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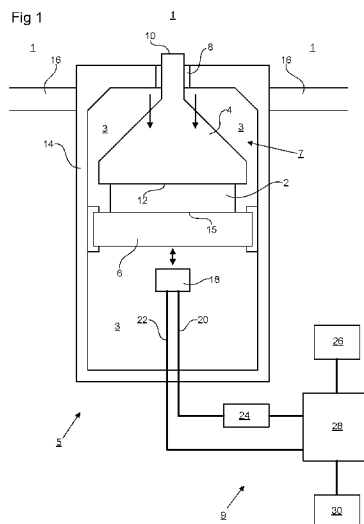
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(57) Abstract: The invention relates to a pressure sensor, particularly for use at extremely high temperatures and/or pressures. In a disclosed embodiment, the pressure sensor is configured to measure the pressure in a test environment and comprises: a housing comprising a chamber that is sealed from the test environment; a force-transmitting element comprising an outer surface and an inner surface, the outer surface being exposed directly to the test environment and the inner surface being arranged to face into the chamber, the force-transmitting element being slidably mounted within the housing so that a force applied to the outer surface is transmitted to the inner surface; a sensor element mounted in the chamber and configured to receive a force transmitted by the force-transmitting element via the inner surface of the force-transmitting element; and a measurement system configured to measure a change of a dimension of the sensor element and/or of a dimension of a region within the sensor element, caused by the force transmitted thereto by the force-transmitting element, thereby providing a measure of the pressure in the test environment

PRESSURE SENSOR

The invention relates to a pressure sensor for measuring the pressure in a test environment, and is particularly relevant to test environments at extremely high temperatures and/or pressures, for example in region of 1-15GPa and 2000 degrees C.

Various types of pressure sensor are known in the art which allow remote interrogation of pressure in a test environment.

For example, a sensor is known which comprises an element, such as a membrane, which deflects by an amount which is indicative of the pressure in the test environment. Optical measurement devices can be used to measure the deflection remotely and thereby obtain a measurement of the pressure in the test environment. A problem with this approach, however, is that fluctuations in the pressure can lead to fatigue and eventual failure of the deflecting element. Furthermore, deflecting elements in known sensors are not able to withstand environments where the pressure is above 1 GPa and the temperature is in the region of 2000 degrees C or greater.

X-rays can be used to interrogate changes in the unit cell size of test samples positioned within the test environment. Ruby chips can be placed within the test environment and a laser used to cause fluorescence of the chips. Measuring changes in the colour of the fluorescence can be used to determine the pressure in the test environment. However, using X-rays or ruby fluorescence requires complex apparatus and may not be suitable for use where the test environment is difficult to access or where space is limited. Furthermore, where the test environment is at high temperature as well as high pressure, interpretation of the x-ray or ruby fluorescent pressure analysis may be more complicated and apparatus associated with these methods may be damaged by the high temperatures.

It is an object of the invention to provide an alternative pressure sensor which at least partially addresses one or more of the problems discussed above.

According to an aspect of the invention, there is provided a pressure sensor for measuring the pressure in a test environment, comprising: a housing comprising a chamber that is sealed from the test environment; a force-transmitting element comprising an outer surface and an inner surface, the outer surface being exposed directly to the test environment and the inner surface being arranged to face into the chamber, the force-transmitting element being slidably mounted within the housing so that a force applied to the outer surface is transmitted to the inner surface; a sensor element mounted in the chamber and configured to receive a force transmitted by the force-transmitting element via the inner surface of the force-transmitting element; and a measurement system configured to measure a change of a dimension of the sensor element and/or of a dimension of a region within the sensor element, caused by the force transmitted thereto by the force-transmitting element, thereby providing a measure of the pressure in the test environment.

Thus, an arrangement is provided in which a sensor element is separated from the test environment

by a force-transmitting element. The sensor element can therefore be exposed to lower temperatures and/or different pressures than are present in the test environment.

In an embodiment, the force-transmitting element serves to reduce the pressure applied to the sensor element relative to the pressure in the test environment, which expands the range of materials that can be used for the sensor element.

In other embodiments, the force-transmitting element may increase the pressure that is applied to the sensor element relative to the test environment, which may improve the sensitivity of the pressure measurement.

The force-transmitting element may provide thermal insulation between the sensor element and the test environment. This reduces the temperature that the sensor element has to withstand and also reduces the effect of temperature on the dimensions of the sensor element, thus helping to increase the accuracy of the pressure measurement and/or simplify processing of the measurements of the dimensions of the sensor element. Reducing the temperature at the sensor element relative to the test environment also increases the range of different techniques that can be used for measuring the changes in the dimension of the sensor element, thus simplifying construction, reducing cost and/or improving accuracy and reliability.

Embodiments of the invention will now be described, by way of example only, with reference to the accompanying drawings in which corresponding reference symbols indicate corresponding parts, and in which:

Figure 1 depicts a pressure sensor comprising a force-transmitting element which acts as a pressure reducing element and a measurement system configured to measure optically a change in a dimension of a sensor element;

Figure 2 depicts an embodiment in which the sensor element comprises a plurality of semi-reflective layers embedded within the sensor element for measuring differential changes in the geometry of the sensor element;

Figure 3 depicts an embodiment in which the sensor element comprises an opening for allowing optical access to an inner surface of the force-transmitting element;

Figure 4 depicts an embodiment in which conductive layers are provided on the inner surface of the force-transmitting element and on an upper surface of a support table for supporting the sensor element;

Figure 5 depicts an embodiment in which the force-transmitting element acts as a pressure increasing element.

Figure 1 depicts an example pressure sensor 5 according to an embodiment. The pressure sensor 5 is configured to measure the pressure in a test environment 1. In this embodiment, the pressure sensor 5 comprises a housing 14 which is configured to protrude into the test environment 1 through a wall 16 of the test environment 1. The wall 16 of the test environment 1 and at least the upper region of the housing 14 of the pressure sensor 5 are configured (e.g. thickened) so as to be able to withstand the pressures and

temperatures within the test environment 1. Regions 3 that are separated from the test environment 1 are maintained at a lower pressure and/or temperature than that present within the test environment 1.

In an embodiment, the housing 14 comprises a chamber 7 that is substantially sealed from the test environment 1. For example, the seal may be such that the pressure in the chamber 7 is substantially maintained at atmospheric pressure. A force-transmitting element 4 is provided within the pressure sensor 5. The force-transmitting element 4 comprises an outer surface 10 and an inner surface 12. The outer surface 10 is arranged so as to be directly exposed to (e.g. to face into and/or be in contact with) the test environment 1. The inner surface 12 is arranged to face into the chamber 7. In an embodiment, the force-transmitting element 4 is formed such that there is a significant thermal resistance between the sensor element 2 and the test environment, such that in use there is a substantial temperature gradient along the force-transmitting element. This approach means that the sensor element 2 and/or components in close proximity to the sensor element 2 do not need to withstand the temperatures of the test environment.

In an embodiment, the force-transmitting element 4 is slidably mounted within the housing 14 so that a force applied to the outer surface 10 by the pressure in the test environment 1 is transmitted to the inner surface 12. In the embodiment shown, a sliding seal 8 is provided to allow the force-transmitting element 4 to slide within the housing 14 while at the same time sealing the test environment 1 from the environment 3 within the chamber 7. In an embodiment, the force-transmitting element 4 and the sensor element 2 are configured to remain in their solid states during operation of the sensor. Thus, the sliding seal 8 is configured to accommodate sliding of a solid member through it, rather than a liquid or gaseous member.

A sensor element 12 is mounted within the chamber 7 and configured to receive a force transmitted by the force-transmitting element 4 via the inner surface 12 of the force-transmitting element 4. In the example shown, the sensor element 2 is compressed between the inner surface 12 of the force-transmitting element 4 and an upper surface 15 of a support table 6 for supporting the sensor element 2.

A measurement system 9 is provided for measuring a change in a dimension of the sensor element 2, and/or of a dimension of a region within the sensor element 2, caused by the force transmitted to the sensor element 2 by the force-transmitted element 4. Calibration measurements and/or mathematical analysis may be used to determine the relationship between the measured change in the dimension of the sensor element 2 (and/or of regions within the sensor element 2) and the pressure and/or temperature within the test environment 1. The measurement system is thereby able to provide a measure of the pressure and/or temperature within the test environment 1.

In an embodiment, the sensor element 2 is formed from an elastic material. In an embodiment, the pressure sensor is configured so that compression of the sensor element 2 is such as to remain within the elastic limits of the sensor element 2. In this way, fatigue to the sensor element 2 due to variations in the pressure in the test environment 1 (which will result in corresponding variations in the degree of compression of the sensor element 2) may be reduced. In an embodiment, the sensor element 2 is formed

from platinum, diamond, or a nickel based alloy such as invar. Invar may be particularly advantageous because of its extremely low coefficient of thermal expansion. Thus, any change in the dimensions of the invar are likely to be dominated to a very large extent by the effects of the force applied to the invar by the force-transmitting element 4, thus reducing or obviating the need to correct for temperature and/or improving the accuracy of the pressure measurement.

In an embodiment, the sensor element 2 and/or force-transmitting element 4 is/are each formed from a solid, compositionally uniform structure, characterized for example by an absence of cavities (or inclusions of gas or liquid) and/or by the absence of inclusions of a different composition (excluding inclusions that are present at the atomic or molecular level). Cavities (or inclusions of gas or liquid) may explode at high temperatures, implode at high pressures, and/or otherwise cause structural failure within the sensor.

In the particular example shown, the measurement system 9 comprises optical fibres 20 and 22 for directing radiation towards the sensor element 2 and/or for receiving radiation reflected or emitted from the sensor element 2 and/or from the inner surface 12 of the force-transmitting element 4 and/or from the upper surface of the support table 6. In the particular example shown, a beam splitter 28 is provided for channelling radiation to and from a light source 26 and a detector 30. A phase compensator 24 may be provided along one of the optical fibres 20 to cause and/or control the phase difference between coherent radiation reflected from different interfaces within the pressure sensor. Changes in the nature of a interference fringes detected by the detector 30 can be used to determine corresponding changes in the separation between interfaces from which the radiation is reflected or emitted.

For example, the measurement system 9 can be configured to measure interferometrically changes in the separation between the inner surface 12 of the force-transmitted element 4 and the upper surface 15 of the support table 6 in order to measure a change in the corresponding dimension (i.e. height/thickness) of the sensor element 2.

In the example shown, an optical element 18 is provided for conditioning radiation output by the optical fibres 20 and 22. In an embodiment, the optical element 18 comprises a lens, for example a ball lens, that is configured to collimate the beam output from the optical fibres 20 and 22. In the example shown, two optical fibres 20 and 22 are depicted. However, this is not essential. Fewer than two or more than two optical fibres may be provided. Other mechanisms for directing the radiation to the sensor element 2 may be provided. In an embodiment, the light source 26 is configured to output a single wavelength or range of wavelengths. In other embodiments, multiple different wavelengths or different ranges of wavelengths may be used. To reduce noise in the signal detected by the detector 30, various techniques known in the art may be used. For example, frequency modulation and/or optical coherent tomography (OCT) may be used.

In an embodiment, as shown, all of the elements of the measurement system 9 are separated from the test environment 1 (i.e. none of the elements is exposed directly to the pressures and/or temperatures of the test environment 1). However, this is not essential. In other embodiments, one or more of the components

of the measurement system may be located within the test environment 1 and/or exposed to the test environment 1. Optical materials that are resistant to high temperature and/or pressures, such as diamond, sapphire, or ruby quartz, may be used for elements that are exposed to the test environment 1. Similarly, such materials can be used for elements that are not directly exposed to the test environment but which are nevertheless exposed to high temperatures and/or pressures in regions proximate to the test environment 1.

In order to allow optical access to the sensor element 2, the support table 6 may be formed from an optically transparent material. For example, diamond, sapphire, or ruby quartz may be used. In an embodiment, the force-transmitting element 4 is also formed from an optically transparent material (for example diamond, sapphire, or ruby quartz), but this is not essential. In other embodiments an opaque material is used for this element (e.g. tungsten carbide).

Figure 2 depicts an alternative embodiment in which the sensor element 2 comprises a plurality of semi-reflective layers 32 embedded within the sensor element 2. In this embodiment, the measurement system 9 is configured to measure optical radiation reflected from the semi-reflective layers 32 and/or the upper surface 15 of the support table 6 and/or the inner surface 12 of the force-transmitting element 4. The semi-reflective layers 32 may be interstitial layers for example. Interferometry may be used to measure the separation between different pairs of reflective interfaces. In this way, it is possible to measure the differential compression within the sensor element 2 (i.e. the variation of compression as a function of position within the sensor element 2). The compression within the sensor element 2 may vary, for example, as a function of the temperature within the sensor element 2. For example, where the test environment 1 is at a higher temperature than the surrounding environment, regions of the sensor element 2 that are closer to the test environment (upper regions in the example shown) may be at a higher temperature than regions that are further away (lower regions in the example shown).

In an embodiment, measurements of the differential compression are used to determine a temperature gradient within the sensor element 2 and/or to provide a measurement of the temperature in the test environment 1. Alternatively or additionally, the measurements of the temperature gradient are used to correct for temperature effects on the pressure measurements, making it possible to distinguish between the changes in geometry of the sensor element 2 that are due to temperature effects and those that are due to pressure effects. This approach therefore provides a more accurate measurement of pressure within the test environment 1.

In an embodiment, one or more semi-reflective layers may be embedded within the force-transmitting element 4 (in addition to or separately from semi-reflective layers being embedded within the sensor element). In this way, it is possible to measure differential compression within the force-transmitting element itself, which may provide further information about the pressure and/or temperature within the test environment 1.

In an embodiment, temperature sensors, for example thermocouples, are provided to make direct

measurements of the temperature of various components in the sensor 5. For example, one or more temperature sensors may be configured to measure the temperature at one or more corresponding positions or regions on the sensor element 2 and/or on the force-transmitting element 4 and/or on the support table 6. The output from these sensors can be used to correct for temperature effects, for example due to thermal expansion of elements whose geometry is being measured, and thereby improve the accuracy of the pressure measurement.

In an embodiment, a plurality of the sensor elements 2 are provided, each exposed to different temperatures and/or pressures.

In an embodiment, all of the sensor elements 2 could be arranged to be subjected to the same force but one or more of the sensor elements 2 may be maintained substantially at ambient temperature (e.g. due to a high resistance thermal coupling to the test environment and/or an applied cooling) while one or more other sensor elements 2 may be maintained substantially at the temperature of the test environment (e.g. due to a low resistance thermal coupling to the test environment). In this way, the ambient temperature sensor element(s) 2 may be used primarily to measure the pressure (because the pressure will be the dominant factor determining any change in the size of such sensor element(s)) and the high temperature sensor element(s) 2 may be used primarily to measure the temperature in the test environment (because the pressure on such sensor element(s) can be corrected using the measurement carried out on the ambient temperature sensor(s)).

In an embodiment, two sensor elements 2 are positioned so as to be coupled thermally to the test environment in substantially the same way but only one of them is subjected to the force by the force-transmitting element. In this way, any change in the dimensions of the pressurized sensor element 2 due to temperature could be corrected by reference to a measured change in the dimensions of the non-pressurized sensor element 2. In the case where the sensor elements 2 are maintained at substantially the same temperature as the test environment, the change in the dimensions of the non-pressurized element would also provide the basis for a direct measure of the temperature in the test environment.

Thus, the use of a plurality of sensor elements 2 allow separate temperature and pressure measurements to be carried out conveniently and efficiently.

Figure 3 depicts an embodiment in which the sensor element 2 comprises a through-hole 34. This arrangement may be used, for example, where the sensor element 2 is formed from an opaque material and optical access is required to the inner surface 12 of the force-transmitting element 4, for example to measure a change in thickness of the sensor element 2 under pressure. Depending on the pressure being applied by the force-transmitting element 4 on the sensor element 2 it may be desirable to fill the through-hole 34 with an optically transparent material to prevent the through-hole 34 closing up due to inward deformation of the sensor element 2.

In an embodiment, a coating is applied to the inner surface 12 of the force-transmitting element 4 and/or to the upper surface 15 of the support table 6. Figure 4 depicts an embodiment in which coatings 36

and 38 are provided to both of these surfaces. Such coatings can be used to provide a direct optical measurement of the temperature and/or pressure to which the sensor element 2 is being subjected. For example, the measurement system 9 may be configured to make a spectral measurement (based on absorption or emission) of one or both of the coatings 36, 38. For example, one or both of the coatings 36, 38 may comprise graphene, which is known to have temperature and pressure dependent spectral signature. Graphene is particularly advantageous because it can withstand up to about 64 GPa and temperatures of more than 2600 degrees C. Chemiluminescence, fluorescence and/or photon-photon interaction mechanisms may also be used to interrogate the nature of one or both of the coatings 36, 38. For example, graphene is known to exhibit passive and active emission in high temperature and high pressure environments. Additional layers (not shown) could be added at lower temperature and/or pressure positions in the optical path to the sensor element 2 and can be used for comparison and/or calibration purposes. For example, a coating for the purposes of comparison could be provided on a lower surface 17 of the support table 6.

In an embodiment, a coating could additionally or alternatively be applied to the outer surface 10 of the force-transmitting element. This surface is exposed directly to the test environment 1 and would therefore provide the basis for a direct measure of the temperature and/or pressure within the test environment 1 (e.g. via optical access provided through the force-transmitting element 4, sensor element 2 and support table 6).

In an embodiment, one or more coatings may additionally or alternatively be provided to allow electrical measurements of the change in a dimension of the sensor element 2 (or region within the sensor element 2). For example, as shown in the example of Figure 4, the layers 36 and 38 may be configured to act as plates of a capacitor. In this example, an electrical measurement system 40 is provided that is configured to measure the capacitance, which depends in a well known way on the separation of the plates and therefore provides a convenient way of measuring the separation between the plates and therefore the thickness of the sensor element 2.

In an embodiment, the coatings 36 and 38 have a substantially planar form, which may be effective for the capacitance measurement discussed above. However, this is not essential. More complex patterns could be formed to provide for other electrical measurements.

In an alternative embodiment, coatings (or layers formed in other ways) on one or more pairs of interfaces are arranged to form one or more resonant cavities, which may be interrogated remotely, for example using radio frequencies (e.g. at Mhz or Ghz frequencies). For example, the separation between the layers 36 and 38 in Figure 4 could be determined remotely using radio waves instead of by direct electrical measurement. The resonant frequencies are temperature and/or pressure dependent, so can be used to obtain a measure of the temperature and/or pressure in the region between the interfaces forming the cavity. This approach could be applied to coatings/layers embedded within the sensor element 2 and/or to coatings/layers embedded within the force-transmitting element 4 and/or within the support table 6. By monitoring the

changes in the resonant frequency of resonant cavities formed at different positions it is possible to determine temperature and/or or pressure gradients within the pressure sensor.

In an alternative embodiment, coatings (or layers formed in other ways) are configured to form a Bragg diffraction grating. Such a grating can be interrogated optically based for example on reflection and/or absorption of radiation from the grating to monitor changes in the geometry of the grating caused by pressure and/or temperature variations in the region of the grating.

In an embodiment, the compression of the sensor element 2 may be determined in other ways, such as by using an eddy current sensor or linear variable differential transformer (LVDT), either of which may be used for example to measure a change in a distance of one of the surfaces of the sensor element 2 relative to a reference position, or a strain gauge.

In a further embodiment, x-rays could be used to monitor changes in the dimensions in the sensor element 2.

In an embodiment, the relative shape and dimensions of the inner surface 12 and the outer surface 10 of the force-transmitting element 4 are configured so that the force-transmitting element 4 acts as a pressure reducing element. Thus, the pressure applied to the sensor element 2 by the inner surface 12 is less than the pressure in the test environment 1. This is the case, for example, in all of the embodiments discussed above with reference to Figures 1 to 4. Reducing the pressure means that the sensor element 2 does not need to be able to withstand the pressures within the test environment 1. This facilitates use of the pressure sensor 5 in extremely high pressure environments. The range of materials and configurations that may be used for the sensor element 2 is increased.

In an embodiment, the pressure reducing functionality of the force-transmitting element 4 is achieved by arranging for the outer surface 10 to be smaller than the inner surface 12 when viewed in a direction parallel to the direction of movement of the force-transmitting element 4. In the simplest case where the inner and outer surfaces 12,10 are planar and parallel, the difference in pressure may simply be given by the ratio of the surface areas of these elements. However, in other embodiments the relationship may be more complex. Calibration elements may be performed in order to determine the detailed relationship between the pressure exerted on the outer surface 10 and the pressure exerted by the inner surface 12.

In an alternative embodiment, the relative shape and dimensions of the inner surface 12 and the outer surface 10 of the force-transmitting element 4 are configured so that the force-transmitting element 4 acts as a pressure increasing element. Thus, the pressure applied to the sensor element 2 by the inner surface 12 is greater than the pressure in the test environment 1. This arrangement may increase the sensitivity of the pressure measurement. In an embodiment, the pressure increasing functionality is provided by arranging for the outer surface 10 of the force-transmitting element 4 to have a larger surface area than the inner surface 12 when viewed in a direction parallel to the direction of movement of the force-transmitting element 4.

An example of an embodiment in which the force-transmitting element 4 is configured to act as a pressure increasing element is shown in Figure 5. In this example, instead of the force-transmitting element 4 protruding through the housing 14 into the test environment 1, an opening 40 is provided in the housing 14 which allows access for the high pressure environment into an upper region of the housing 14. In this embodiment, the force-transmitting element 4 may comprise an anvil (formed, for example, from a single crystal of diamond or sapphire) arranged in an opposed configuration relative to a corresponding anvil forming part of the support table 6. The change in a dimension of the sensor element 2 may be measured using any of the methods discussed above with reference to the embodiment of Figures 1 to 4, for example. Alternatively or additionally, the opposed anvils may be configured to operate as a conventional diamond- or sapphire-anvil cell and any of the conventional techniques used for measuring the pressures between such anvils may be used. For example, a gasket may be provided for containing a sensor element 2 comprising a ruby chip within a sample measurement volume (containing a pressure transmitting medium) and ruby fluorescence may be used to measure the pressure to which the ruby chip is subjected.

In an embodiment, the force-transmitting element 4 is configured such that the pressure applied by the inner surface 12 to the sensor element 2 is substantially the same as the pressure in the test environment. In this case, the force-transmitting element 4 serves mainly as a mechanism for thermally insulating the sensor element 2 from the test environment 1. In any of the embodiments in which the force-transmitting element 4 acts to reduce or increase the pressure on the sensor element 2 relative to the test environment 1, the force-transmitting element 4 may also serve to thermally insulate the sensor element 2 from the test environment 1.

Thermally insulating the sensor element 2 from the test environment 1 may be particularly beneficial where the temperature in the test environment 1 is extremely high (for example in the region of 2000 degrees C). The range of materials that can be used for the sensor element 2 can be expanded (to materials that would not be able to withstand the temperatures in the test environment 1, for example) and/or the effects of temperature on the dimension of the sensor element 2 are reduced, thus improving the accuracy of the pressure measurement based on measurements of a change in a dimension of the sensor element 2.

Using approaches according to one or more of the embodiments discussed above it is possible to make pressure measurements reliably at higher temperatures and pressures than is possible with prior art devices. For example, pressure measurements can be obtained in test environments that are at pressures in excess of 1 GPa (e.g. in the range of 1-15GPa) and in excess of 1900 degrees C (e.g. in the region of 2000 degrees C) using diamond to form the force-transmitting element 4.

CLAIMS

1. A pressure sensor for measuring the pressure in a test environment, comprising:
 - a housing comprising a chamber that is sealed from the test environment;
 - a force-transmitting element comprising an outer surface and an inner surface, the outer surface being exposed directly to the test environment and the inner surface being arranged to face into the chamber, the force-transmitting element being slidably mounted within the housing so that a force applied to the outer surface is transmitted to the inner surface;
 - a sensor element mounted in the chamber and configured to receive a force transmitted by the force-transmitting element via the inner surface of the force-transmitting element; and
 - a measurement system configured to measure a change of a dimension of the sensor element and/or of a dimension of a region within the sensor element, caused by the force transmitted thereto by the force-transmitting element, thereby providing a measure of the pressure in the test environment.
2. A sensor according to claim 1, wherein the relative shape and dimensions of the inner and outer surfaces of the force-transmitting element are configured so the force-transmitting element acts as a pressure reducing element, the pressure applied to the sensor element by the inner surface of the force-transmitting element being less than the pressure in the test environment.
3. A sensor according to claim 2, wherein the outer surface has a smaller surface area than the inner surface when viewed in a direction parallel to the direction of movement of the force-transmitting element 4.
4. A sensor according to claim 1, wherein the relative shape and dimensions of the inner and outer surfaces of the force-transmitting element are configured so the force-transmitting element acts as a pressure increasing element, the pressure applied to the sensor element by the inner surface of the force-transmitting element being greater than the pressure in the test environment.
5. A sensor according to claim 4, wherein the outer surface has a larger surface area than the inner surface when viewed in a direction parallel to the direction of movement of the force-transmitting element.
6. A sensor according to any of the preceding claims, wherein the sensor element is thermally insulated from the test environment such that in use the sensor element is maintained at a temperature that is substantially different from the temperature in the test environment.

7. A sensor according to any of the preceding claims, further comprising a support table for supporting the sensor element on a side of the sensor element that is opposite to the inner surface of the force-transmitting element.
8. A sensor according to claim 7, wherein at least a portion of the support table is optically transparent and the measurement system is configured to measure the change of a dimension of the sensor element and/or of a change in a dimension of a region within the sensor element by transmitting and/or receiving optical radiation through the optically transparent portion of the support table.
9. A sensor according to claim 8, wherein the measurement system is configured to use interferometry between radiation reflected or emitted from different interfaces of the sensor element to measure a change in a dimension of the sensor element and/or of a dimension of a region within the sensor element.
10. A sensor according to any of the preceding claims, wherein the sensor element comprises one or more semi-reflective layers embedded within the sensor element and the measurement system is configured to reflect radiation from the one or more semi-reflective layers in order to measure differential compression within the sensor element.
11. A sensor according to any of the preceding claims, wherein the force-transmitting element is formed from sapphire or diamond.
12. A sensor according to any of the preceding claims, further comprising a layer of graphene formed on a surface of the sensor element or embedded within the sensor element.
13. A sensor according to claim 12, wherein the measurement system is configured to measure an optical property of the layer of graphene in order to determine the pressure and/or temperature to which the graphene is being subjected and thereby to obtain a measure of the temperature and/or pressure in the test environment.
14. A sensor according to claim 12 or 13, wherein the sensor comprises a pair of the layers of graphene and the measurement system is configured to measure a change in the separation between the layers, and thereby of a corresponding dimension of the sensor element or of a region within the sensor element, by measuring a change in the capacitance of a capacitor formed by the layers.

15. A sensor according to claim 14, wherein the measurement system is configured to measure the change in the capacitance remotely using radio waves.
16. A sensor according to any of the preceding claims, further comprising a layer of graphene formed on the outer surface of the force-transmitting element or embedded within the force-transmitting element, wherein the measurement system is configured to measure an optical property of the layer of graphene in order to determine the pressure and /or temperature to which the graphene is being subjected.
17. A sensor according to any of the preceding claims, wherein the sensor element is formed from an elastic material and the sensor is configured to operate in a range of temperatures and pressures for which the change in a dimension of the sensor element caused by the force transmitted thereto by the force-transmitting element is within the elastic limit of the sensor material.
18. A sensor according to any of the preceding claims, wherein the sensor is configured to operate with the force-transmitting element and the sensor element each being in their solid, rather than liquid or gaseous, states.
19. A sensor according to claim 18, wherein the force-transmitting element and/or the sensor element are each formed as solid, compositionally uniform structures, without any cavities or without any inclusions of material of a different composition.
20. A sensor according to any of the preceding claims, configured to measure the pressure or temperature in the test environment when the test environment is at a temperature in excess of 1900 degrees C.
21. A sensor according to any of the preceding claims, configured to measure the pressure or temperature in the test environment when the test environment is at a pressure in excess of 1 GPa.
22. A pressure sensor for measuring the pressure in a test environment configured and arranged to operate substantially as hereinbefore described with reference to and/or as illustrated in the accompanying drawings.

Fig 1

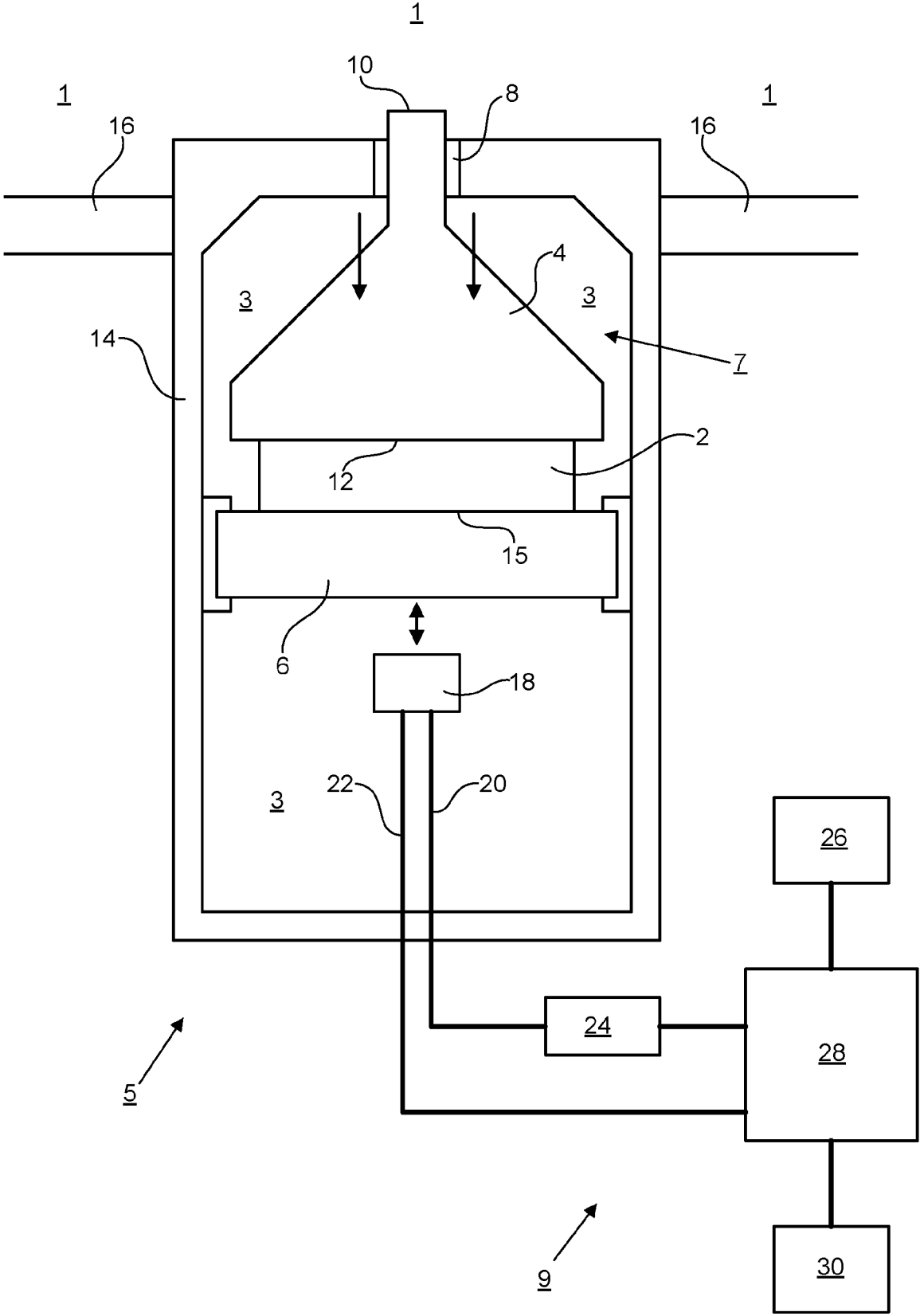


Fig 2

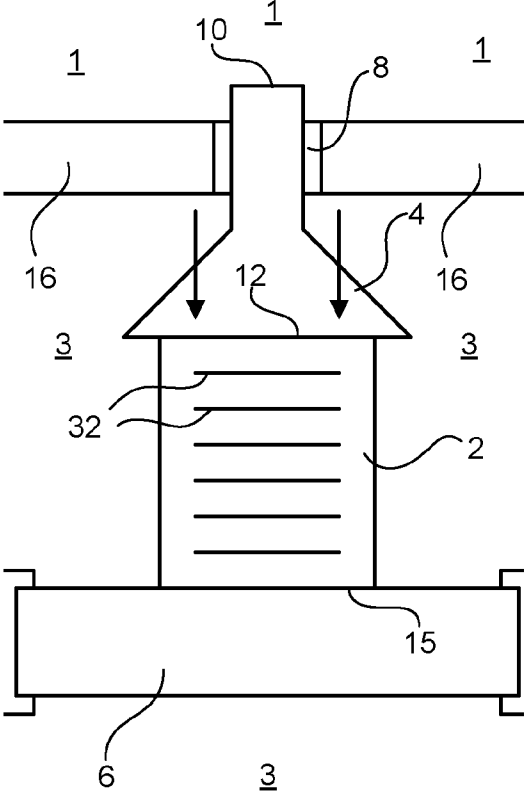
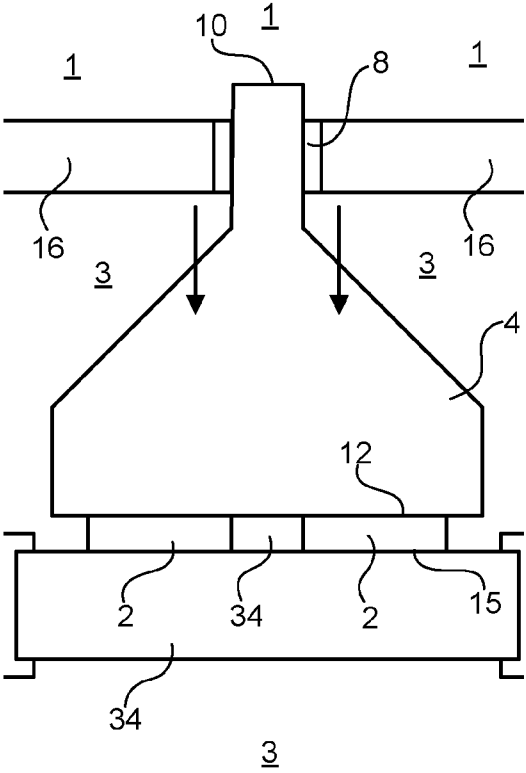
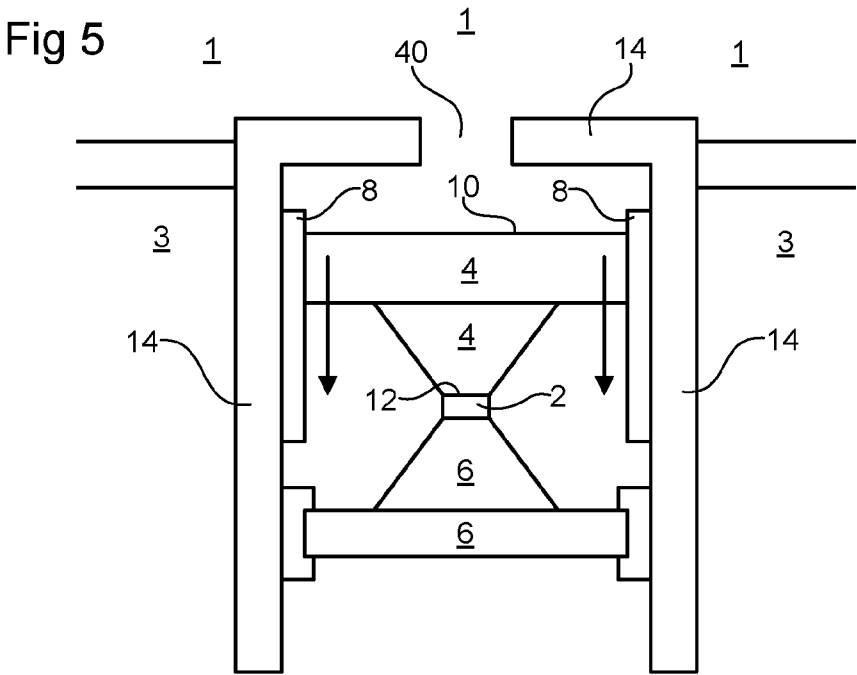
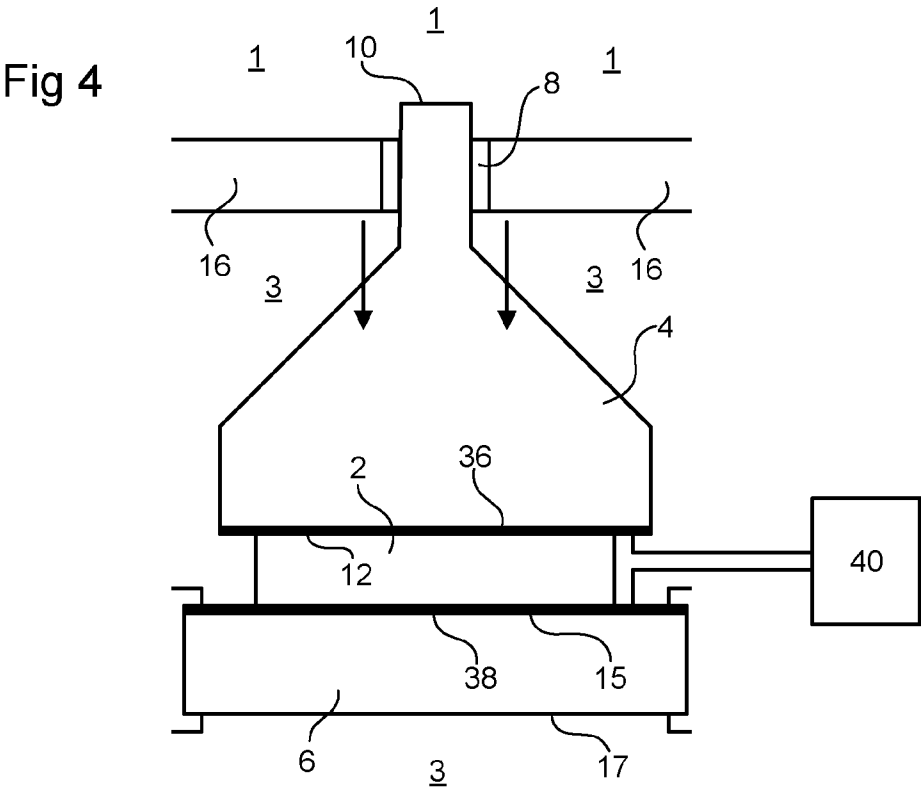


Fig 3





INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2014/053082

A. CLASSIFICATION OF SUBJECT MATTER

INV. G01L9/00 G01L23/12 G01L23/16 G01L1/14
ADD.

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)

G01L

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)

EP0-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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X	EP 2 444 786 A1 (SENSATA TECHNOLOGIES INC [US]) 25 April 2012 (2012-04-25) the whole document	1-22
A	US 2009/273483 A1 (TOMPKINS MICHAEL [US] ET AL) 5 November 2009 (2009-11-05) abstract figures 1-4 claims 1-14	1-19
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See patent family annex.

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Date of the actual completion of the international search

30 January 2015

Date of mailing of the international search report

09/02/2015

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INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2014/053082

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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International application No

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