other sample patterns which may be used for the temperature sensors 18 of device 11 to provide temperature sensing in accord with the above descriptions. The temperature sensing circuits need not be spiral in shape, many different shapes could be utilized, as seen in FIGS. 2-7. For example, temperature sensor 31 illustrated in FIGS. 2-3 is formed from a thin film resistive trace 32 having a zig-zag or serpentine shape or pattern 33. The circuit 36 provided by trace 32 has first and second ends 37, 38 provided with respective
soldering pads 41, 42 thereon for permitting connections to the circuit 36. Sample dimensions of one embodiment of the trace 32 and pattern 33 are provided in FIG. 3. Sample temperature sensor 51 illustrated in FIGS. 4-5 is formed from a thin film resistive trace 52 formed with concentric circular segments 53 so as to have a circular-like pattern 54. The circuit 56 provided by trace 52 has first and second ends 57, 58 provided with respective soldering pads 61, 62 thereon for permitting connections to the circuit 56. Soldering or connection pads 61, 62 are adjacent to each other at the periphery or outside of the pattern 54 to facilitate electrical connection to the pads 61, 62 and thus sensor 51. Sample dimensions of one embodiment of the trace 52 and pattern 54 are provided in FIG. 5. Sample temperature sensor 71 illustrated in FIGS. 6-7 is similar in shape to temperature sensor 31 and is formed from a thin film resistive trace 72 having a zig-zag or serpentine shape or pattern 73. The circuit 76 provided by trace 72 has first and second ends 77, 78 provided with respective soldering pads 81, 82 thereon for permitting connections to the circuit 76. Soldering or connection pads 81, 82 extend outside the profile of pattern 73 to facilitate electrical connection to the pads 81, 82 and thus sensor 71. Sample dimensions of one embodiment of the trace 72 and pattern 73 are provided in FIG. 7.

[0024] Materials, including the materials of temperature sensors of the invention, have a property which is called TCR, or Thermal Coefficient of Resistance. This property is defined as the change in electrical resistance as a function of temperature for any given material, including for the oxidation resistant materials of the invention. If the TCR of a given material is high enough, then it is possible to utilize the electrical resistance change in said material as a measurement of temperature. Measurement of the resistance of the subject material at a first temperature, and then a second temperature, and correlating the resistance measurements to those temperatures provides an accurate, repeatable method for utilizing electrical resistance measurements to determine temperature.

[0025] Utilizing electrical resistance measurements correlated to temperature provides the ability to operate in a plasma environment. Electrical resistance measurements can be done with signals strong enough to filter out the electrical noise induced by plasma which drowns thermocouple signals. There are many materials with TCR values high enough for practical use of resistance levels correlated with temperature. Many of those materials are oxidation resistant, particularly at elevated temperatures, eliminating the oxidation issue inherent with thermocouples. Such materials include the oxidation resistant materials of the invention.
Small circuits of a suitable material can easily be deposited onto a temperature measuring substrate utilizing methods such as sputtering or electrochemical plating among others, allowing for the use of hundreds or thousands of sensing locations on a 300mm wafer. Such circuits can be formed from thin film resistive traces, and can form the temperature sensors of the invention.

It is proposed to leverage the change in resistance with temperature of thin or thick film deposited patterns, using VI (Ohm’s Law) techniques, for characterizing the temperature of the patterns and thereby the surface(s) upon which they are deposited.

Materials, such as the oxidation resistant materials of the invention, with large temperature coefficients of resistance, or TCRs, lend themselves best to this application inasmuch as small changes in temperature result in larger changes in resistance than do materials with low TCRs. Importantly the reverse is also true: the relation of the resistance to be measured to the corresponding temperature, and so large TCR materials afford better resolution in this approach to temperature measurement.

Among the challenges in implementing this approach is the required reduction of “parasitic” resistance contributed by connection circuitry, for example the connection leads to the temperature sensors of the invention, between the deposited patterns and the measurement instrumentation. The connection circuitry will have some resistance that requires its subtraction from the measured values. Also, the connection circuitry will have its own TCR value(s) that similarly require compensation when deriving the pattern temperature(s).

Available approaches to compensating for connection TCR include:

Employ connection material(s) that have very linear TCRs in the temperature range of interest. Linear connection TCRs allow a simple numerical correction to the measured values in a way the same as the required correction for the baseline connection resistance. In other words, we subtract $R + \Delta R$ of the connection material. This is much easier if the $\Delta R$ component is linear. If it is not linear, then the TCR curve must be incorporated as a nonlinear equation or as a “lookup table” to allow correct compensation.

Employ connection material(s) that have sufficiently small TCRs to be ignored. There are some candidates, as we shall see.

In some aspects, molybdenum is used as the material for the temperature sensor. In some aspects, tungsten in used as the material for the temperature sensor.
Molybdenum may be used as an exemplary material for the temperature measurement patterned position sensors. Its characteristic resistivity curve is seen in Table 1.

![Molybdenum Resistivity](image)

**Table 1**

The resistance of a conductor has a relationship of $R = \rho L / A$ where $L$ is the length of the conductor, $A$ is the cross-sectional area, and $\rho$ is the resistivity. For a given deposited pattern, $L$ and $A$ are fixed, and so the resistance of the pattern is directly proportional to the material resistivity. Working with the linear regression equation shown in Table 1, we can quickly determine that a 1% change, or error, in the measured resistance (resistivity) equates to a 5 degree change, or error, in the corresponding temperature. This is an attribute to the slope of the resistivity curve.

In order to measure to better than 1% accuracy (5 degrees C) using the strategy of using low TCR connections, we now have a discriminator for their selection - the TCR contribution of the connecting wires should be on the order of .1%, or a corresponding 0.5 degrees C temperature error, in order to be considered negligible. In some aspects, this is achieved using a lower resistance sensor in conjunction with very low TCR connection materials. In some aspects, this is achieved using a higher resistance sensor with connection materials that are more typical of IC processing techniques, such as copper traces.

Exemplary connection materials include Constantan (aka Ferry Alloy, 55% Ni, 55% Cu), Manganin (CuMnNi), and Evanohm R and S alloys (NiCrAlCuMnSi), among others.
In an exemplary preliminary design, Ferry Alloy, with a TCR (α) of .000030 ohms/C was selected. Molybdenum has a TCR of .004579 or a bit more than 100X that of Ferry. Although that provides the sought 1%, another decade of relative resistance between the measurement pattern resistance and the connection resistance is desired/needed.

Using an approximation of 3 feet for connection lead length, a pair of 22 gauge Ferry Alloy wires has a combined resistance of 3 ohms. Using a moly pattern designed to have 30 ohms at a temperature of 550C, there is then an additional decade of relative TCR effect, or 1000:1 between the molybdenum and the connecting leads. This, in turn, translates to molybdenum patterns with a room temperature resistance of 8.75 ohms.

Another approach to reduce or eliminate the effect of parasitic resistances, or to otherwise reduce the effect of lead wire changes, is to use a temperature measurement patterned sensor which has a resistance that is significantly higher than that of the connection wires, or connection traces. In some aspects, temperature measurement patterned sensors are used which have resistances on the order of two (or more) orders of magnitude higher than that of the connection wire resistances for that circuit.

In an exemplary embodiment wherein the patterned temperature measurement sensor is a thin film resistive element with a resistance of 2000 Ohms. Copper lead traces may be used with a resistance of 25 Ohms. With a TCR for copper of 0.0039 ohm/C, the resistance change in the lead wires (or traces) over a 500C change in temperature would be 500 x 0.0039, which is approximately 2 ohms. With a resistive element resistance of 2000 Ohms, the variation introduced by the copper leads is low enough that it would not interfere with a design of 0.5 degree accuracy, for example. In practice, the resistance of the lead wires and connecting traces for each patterned temperature measurement sensor could be measured and then subtracted from the measured resistance value of the circuit, allowing for a more accurate temperature measurement based on the change in resistance of the high TCR thin film resistance element.

With the use of tungsten or molybdenum thin film elements as the high TCR resistive element, and then the use of copper, for example, traces for the leads to these high TCR resistive elements, a temperature sensing wafer may be fabricated using known and achievable processes.
In another exemplary embodiment, a temperature sensor is made with tungsten applied with a thin film deposition technique. The thin film resistance of a 0.25 micron film of tungsten is approximately $4 \times 10^4 \Omega$/sq. With such a resistance, for each 1000 Ohm of resistance a sensor trace length of approximately 2.5 cm is needed, such that a 10,000 Ohm trace would be 25 cm in length. With a 1 micron copper trace at each end of the resistive sensor trace of 300 mm (600 mm total), the resistance of the copper lead traces would be approximately 50 Ohms.

In some embodiments, the resistance of the temperature sensor of the invention is at least 1000 Ohms. In some embodiments, the resistance of the temperature sensor of the invention is greater than 1000 Ohms. In some embodiments, the resistance of the temperature sensor is in the range of 1000 to 10,000 Ohms. In some embodiments, the resistance of the temperature sensor is in the range of 2000 to 6000 Ohms. In some embodiments, the temperature sensor is made from any suitable oxidation-resistant materials. In some embodiments, the temperature sensor comprises molybdenum. In some embodiments, the temperature sensor comprises tungsten. In some embodiments, the temperature sensor of the invention, including those discussed in this paragraph, is referred to as a patterned temperature sensor.

In one embodiment using high resistance sensors, a plurality of patterned temperature measurement sensors or temperature sensors are created of tungsten using a thin film deposition technique. The thin film tungsten traces may have a resistance in the range of 1000 to 10000 Ohms. In one embodiment using high resistance sensors, a plurality of patterned temperature measurement sensors or temperature sensors are created of molybdenum using a thin film deposition technique. The thin film molybdenum traces may have a resistance in the range of 1000 to 10000 Ohms.

In one embodiment, a temperature sensing device for use with semiconductor processing is provided and can include a substrate having a surface, a plurality of temperature sensors formed on the surface, each of the plurality of temperature sensors formed from a thin film resistive trace made from an oxidation resistant material, each trace having first and second ends for permitting first and second electrical connections to the trace.

The substrate can be a silicon wafer. The wafer can have a size corresponding to the size of a conventional wafer used in mass semiconductor processing. The oxidation resistant material can have a high temperature coefficient of resistivity. The oxidation
resistant material can be selected from the group consisting of molybdenum and tungsten. Each thin film resistive trace can have a resistance between the first and second ends of at least 1000 ohms. The resistance of the thin film resistive trace between first and second ends can be in the range of 1000 to 10000 ohms. The temperature sensing device can include a first connection lead coupled to the first end of each thin film resistive trace and a second connection lead coupled to the second end of each thin film resistive trace. Each thin film resistive trace can have a resistance and the respective first connection lead and the second connection lead of the trace can have a combined resistance that is less than 10% of the resistance of the trace. Each thin film resistive trace can have a resistance and the respective first connection lead and the second connection lead of the trace can have a combined resistance that is less than 1% of the resistance of the trace. Each of the first and second connection leads can be made of copper. Each of the first and second connection leads can be a thin film deposited on the substrate. Each thin film resistive trace can be a deposited thin film resistive trace having a thickness of less than one micron.

[0047] In one embodiment, a method for manufacturing a temperature sensing device is provided and includes depositing a plurality of thin film resistive traces made from an oxidation resistant material on a substrate, each of the thin film resistive traces having first and second ends, depositing a first connection lead to the first end of each thin film resistive trace and depositing a second connection lead to the second end of each thin film resistive trace.

[0048] The substrate can be a silicon wafer. The oxidation resistant material can be selected from the group consisting of molybdenum and tungsten. Each thin film resistive trace can have a resistance between the first and second ends of at least 1000 ohms. Each thin film resistive trace can have a resistance and the respective first connection lead and the second connection lead of the trace can have a combined resistance that is less than 10% of the resistance of the trace. Each thin film resistive trace can have a resistance and the respective first connection lead and the second connection lead of the trace can have a combined resistance that is less than 1% of the resistance of the trace.

[0049] In one embodiment, a temperature sensing wafer is provided and can include a substrate and a plurality of temperature sensing positions on said substrate, wherein each of said plurality of temperature sensing positions comprises a pattern of high temperature
coefficient of resistivity material, said pattern of high temperature coefficient of resistivity material having a first end and a second end.

[0050] The high temperature coefficient of resistivity material can be molybdenum. The high temperature coefficient of resistivity material can be tungsten. The temperature sensing wafer can include a plurality of connection leads, wherein each of the plurality of temperature sensing positions has a first connection lead coupled to its first end and a second connection lead coupled to its second end. The resistance of the molybdenum sensing position pattern can be in the range of 1000 to 10000 ohms. The resistance of the tungsten sensing position pattern can be in the range of 1000 to 10000 ohms. The combined resistance of the first connection lead and the second connection lead can be less than 10% of the resistance of the molybdenum sensing position pattern. The combined resistance of the first connection lead and the second connection lead can be less than 1% of the resistance of the molybdenum sensing position pattern. The combined resistance of the first connection lead and the second connection lead can be less than 10% of the resistance of the tungsten sensing position pattern. The combined resistance of the first connection lead and the second connection lead can be less than 1% of the resistance of the tungsten sensing position pattern. The connection leads can be copper. The molybdenum sensing position pattern can be deposited on said substrate to a thickness of less than one micron. The connection leads can be copper traces deposited on said substrate. The molybdenum sensing position pattern can be deposited on said substrate to a thickness of less than one micron. The connection leads can be copper traces deposited on said substrate.

[0051] In one embodiment, a method for manufacturing a temperature sensing wafer is provided and can include depositing a plurality of patterns of high temperature coefficient of resistivity material on a substrate, depositing a first connection lead to a first end of said patterns of high temperature coefficient of resistivity material and depositing a second connection lead to a second end of said patterns of high temperature coefficient of resistivity material.

[0052] The high temperature coefficient of resistivity material can be molybdenum. The high temperature coefficient of resistivity material can be tungsten. The combined resistance of the first connection lead and the second connection lead connected to a pattern of high temperature coefficient of resistivity material can be less than 10% of the resistance of the pattern. The first connection lead and the second connection lead connected to a pattern of
high temperature coefficient of resistivity material can be less than 1% of the resistance of the pattern.

[0053] As evident from the above description, a wide variety of embodiments may be configured from the description given herein and additional advantages and modifications will readily occur to those skilled in the art. The invention in its broader aspects is, therefore, not limited to the specific details and illustrative examples shown and described. Accordingly, departures from such details may be made without departing from the spirit or scope of the applicant’s general invention.
What is claimed is:

1. A temperature sensing device for use with semiconductor processing, comprising a substrate having a surface, a plurality of temperature sensors formed on the surface, each of the plurality of temperature sensors formed from a thin film resistive trace made from an oxidation resistant material, each trace having first and second ends for permitting first and second electrical connections to the trace.

2. The temperature sensing device of Claim 1, wherein the substrate is a silicon wafer.

3. The temperature sensing device of Claim 2, wherein the wafer has a size corresponding to the size of a conventional wafer used in mass semiconductor processing.

4. The temperature sensing device of Claim 1, wherein the oxidation resistant material has a high temperature coefficient of resistivity.

5. The temperature sensing device of Claim 4, wherein the oxidation resistant material is selected from the group consisting of molybdenum and tungsten.

6. The temperature sensing device of Claim 1, wherein each thin film resistive trace has a resistance between the first and second ends of at least 1000 ohms.

7. The temperature sensing device of Claim 6, wherein the resistance of the thin film resistive trace between first and second ends is in the range of 1000 to 10000 ohms.

8. The temperature sensing device of Claim 1, further comprising a first connection lead coupled to the first end of each thin film resistive trace and a second connection lead coupled to the second end of each thin film resistive trace.

9. The temperature sensing device of Claim 8, wherein each thin film resistive trace has a resistance and wherein the respective first connection lead and the second connection lead of the trace have a combined resistance that is less than 10% of the resistance of the trace.

10. The temperature sensing device of Claim 8, wherein each thin film resistive trace has a resistance and wherein the respective first connection lead and the second connection lead of the trace have a combined resistance that is less than 1% of the resistance of the trace.

11. The temperature sensing device of Claim 8, wherein each of the first and second connection leads is made of copper.

12. The temperature sensing device of Claim 8, wherein each of the first and second connection leads is a thin film deposited on the substrate.
13. The temperature sensing device of Claim 1, wherein each thin film resistive trace is a deposited thin film resistive trace having a thickness of less than one micron.

14. A method for manufacturing a temperature sensing device, comprising depositing a plurality of thin film resistive traces made from an oxidation resistant material on a substrate, each of the thin film resistive traces having first and second ends, depositing a first connection lead to the first end of each thin film resistive trace and depositing a second connection lead to the second end of each thin film resistive trace.

15. The method of Claim 14, wherein the substrate is a silicon wafer.

16. The method of Claim 14, wherein the oxidation resistant material is selected from the group consisting of molybdenum and tungsten.

17. The method of Claim 14, wherein each thin film resistive trace has a resistance between the first and second ends of at least 1000 ohms.

18. The method of Claim 14, wherein each thin film resistive trace has a resistance and wherein the respective first connection lead and the second connection lead of the trace have a combined resistance that is less than 10% of the resistance of the trace.

19. The method of Claim 14, wherein each thin film resistive trace has a resistance and wherein the respective first connection lead and the second connection lead of the trace have a combined resistance that is less than 1% of the resistance of the trace.
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - H01L 21/3205, 21/66, 23/58, 41/08; G01K 7/16, (2016.01)
CPC - H01L 21/67, 21/67248, 23/58, 41/08; G01K 7/16
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED
Minimum documentation searched (classification system followed by classification symbols)
IPC(8) - H01L 21/3205, 21/66, 23/58, 35/00, 35/08, 35/10, 35/32, 41/08, 41/083; G01K 7/01, 7/02, 7/16, 13/10 (2016.01)
CPC - H01L 21/67, 21/67248, 23/58, 35/00, 35/08, 35/10, 35/32, 41/0471, 41/08, 41/083; G01K 7/01, 7/02, 7/16, 13/10

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
Patent (US, EP, WO, JP, DE, GB, CN, FR, KR, ES, AU, IN, CA, INPADOC Data); EBSCO; IEEE; Google Scholar:
temperature sensor, thermal, detector, probe, substrate, wafer, resistive, thin film, trace

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
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<tbody>
<tr>
<td>X</td>
<td>US 7,495,542 B2 (SAIO, K et al.) 24 February 2009; title; abstract; figures 3, 7; column 2, lines 50-57; column 3, lines 1-16, 30-34; column 6, lines 54-67; column 7, lines 21-24; column 8, lines 3-8; column 9, lines 26-32; column 10, lines 35-41; claim 1</td>
<td>1, 8, 12, 14</td>
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<td>Y</td>
<td>US 6,190,040 B1 (RENKEN, WG et al.) 20 February 2001; column 8, lines 32-36; column 9, lines 24-28</td>
<td>2-3, 15</td>
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<tr>
<td>Y</td>
<td>US 2006/0267724 A1 (PARSONS, JD) 30 November 2006; abstract; paragraphs [0025]-[0026], [0046], [0060], [0064]</td>
<td>4-5, 13, 16</td>
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<tr>
<td>Y</td>
<td>US 2012/0275484 A1 (HAYASHI, M et al.) 1 November 2012; abstract; figure 3; paragraphs [0032], [0034], [0051]-[0052]</td>
<td>6-7, 17</td>
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Further documents are listed in the continuation of Box C. See patent family annex.

* Special categories of cited documents:
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Date of the actual completion of the international search
24 August 2016 (24.08.2016)

Date of mailing of the international search report
15 SEP 2016

Name and mailing address of the ISA/
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P.O. Box 1450, Alexandria, Virginia 22313-1450
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PCT Helpdesk: 571-272-4300
PCT OSP: 571-272-7774

Form PCT/ISA/210 (second sheet) (January 2015)