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U1S S1915

(56) Documents cited
GB 1589725 A GB 1556505 A GB 1497781 A
GB 1449787 A GB 1252126 A

(58) Field of search
UK CL (Edition K) C1M MRC, G2J JGEA
INT CL^5 C03B, G01L
On-line databases: DIALOG

(54) **Method of making an optical fibre sensor**

(57) Comprises the controlled heating of a controlled length of tubing (2), and the controlled pulling of the tubing (2) such that the diameter of the tubing (2) reduces in such a way that the tubing (2) grips, radially and uniformly, a length of optical fibre (1) contained within the tubing (2), over the said controlled length. The heating may be effected by heating means (6) and the pulling may be effected by pulling means (5).

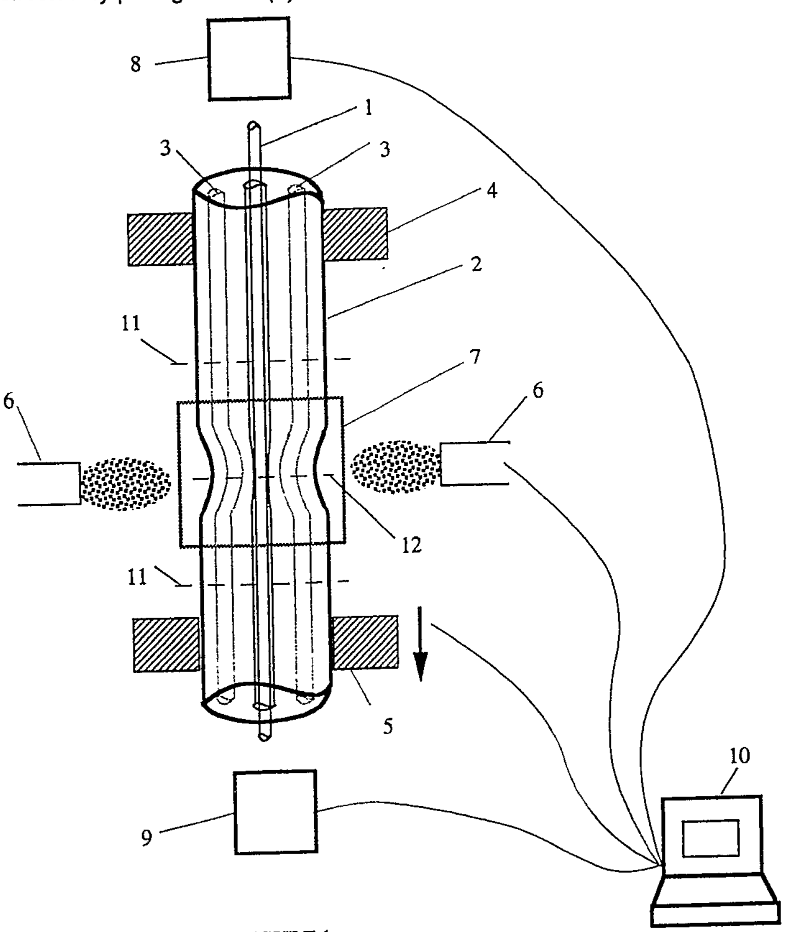

FIGURE 1

The claims were filed later than the filing date within the period prescribed by Rule 25(1) of the Patents Rules 1990.

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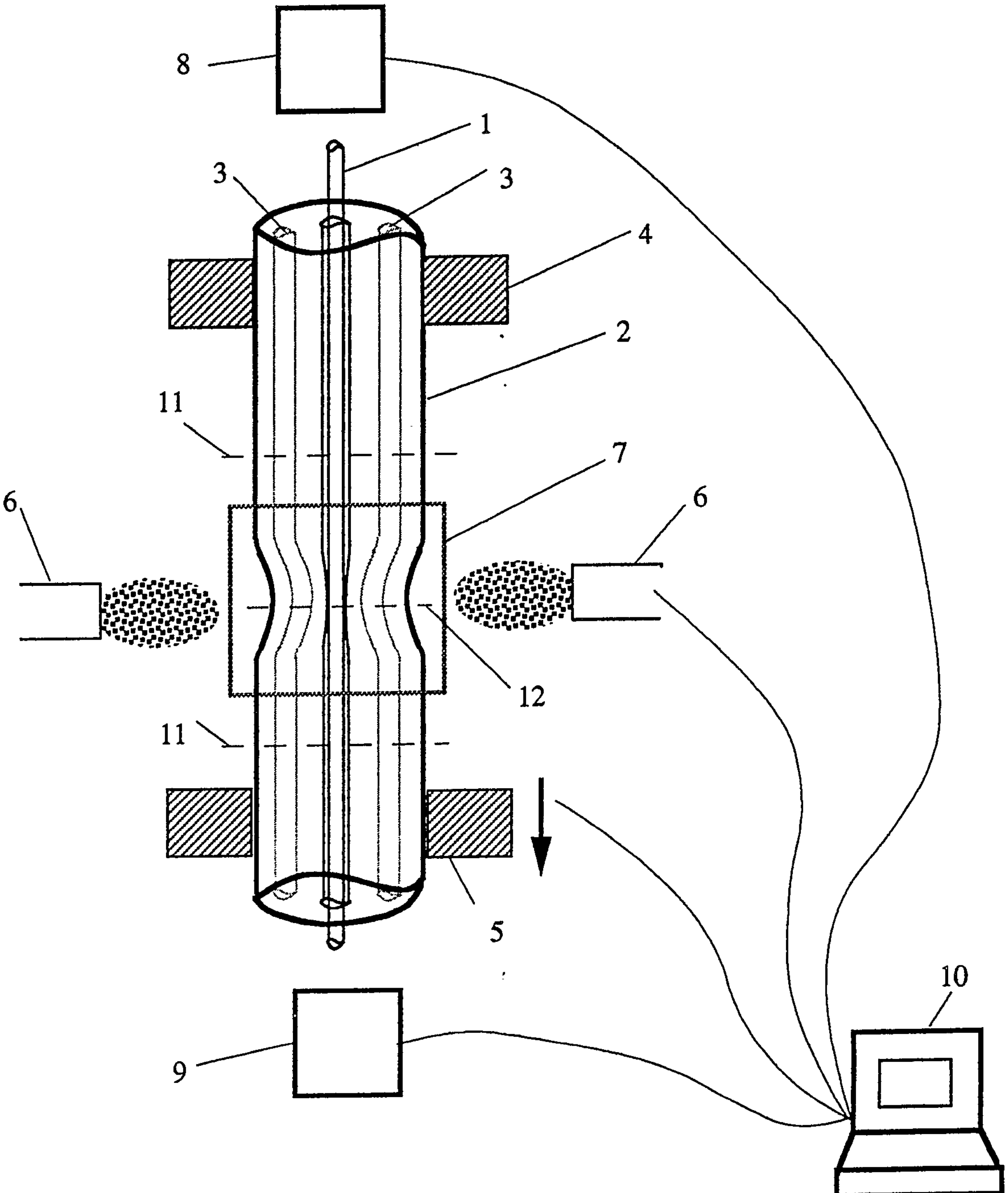

FIGURE 1

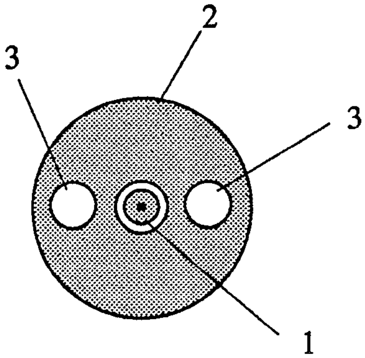

FIGURE 2a

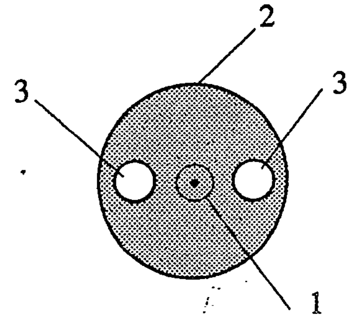

FIGURE 2b

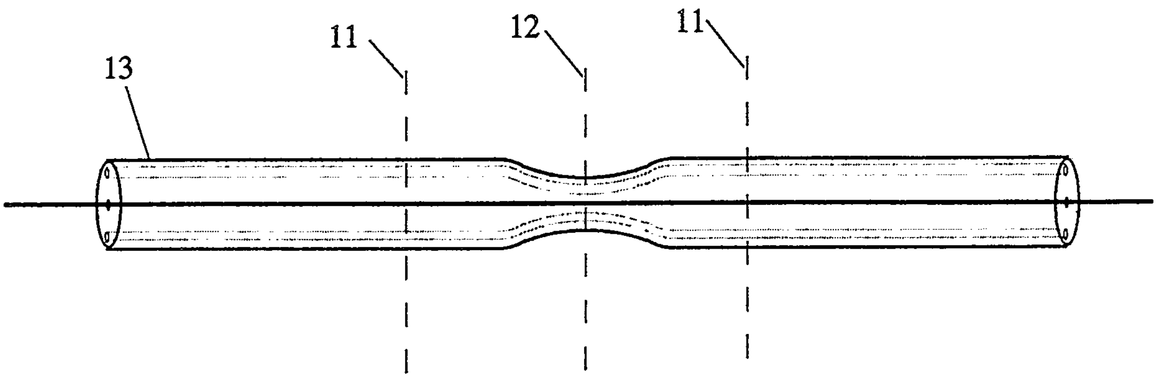

FIGURE 3

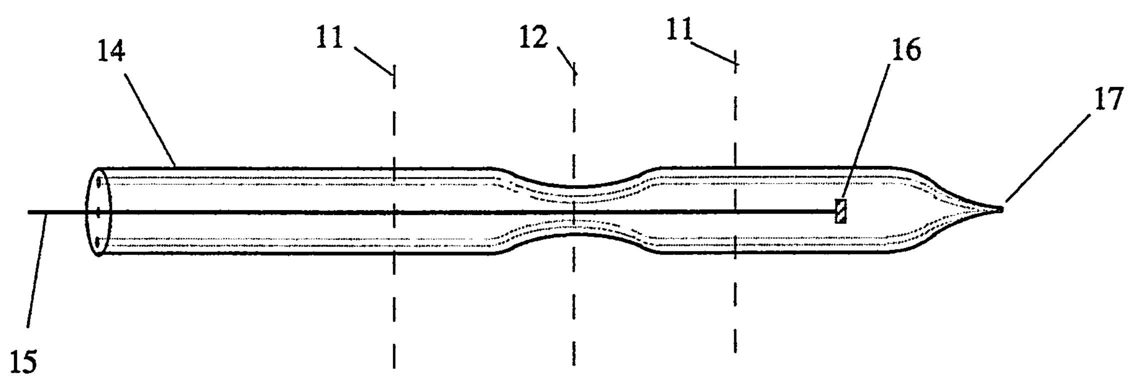

FIGURE 4

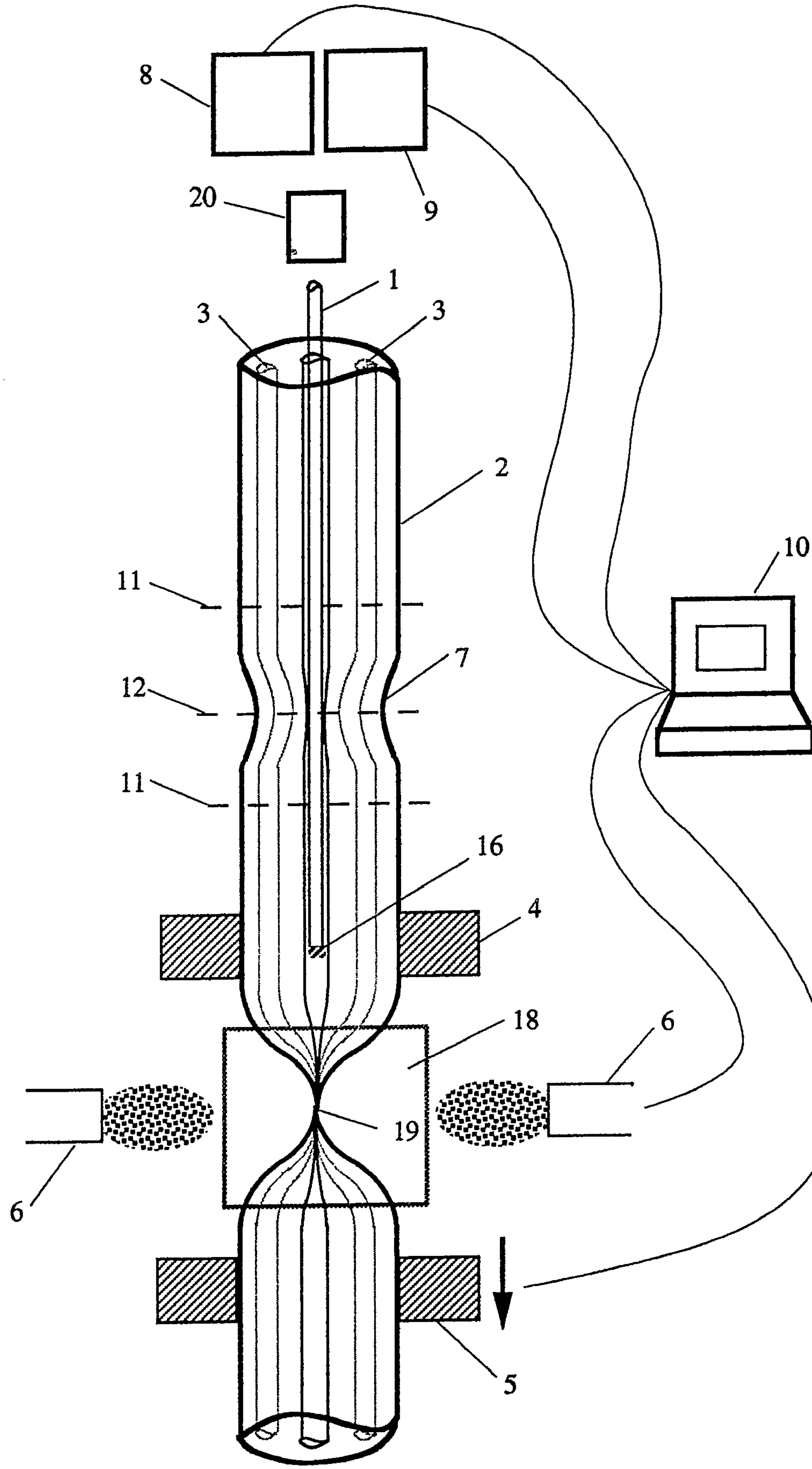

FIGURE 5

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METHOD OF MAKING AN OPTICAL FIBRE SENSOR

FIELD OF THE INVENTION

A variety of industrial processes require knowledge of fluid pressure and temperature in order to control productivity and quality of the process effectively. In particular, the pressures and temperatures encountered are often very different to those of ambient conditions. Examples are the chemical process industries, internal combustion engine control and oil production. A sensor manufactured of a robust material such as silica can withstand extremes of pressure and temperature and thus is particularly useful.

BACKGROUND OF THE INVENTION

European Patent Application EP 0 144 509 A3 "Fiber Optic interferometer transducer" teaches how a dual path polarimetric interferometer may be constructed so that, when suitable means convert isotropic forces to anisotropic radial forces on an optical fibre, a useful signal results, which may be used as a measure of the isotropic forces. When a material experiences pressure, stress forces result from the differences between the bulk modulus of elasticity of different regions within the material. Similarly, stress forces result from the differences between the thermal coefficient of expansion of different regions within a material when the temperature of the material changes. The present invention relates to an advantageous method of constructing an optical fibre sensor which utilises these stress forces.

SUMMARY OF THE INVENTION

An object of the present invention is to provide a method of manufacturing an optical fibre sensor such that environmental parameters, such as pressure and temperature, cause anisotropic forces on an optical fibre.

BRIEF DESCRIPTION OF THE INVENTION

The present invention comprises a method of making an optical fibre sensor, which method comprises the controlled heating of a controlled length of tubing, and the controlled pulling of the tubing such that the diameter of the tubing reduces in such a way that the tubing grips, radially and uniformly, a length of optical fibre contained within the tubing, over the said controlled length.

The tubing may contain regions of different elastic bulk modulus, or different coefficients of thermal expansion, or both, which may vary both radially and circumferentially, but are preferably uniform along the longitudinal axis over the controlled length of the tubing which grips the optical fibre.

The tubing is preferably, but not necessarily, cylindrical, and, prior to heating, the tubing may have an inner diameter greater than that of the said optical fibre.

Preferably, the method also comprises the monitoring of the light transmitted by the fibre and its cladding, for which purpose light delivery and detection apparatus are provided. The changes in the light transmitted during manufacture of the sensor, according to the present invention, may be used to determine the duration and degree of the heating and pulling of the tubing so that the consistency of the method of the present invention is increased.

Preferably, the method comprises sufficient heating so that, when the tubing is made of silica and when the optical fibre is manufactured with silica cladding, the tubing fuses to the optical fibre over the controlled length.

Preferably, the method includes providing a layer of sol-gel material between the silica optical fibre and the silica tubing so that the quality of fusion over the controlled length is improved and the degree of control required by the method is reduced.

Preferably, the method includes the step of completely sealing one end of the tubing either before or after the tubing is caused to grip the optical fibre. More preferably when the tubing is silica, or any material with similar properties, the sealing is achieved by heating the tubing and pulling the tubing to such a point that the diameter has reduced to the point, or beyond, at which the central hole in the tubing, and any other holes, disappears by the material of the tubing fusing to form a continuum. More preferably, the method consists of using the same heating apparatus for the sealing as that for causing the tube to grip the optical fibre, and or the method consists of using the same apparatus for gripping and pulling the tubing for forming the seal as for causing the tubing to grip the optical fibre. Once this sealed region has been formed the tubing is cut or broken or otherwise separated at the said sealed region.

Preferably, the method is carried out with the axis of the tubing vertical so that gravitational force does not distort the tubing during heating, and so that gravitational force may provide part or all of the pulling force required to cause the tubing to grip and or fuse with the optical fibre.

Preferably, the method is carried out with the tubing and optical fibre rotated about its axis so that the longitudinal axis of the tubing may be horizontal without deleterious effects from gravitational forces.

Preferably, the method is carried out with a heating means which is uniform circumferentially around the tubing. Such heating may be achieved using a point source of heat, such as flame, and either rotating the flame around the longitudinal axis of the tubing, or rotating the tubing and fibre about their longitudinal axis.

The means of heating may be provided by a gas flame or an electromagnetic induction heating, or any other suitable means which raises the temperature of the tubing so that the method may be carried out according to the present invention.

The means of pulling may be provided by gravitational force or a motorised grip under computer control or any other suitable controlled means which supplies enough force to pull the tubing according to the present invention.

The means of monitoring may be provided by light source means, in which light is launched into the optical fibre and its cladding, light detector means in which the light guided through the fibre core and cladding is detected, and means of indicating change in said light during the manufacturing process according to the present invention. An alternative method of monitoring is to detect the light that has returned back along the fibre having been reflected from a mirror at the other end of the fibre to that where the light was launched into the fibre.

BRIEF DESCRIPTION OF THE DRAWINGS

Specific embodiments of the invention will be described solely by way of example and with reference to the accompanying diagrams in which:

Figure 1 is a longitudinal section of a sensor during manufacture according to the present invention;

Figure 2a is a cross-section view of the sensor at an unheated point in Figure 1;

Figure 2b is a cross-section view of the sensor at the heated point in Figure 1;

Figure 3 is a longitudinal section view of a sensor manufactured according to the present invention;

Figure 4 is a longitudinal section view of a sensor manufactured according to the present invention described by Figure 5; and

Figure 5 is a longitudinal section view of a sensor during manufacture, according to the embodiment of the present invention which includes the step of sealing.

DETAILED DESCRIPTION OF THE INVENTION

With reference to Figure 1, an optical fibre 1 is placed inside a tube 2. Preferably the tube 2 is made of silica material, containing longitudinal holes 3, preferably lying on opposite sides of a diameter of the tube 2. The tube 2 is supported, preferably vertically, by supporting means 4 and pulling and supporting means 5. Heating means 6, such as a gas torch flame, heat the region 7 of the tube 2, and pulling means 5 exerts a tension such that when region 7 reaches a certain temperature the tube 2 elongates in region 7 and the diameter reduces. The heating and pulling are stopped when the inner walls of the tube are in intimate contact with the outside of the optical fibre 1, and the tube 2 is allowed to cool before being used as a sensor. Figure 2a shows a cross-section of the tube at 11 outside the heated region 7, and Figure 2b shows the cross-section 12 inside the heated region 7, in which the optical fibre is shown fused to the tube.

In a preferred embodiment, also with reference to Figure 1, the length of the region 7 is selected to have a specific value so that the optical fibre sensor will have a particular sensitivity. The said length is achieved either by controlling the width of the heating means 6, such as the size of the flame, or by traversing the heating means 6 relative to the tube 2 along the longitudinal axis of the tube 2, to and fro, sufficiently quickly for the whole region 7 to be heated to, and maintained at, sufficiently the same temperature for the purposes of carrying out the method according to the present invention.

In a preferred embodiment, also with reference to Figure 1, light is transmitted through the fibre from source apparatus 8 to detection apparatus 9, and a signal, indicating the amount of light transmitted by both the waveguide core and cladding of the optical fibre 1, is transmitted to a computer or other computing means 10. In addition, heating means 6, and pulling means 5, are controllable by the computing means 10, such that a set of computer programme instructions may be used to determine the start time of, the duration of, and the degree of, the heating and pulling, so that many sensors may be manufactured so that each has the same dimensions of region 7, and hence each has similar performance as a pressure or temperature sensor.

Figure 3 shows a longitudinal section of an optical fibre sensor 13 manufactured according to the embodiment of the invention described by Figure 1. The cross-section described by Figure 2a occurs at 11, the unheated region, and that described by Figure 2b occurs at 12, the heated region.

Figure 4 shows a longitudinal section of an optical fibre sensor 14 which advantageously consists of a length of optical fibre 15, one of whose ends acts a mirror 16 to light guided by the fibre 15, and which has one end of the tube sealed 17. Such an optical fibre sensor may be manufactured, according to an embodiment of the present invention, by carrying out the method described by Figure 1 and following it with the additional step described by Figure 5.

With reference to Figure 5, a preferred additional step of the method, according to the present invention, is the sealing of the tube 2. Following the method described by Figure 1 in which region 7 is formed, the tube 2 is moved within support means 4 and pulling means 5 so that mirror 16 on the end of fibre 1 is clear of region 18. Region 18 is heated, by heating means 6, to a temperature, and for a duration, that when pulling means 5 exerts a tension on tube 2, the diameter of the tube 2 reduces to the point where the tube 2 fuses to a continuum and so seals the tube at 19. The tube 2 is then cut or broken by some suitable means (not shown) at 19.

In a preferred embodiment, also with reference to Figure 5, light is transmitted through the fibre from source apparatus 8, via reflection at mirror 16, and back to detection apparatus 9, via suitable coupling/splitting means 20, which generates a signal, which indicates the amount of light guided by both the waveguide core and cladding. The said signal is transmitted to a computer or other computing means 10. In addition, heating means 6, and pulling means 5, are controllable by the computing means 10, such that a set of computer programme instructions may be used to determine the start time of, the duration of, and the degree of, the heating and pulling, so that the seal at 19 may be formed in a controlled fashion so as to manufacture optical fibre sensors consistently. The purpose of the light monitoring apparatus in this additional step of the method, according to the present invention, is to ensure that there has been no deterioration of the optical fibre 1 and mirror 16 during the process of forming the seal at 19.

In Figure 5, the cross-section described by Figure 2a occurs at 11, the unheated region, and that described by Figure 2b occurs at 12, the heated region.

CLAIMS

1. A method of making an optical fibre sensor, which method comprises the controlled heating of a controlled length of tubing and the controlled pulling of the tubing such that the diameter of the tubing reduces in such a way that the tubing grips, radially and uniformly, a length of optical fibre contained within the tubing, over the said controlled length.

2. A method according to claim 1 in which the tubing contains regions of different elastic bulk modulus and/or different co-efficients of thermal expansion.

3. A method according to claim 1 or claim 2 in which the tubing is cylindrical.

4. A method according to any one of the preceding claims in which the tubing has an inner diameter greater than that of the optical fibre.

5. A method according to any one of the preceding claims and including monitoring of the light transmitted by the fibre and its cladding, using light delivery and detection apparatus.

6. A method according to any one of the preceding claims and including sufficient heating so that, when the tubing is made of silica and when the optical fibre is manufactured with silica cladding, the tubing fuses to the optical fibre over the controlled length.

7. A method according to claim 6 in which a layer of sol-gel material is provided between the silica optical fibre and the silica tubing so that the quality of fusion along the controlled length is improved and the degree of control required by the method is reduced.

8. A method according to any one of the preceding claims and including the step of completely sealing one end of the tubing either before or after the tubing is caused to grip the optical fibre.

9. A method according to any one of the preceding claims in which the tubing is silica, or any material with similar properties, and in which the sealing is achieved by heating the tubing and pulling the tubing to such a point that the diameter has reduced to the point, or beyond, at which the central hole in the tubing, and any other holes, disappears by the material of the tubing fusing to form a continuum.

10. A method according to claim 9 and comprising using the same heating apparatus for the sealing as that for causing the tubing to grip the optical fibre.

11. A method according to claim 9 or claim 10 and comprising using the same apparatus for gripping and pulling the tubing for forming the seal as for causing the tubing to grip the optical fibre.

12. A method according to any one of the preceding claims and which is carried out with the axis of the tubing vertical so that gravitational force does not distort the tubing during heating, and so that gravitational force may provide part or all of the pulling force required to cause the tubing to grip and/or fuse with the optical fibre.

13. A method according to any one of the preceding claims and which is effected with the tubing and optical fibre rotated about its axis so that the longitudinal axis of the tubing may be horizontal without deleterious effects from gravitational forces.

14. A method according to any one of the preceding claims and including heating with a heating means which is uniform circumferentially around the tubing.

15. A method according to any one of the preceding claims in which the pulling is provided by gravitational force or a motorised grip under computer control or any other suitable controlled means which applies enough force to pull the tubing.

16. A method according to any one of the preceding claims and including monitoring by providing light source means in which light is launched into the optical fibre and its cladding, light detector means in which light guided through the fibre core and cladding is detected, and means of indicating change in the light during the manufacturing process.

17. A method according to any one of claims 1 to 15 in which monitoring is effected by detecting the light that is returned back along the fibre having been reflective from a mirror at the other end of the fibre to that where the light was launched into the fibre.

18. A method of making an optical fibre sensor, substantially as herein described with reference to the accompanying drawings.

19. An optical fibre sensor when made by the method claimed in any one of the preceding claims.

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

Application number

GB 9203922.1

Relevant Technical fields

(i) UK Cl (Edition K) C1M (MRC) : G2J (JGEA)

(ii) Int Cl (Edition 5) G01L : C03B

Search Examiner

V V BAILEY-WOOD

Databases (see over)

(i) UK Patent Office

(ii) ONLINE DATABASE: DIALOG

Date of Search

8 SEPTEMBER 1992

Documents considered relevant following a search in respect of claims 1-19

Category (see over)	Identity of document and relevant passages	Relevant to claim(s)
X	GB 1589725 (STANDARD TELEPHONES) - whole document	1,3,4,6
X	GB 1556505 (STANDARD TELEPHONES) - whole document	1,3,4,6
X	GB 1497781 (STANDARD TELEPHONES) - whole document	1,3,4,6
X	GB 1449787 (STANDARD TELEPHONES) - whole document	1,3,4,6
X	GB 1252126 (POST OFFICE) - whole document	1,3,4,6

Category	Identity of document and relevant passages	Relevant to claim(s)

Categories of documents

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