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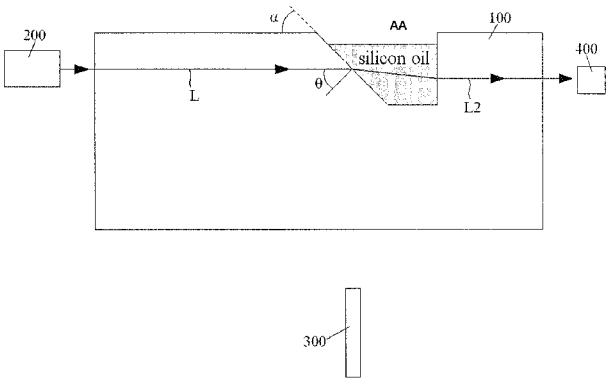


Fig.4

(57) Abstract: A silicon oil sensor, comprising: a transparent member made of a transparent material; and a laser source for emitting a laser beam into the transparent member. A recess is formed in the transparent member and has a side surface facing the laser beam emitted from the laser source. An incident angle θ of the laser beam with respect to the side surface is selected so that: when the recess is filled with air, the laser beam occurs a total reflection on the side surface and exits out of the transparent member in a total reflection path; when the recess is filled with silicon oil, the laser beam occurs a refraction instead of a total reflection on the side surface and exits out of the transparent member in a refraction path different from the total reflection path. As a result, it can determine whether the silicon oil is leaked into the recess according to a path in which the laser beam exits out of the transparent member.

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SILICON OIL LEAK DETECTOR AND ELECTRIC POWER TERMINAL ASSEMBLY

CROSS-REFERENCE TO RELATED APPLICATION

This application claims the benefit of Chinese Patent Application No. 201310040832.1 filed on February 1, 2013 in the State Intellectual Property Office of China, the whole disclosure of which is incorporated herein by reference.

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a silicon oil sensor, more particularly, relates to a silicon oil sensor for detecting silicon oil leaked out of an outdoor electric power terminal filled with the silicon oil.

Description of the Related Art

An outdoor electric power terminal filled with silicon oil may be applied to a high voltage cable of, for example, 170kV. However, there is a risk that the silicon oil may be leaked out of the outdoor electric power terminal and cause a serious power failure. Furthermore, the outdoor electric power terminal is often mounted high above the ground, therefore it is difficult to find the leaked silicon oil in time.

In prior arts, a silicon oil sensor generally comprises a conductive layer directly formed by conductive particles or a porous material, for example, polytetrafluoroethylene (PTEE) filled by conductive particles. When the silicon oil is flowed to the conductive layer of the silicon oil sensor, the conductive particles directly contact the silicon oil and are wrapped by the silicon oil, and it results in changes of the electric resistance of the conductive layer. Thereby, it is possible to detect whether the silicon oil is leaked out of the outdoor electric power terminal based on the change of the electric resistance of the conductive layer of the silicon oil sensor. However, in this conventional silicon oil sensor, when the conductive particles are wrapped by the leaked silicon oil, the change of the electric resistance of the conductive layer is very slow and not significant, that is, this conventional silicon oil sensor has poor detection sensitivity and cannot detect the leaked silicon oil in time. As a result, it cannot reliably prevent the power failure due to the leaked silicon oil.

In order to overcome the disadvantages of the above conventional silicon oil sensor, a Japanese Patent Document No.JP1265138A discloses a fiber sensor for the silicon oil. The

fiber sensor comprises a fiber core fixed on a surface of a plastic body. Once the silicon oil is dropped onto the fiber core, the fiber sensor can determine that the silicon oil is leaked out of the electric power terminal. However, in the fiber sensor,

1) it needs to form the plastic body by pouring polymer material on the fiber and polishing the plastic body until the fiber core of the fiber is exposed, therefore, the process of manufacture of the fiber sensor is very complicated and difficult;

2) the size of the fiber is very small and cannot detect a large area, therefore, it needs an additional funnel to collect the leaked silicon oil within the large area; and

3) the fiber sensor is also affected by rain water or other liquid like the silicon oil, therefore, it may mistake the rain water as the leaked silicon oil when it is used in the outdoor environment.

SUMMARY OF THE INVENTION

The present invention has been made to overcome or alleviate at least one aspect of the above mentioned disadvantages.

Accordingly, it is an object of the present invention to provide a silicon oil sensor that has high detection sensitivity and can detect leaked silicon oil in time.

Accordingly, it is another object of the present invention to provide a silicon oil sensor that has a simple structure and is not affected by rain water.

According to an aspect of the present invention, there is provided a silicon oil sensor, comprising: a transparent member made of a transparent material; and a laser source for emitting a laser beam into the transparent member, wherein a recess is formed in the transparent member and has a side surface facing the laser beam emitted from the laser source, and wherein an incident angle θ of the laser beam with respect to the side surface is selected so that:

(i) when the recess is filled with air, the laser beam occurs a total reflection on the side surface and exits out of the transparent member in a total reflection path; and

(ii) when the recess is filled with silicon oil, the laser beam occurs a refraction instead of a total reflection on the side surface and exits out of the transparent member in a refraction path different from the total reflection path.

In an exemplary embodiment of the present invention, when the refractive index n_1 of the transparent material is larger than the refractive index n_2 of the silicon oil, the incident angle θ of the laser beam with respect to the side surface is selected to satisfy the following expression (1):

$$\arcsin(1/n_1) = \theta_{c1} \leq \theta < \theta_{c2} = \arcsin(n_2/n_1) \qquad (1),$$

when the refractive index n_1 of the transparent material is less than the refractive index n_2 of the silicon oil, the incident angle θ of the laser beam with respect to the side surface is

selected to satisfy the following expression (2):

$$\arcsin(1/n_1) = \theta_{c1} \leq \theta < 90^\circ \quad (2),$$

wherein,

θ_{c1} refers to a critical angle at which the laser beam emitted into the transparent material occurs the total reflection on an interface between the transparent material and the air,

θ_{c2} refers to a critical angle at which the laser beam emitted into the transparent material occurs the total reflection on an interface between the transparent material and the silicon oil, and

the refractive index of the air is equal to 1.

In another exemplary embodiment of the present invention, the refractive index n_1 of the transparent material and the incident angle θ of the laser beam with respect to the side surface are selected so that: when the recess is filled with water, the laser beam occurs the total reflection on the side surface and exits out of the transparent member in the total reflection path.

In another exemplary embodiment of the present invention, when the refractive index n_1 of the transparent material is larger than the refractive index n_2 of the silicon oil, the incident angle θ of the laser beam with respect to the side surface is selected to satisfy the following expression (3):

$$\arcsin(n_3/n_1) = \theta_{c3} \leq \theta < \theta_{c2} \quad (3),$$

when the refractive index n_1 of the transparent material is less than the refractive index n_2 of the silicon oil, the incident angle θ of the laser beam with respect to the side surface is selected to satisfy the following expression (4):

$$\arcsin(n_3/n_1) = \theta_{c3} \leq \theta < 90^\circ \quad (4),$$

wherein,

θ_{c3} refers to a critical angle at which the laser beam emitted into the transparent material occurs the total reflection on the interface between the transparent material and the water,

n_3 refers to the refractive index of water, and the refractive index n_3 of water is less than the refractive index n_1 of the transparent material and the refractive index n_2 of the silicon oil.

In another exemplary embodiment of the present invention, the side surface of the recess facing the incident laser beam is configured as a slope side surface or a vertical side surface with respect to a horizontal direction.

In another exemplary embodiment of the present invention, an observor determines

whether the silicon oil is leaked into the recess by directly observing the path in which the laser beam exits out of the transparent member with his/her eyes.

In another exemplary embodiment of the present invention, the silicon oil sensor further comprising a first light detection device disposed at a first position corresponding to the total reflection path so as to receive the light of the laser beam led out the transparent member in the total reflection path. When the first light detection device receives the light of the laser beam, it can determine that the silicon oil is not leaked into the recess of the transparent member; when the first light detection device does not receive the light of the laser beam, it can determine that the silicon oil is leaked into the recess of the transparent member.

In another exemplary embodiment of the present invention, the silicon oil sensor further comprising a second light detection device disposed at a second position corresponding to the refractive path so as to receive the light of the laser beam led out the transparent member in the refractive path. When the second light detection device receives the light of the laser beam, it can determine that the silicon oil is leaked into the recess of the transparent member; when the second light detection device does not receive the light of the laser beam, it can determine that the silicon oil is not leaked into the recess of the transparent member.

In another exemplary embodiment of the present invention, the silicon oil sensor further comprising: a first light detection device disposed at a first position corresponding to the total reflection path so as to receive the light of the laser beam led out the transparent member in the total reflection path; and a second light detection device disposed at a second position corresponding to the refractive path so as to receive the light of the laser beam led out the transparent member in the refractive path. When the first light detection device receives the light of the laser beam and when the second light detection device does not receive the light of the laser beam, it can determine that the silicon oil is not leaked into the recess of the transparent member; when the first light detection device does not receive the light of the laser beam and when the second light detection device receives the light of the laser beam, it can determine that the silicon oil is leaked into the recess of the transparent member.

In another exemplary embodiment of the present invention, a plurality of recesses are formed in the transparent member, and the plurality of recesses are separated from each other and arranged in a row.

In another exemplary embodiment of the present invention, the recess is shaped as an elongated groove.

In another exemplary embodiment of the present invention, the transparent member of the silicon oil sensor is disposed below an outdoor electric power terminal filled with the silicon oil so as to detect whether the silicon oil is leaked out of the outdoor electric power

terminal.

In another exemplary embodiment of the present invention, the transparent member of the silicon oil sensor is directly exposed in an outdoor atmosphere environment without any waterproof film thereon.

In another exemplary embodiment of the present invention, the size of the transparent member and the size/the number of the recess(es) are determined based on the size of the outdoor electric power terminal.

In another exemplary embodiment of the present invention, the recess is formed in a trumpet shape and has a flared opening toward the outdoor electric power terminal to receive the silicon oil leaked out of the outdoor electric power terminal.

In another exemplary embodiment of the present invention, the transparent material comprises at least one of glass, methyl methacrylate, polycarbonate, polystyrene, fluorinated ethylene propylene, epoxy resin and polyester.

According to another aspect of the present invention, there is provided an electric power terminal assembly, comprising: an electric power terminal filled with silicon oil; and a silicon oil sensor, according to the above embodiments, disposed below the electric power terminal.

In the various embodiments of the present invention, the silicon oil sensor can detect whether the silicon oil is leaked according to the path in which the laser beam is led out the transparent member. Thereby, the silicon oil sensor of the present invention can accurately and quickly detect the silicon oil leakage accident occurred in the power terminal assembly and give an alarm in time, so that an operator is noticed to deal with the electric power terminal that has occurred silicon oil leakage. Accordingly, it can reliably ensure the electric power system to operate normally. Furthermore, the silicon oil sensor of the present invention can exclude the influence of the rain water by properly selecting the refractive index n_1 of the transparent material and the incident angle θ of the laser beam with respect to the side surface, prevent mistaking the rain water as the leaked silicon oil.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other features of the present invention will become more apparent by describing in detail exemplary embodiments thereof with reference to the accompanying drawings, in which:

Fig.1 is an illustrative principle view of a total reflection of a light on an interface between two different mediums;

Fig.2 is an illustrative view of a silicon oil sensor according to an exemplary embodiment of the present invention;

Fig.3 is an illustrative principle view of a silicon oil sensor according to an exemplary embodiment of the present invention, wherein a recess of a transparent member is filled with

air;

Fig.4 is an illustrative principle view of a silicon oil sensor according to an exemplary embodiment of the present invention, wherein a recess of a transparent member is filled with silicon oil;

Fig.5 is an illustrative principle view of a silicon oil sensor according to an exemplary embodiment of the present invention, wherein a recess of a transparent member is filled with water; and

Fig.6 is an illustrative view of an electric power terminal assembly according to an exemplary embodiment of the present invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS OF THE IVENTION

Exemplary embodiments of the present disclosure will be described hereinafter in detail with reference to the attached drawings, wherein the like reference numerals refer to the like elements. The present disclosure may, however, be embodied in many different forms and should not be construed as being limited to the embodiment set forth herein; rather, these embodiments are provided so that the present disclosure will be thorough and complete, and will fully convey the concept of the disclosure to those skilled in the art.

Fig.1 is an illustrative principle view of a total reflection of a light on an interface between two different mediums.

As shown in Fig.1, when light is transmitted from an optically denser medium, for example, having a refractive index of n1, onto an interface between the optically denser medium and an optically thinner medium, for example, having a refractive index of n2 less than n1, the refractive angle θ2 is increased as the incident angle θ1 is increased, and when the refractive angle θ2 is increased to 90 degrees or the incident angle θ1 of the light is increased to a critical angle θc1, the light occurs the total reflection on the interface between the optically denser medium and the optically thinner medium. That is, when the incident angle θ1 of the light is equal to or larger than the critical angle θc1, the light occurs the total reflection on the interface between the optically denser medium and the optically thinner medium and does not occur the refraction any longer.

Herein, according to the above principle shown in Fig.1, there is provided a silicon oil sensor of the present invention.

Fig.2 is an illustrative view of a silicon oil sensor according to an exemplary embodiment of the present invention; Fig.3 is an illustrative principle view of a silicon oil sensor according to an exemplary embodiment of the present invention, wherein a recess 110 of a transparent member 100 is filled with air.

As shown in Figs.2-3, the silicon oil sensor mainly comprises a transparent member 100 made of a transparent material and a laser source 200 for emitting a laser beam L into

the transparent member 100.

In an exemplary embodiment, as shown in Fig.2, three recesses 110 are formed in the transparent member 100. The three recesses 110 are separated from each other and arranged in a row. Each of the recesses 110 has a side surface 111 facing the incident laser beam L emitted from the laser source 200. Thereby, the incident laser beam L can be irradiated on the side surface 111 of the recess 110.

In an exemplary embodiment, as shown in Figs.2-3, the transparent member 100 is shaped into a cuboid block having a top surface, a bottom surface and four vertical side surfaces. The recesses 110 are formed in the top surface of the transparent member 100. The incident laser beam L is irradiated onto the side surface 111 of the recess 110 in a horizontal direction. The side surface 111 is configured to have an angle α with respect to the horizontal top surface of the transparent member 100. The incident angle θ of the laser beam L with respect to the side surface 111 can be calculated by the expression: $\theta = 90° - \alpha$.

As shown in Fig.3, in an exemplary embodiment, the refractive index n_1 of the transparent material of the transparent member 100 may be selected to be larger than or less than the refractive index n_2 of the silicon oil. Generally, the refractive index of the air is equal to 1, and the refractive index n_2 of the silicon oil is larger than the refractive index of the air or 1.

Fig.4 is an illustrative principle view of a silicon oil sensor according to an exemplary embodiment of the present invention, wherein a recess 110 of a transparent member 100 is filled with silicon oil.

As shown in Figs.3-4, in an exemplary embodiment, the incident angle θ ($= 90° - \alpha$) of the laser beam L with respect to the side surface 111 is selected so that:

(i) when the recess 110 is filled with air (that is, the recess 110 is empty), as shown in Fig.3, the laser beam L occurs a total reflection on the side surface 111 and exits out of the transparent member 100 in a total reflection path L1; and

(ii) when the recess 110 is filled with silicon oil, as shown in Fig.4, the laser beam L occurs a refraction instead of a total reflection on the side surface 111 and exits out of the transparent member 100 in a refraction path L2 different from the total reflection path L1.

Accordingly, in the present invention, it can detect whether the silicon oil is leaked into the recess 110 according to the path in which the laser beam L exits out of the transparent member 100.

As described the above, when the laser beam L occurs the total reflection on the side surface 111 and exits out of the transparent member 100 in a total reflection path L1, a light spot appears below the transparent member 100. When the leaked silicon oil is dropped into the recess 110 of the transparent member 100, the laser beam L does not occur the total reflection on the side surface 111, and the light spot disappear below the transparent member 100. Therefore, an inspector can directly determine whether the silicon oil is leaked

into the recess 110 by viewing whether the light spot appears below the transparent member 100.

In an exemplary embodiment, when the refractive index n_1 of the transparent material is larger than the refractive index n_2 of the silicon oil, the incident angle θ of the laser beam L with respect to the side surface 111 is selected to satisfy a following expression (1):

$$\arcsin 1/n_1 = \theta_{c1} \leq \theta < \theta_{c2} = \arcsin n_2/n_1 \quad (1),$$

wherein,

θ_{c1} refers to a critical angle at which the laser beam L directed into the transparent material occurs the total reflection on an interface between the transparent material and the air,

θ_{c2} refers to a critical angle at which the laser beam L directed into the transparent material occurs the total reflection on an interface between the transparent material and the silicon oil, and

the refractive index of the air is about equal to 1.

In an exemplary embodiment, when the refractive index n_1 of the transparent material is less than the refractive index n_2 of the silicon oil, the incident angle θ of the laser beam L with respect to the side surface 111 is selected to satisfy a following expression (2):

$$\arcsin 1/n_1 = \theta_{c1} \leq \theta < 90^\circ \quad (2).$$

Fig.5 is an illustrative principle view of a silicon oil sensor according to an exemplary embodiment of the present invention, wherein a recess 110 of a transparent member 100 is filled with water.

In an exemplary embodiment, as shown in Fig.5, the refractive index n_1 of the transparent material and the incident angle θ of the laser beam L with respect to the side surface 111 are selected so that:

when the recess 110 is filled with water, as shown in Fig.5, the laser beam L occurs the total reflection on the side surface 111 and exits out of the transparent member 100 in the total reflection path L1. With this configuration, when the recess 110 is filled with water, the silicon oil sensor of the present invention can prevent mistaking the water as the leaked silicon oil.

In an exemplary embodiment, when the refractive index n_1 of the transparent material is larger than the refractive index n_2 of the silicon oil, the incident angle θ of the laser beam L with respect to the side surface 111 is selected to satisfy a following expression (3):

$$\arcsin n_3/n_1 = \theta_{c3} \leq \theta < \theta_{c2} \quad (3),$$

wherein,

θ_{c3} refers to a critical angle at which the laser beam L directed into the transparent

material occurs the total reflection on an interface between the transparent material and the water,

n_3 refers to the refractive index of water, and the refractive index n_3 of water is less than the refractive index n_1 of the transparent material and the refractive index n_2 of the silicon oil.

In an exemplary embodiment, when the refractive index n_1 of the transparent material is less than the refractive index n_2 of the silicon oil, the incident angle θ of the laser beam L with respect to the side surface 111 is selected to satisfy a following expression (4):

$$\arcsin n_3/n_1 = \theta_{c3} \leq \theta < 90^\circ \qquad (4).$$

That is, in the above exemplary embodiment shown in Fig.5, the refractive index n_1 of the transparent material is selected to be larger than the refractive index n_3 of the rain water. In this way, the present invention can prevent mistaking the rain water as the leaked silicon oil.

In an exemplary embodiment, as shown in Fig.2, the side surface 111 of the recess 110 facing the incident laser beam L is configured as a slope side surface with respect to a horizontal direction or the top surface of the transparent member 100. But the present invention is not limited to the illustrated embodiment, in another embodiment, the side surface 111 of the recess 110 facing the incident laser beam L may be configured as a vertical side surface with respect to a horizontal direction.

Although the inspector can simply determine whether the silicon oil is leaked into the recess 110 by viewing whether the light spot appears below the transparent member 100, it is impossible that the inspector is always in the field. Therefore, in another exemplary embodiment, as shown in Fig.3, the silicon oil sensor may further comprise a first light detection device 300. The first light detection device 300 may be disposed at a first position corresponding to the total reflection path L1 below the transparent member 100 so as to receive the light of the laser beam led out the transparent member 100 in the total reflection path L1. As a result, when the first light detection device 300 receives the light of the laser beam, it can determine that the silicon oil is not leaked into the recess 110 of the transparent member 100. When the first light detection device 300 does not receive the light of the laser beam, it can determine that the silicon oil is leaked into the recess 110 of the transparent member 100. In an exemplary embodiment, once the first light detection device 300 does not receive the light of the laser beam, an alarm is given immediately by, for example, an acoustic alarm, an optical alarm, a vibration alarm, etc., so that an operator is noticed to deal with the electric power terminal that has occurred silicon oil leakage.

In an exemplary embodiment, the first light detection device 300 may be an optical fiber, a light receiving device or other light sensitive elements.

In another exemplary embodiment, as shown in Fig.4, the silicon oil sensor may further

comprise a second light detection device 400. The second light detection device 400 is disposed at a second position corresponding to the refractive path L2 so as to receive the light of the laser beam led out the transparent member 100 in the refractive path L2. As a result, when the second light detection device 400 receives the light of the laser beam, it can determine that the silicon oil is leaked into the recess 110 of the transparent member 100; when the second light detection device 400 does not receive the light of the laser beam, it can determine that the silicon oil is not leaked into the recess 110 of the transparent member 100. In an exemplary embodiment, once the second light detection device 400 receives the light of the laser beam, an alarm is given immediately by, for example, an acoustic alarm, an optical alarm, a vibration alarm, etc., so that an operator is noticed to deal with the electric power terminal that has occurred silicon oil leakage.

In an exemplary embodiment, the second light detection device 400 may be an optical fiber, a light receiving device or other light sensitive elements.

Please be noted that the silicon oil sensor of the present invention may comprise only one of the first and second light detection devices 300 and 400 or comprise both of the first and second light detection devices 300 and 400.

In a case where the silicon oil sensor comprises both of the first and second light detection devices 300 and 400, it can determine whether the silicon oil is leaked into the recess 110 according to detection results of both of the first and second light detection devices 300 and 400 rather than one detection result of only one of the first and second light detection devices 300 and 400. For example, when the first light detection device 300 receives the light of the laser beam and when the second light detection device 400 does not receive the light of the laser beam, it determines that the silicon oil is not leaked into the recess 110 of the transparent member 100; when the first light detection device 300 does not receive the light of the laser beam and when the second light detection device 400 receives the light of the laser beam, it can determine that the silicon oil is leaked into the recess 110 of the transparent member 100. In this way, it can improve the reliability and accuracy of detection on the silicon oil leakage.

In the illustrated embodiment of Fig.2, a plurality of recesses 110 are formed in the transparent member 100, and the plurality of recesses 110 are separated from each other and arranged in a row. But the present invention is not limited to the illustrated embodiment, there may be only a single elongate groove or a plurality of elongate grooves formed in the transparent member 100.

Fig.6 is an illustrative view of an electric power terminal assembly according to an exemplary embodiment of the present invention.

As shown in Fig.6, the transparent member 100 of the silicon oil sensor of Fig.2 is disposed below an outdoor electric power terminal 500 filled with the silicon oil so as to detect whether the silicon oil is leaked out of the outdoor electric power terminal 500. In this

way, the outdoor electric power terminal 500 and the silicon oil sensor are combined as an electric power terminal assembly.

In an exemplary embodiment, the sensor is not affected by the rain water, and the transparent member 100 of the silicon oil sensor may be directly exposed in an outdoor atmosphere environment without any waterproof film being formed thereon, as shown in Fig.6.

In an exemplary embodiment, as shown in Fig.6, the recess 110 is formed in a trumpet shape and has a flared opening toward the outdoor electric power terminal 500 to receive the silicon oil leaked out of the outdoor electric power terminal 500. In this way, the trumpet-shaped recess 110 can increase the detect area of the silicon oil sensor without needing an additional funnel to collect the leaked silicon oil.

In an exemplary embodiment, the size of the transparent member 100 and the size/the number of the recesses 110 may be determined based on the size of the outdoor electric power terminal 500. That is, the silicon oil sensor should be adapted to the outdoor electric power terminal 500 in size.

Please be noted that the shape of the recess 110 is not limited to the illustrated embodiment, in another exemplary embodiment, a vertical section of the recess 110 may have a shape of trapezoid (such as isosceles trapezoid), triangle or any other suitable shape.

In order to prevent mistaking the rain water as the leaked silicon oil, the refractive index n_1 of the transparent material must be selected to be larger than the refractive index n_3 of the rain water, but the refractive index n_1 of the transparent material may be less than the refractive index n_2 of the silicon oil. Therefore, the transparent material for forming the transparent member 100 may comprise at least one of glass, methyl methacrylate, polycarbonate, polystyrene, fluorinated ethylene propylene, epoxy resin and polyester.

The following table 1 shows several suitable transparent materials, respective refractive indexes n_1, n_2, n_3 thereof, as well as respective critical angles θ_{c1}, θ_{c2}, θ_{c3} thereof.

Table 1

Transparent material	refractive index n_1	θ_{c1} (refractive index of air is equal to 1)	θ_{c3} (refractive index n_3 of water is equal to 1.33)	θ_{c2} (refractive index n_2 of silicon oil is equal to 1.403)
first glass	1.90	31.8°	44.4°	47.6°
polycarbonate	1.59	39.0°	56.8°	61.9°
polystyrene	1.59	39.0°	56.8°	61.9°

second glass	1.50	41.8°	62.5°	69.3°
methyl methacrylate	1.49	42.2°	63.2°	70.3°
epoxy resin	1.48	42.5°	64.0°	71.4°
quartz glass	1.458	43.3°	65.8°	74.2°
fluorinated ethylene propylene	1.338	47.3°	83.7°	(no total reflection)

It should be appreciated for those skilled in this art that the above embodiments are intended to be illustrated, and not restrictive. For example, many modifications may be made to the above embodiments by those skilled in this art, and various features described in different embodiments may be freely combined with each other without conflicting in configuration or principle, so that more kinds of silicon oil sensors can be achieved with overcoming the technical problem of the present invention.

Although several exemplary embodiments have been shown and described, it would be appreciated by those skilled in the art that various changes or modifications may be made in these embodiments without departing from the principles and spirit of the disclosure, the scope of which is defined in the claims and their equivalents.

As used herein, an element recited in the singular and proceeded with the word "a" or "an" should be understood as not excluding plural of said elements or steps, unless such exclusion is explicitly stated. Furthermore, references to "one embodiment" of the present invention are not intended to be interpreted as excluding the existence of additional embodiments that also incorporate the recited features. Moreover, unless explicitly stated to the contrary, embodiments "comprising" or "having" an element or a plurality of elements having a particular property may include additional such elements not having that property.

What is claimed is,

1. A silicon oil sensor, comprising:

a transparent member (100) made of a transparent material; and

a laser source (200) for emitting a laser beam (L) into the transparent member (100),

wherein a recess (110) for collecting silicon oil is formed on the transparent member (100) and has a side surface (111) facing the laser beam (L) emitted from the laser source (200), and

wherein an incident angle θ of the laser beam (L) with respect to the side surface (111) is selected so that:

(i) when the recess (110) is filled with air, the laser beam (L) occurs a total reflection on the side surface (111) and exits out of the transparent member (100) in a total reflection path (L1); and

(ii) when the recess (110) is filled with silicon oil, the laser beam (L) occurs a refraction instead of a total reflection on the side surface (111) and exits out of the transparent member (100) in a refraction path (L2) different from the total reflection path (L1).

2. The silicon oil sensor according to claim 1,

when the refractive index n_1 of the transparent material is larger than the refractive index n_2 of the silicon oil, the incident angle θ of the laser beam (L) with respect to the side surface (111) is selected to satisfy the following expression (1):

$$\arcsin(1/n_1) = \theta_{c1} \leq \theta < \theta_{c2} = \arcsin(n_2/n_1) \quad (1),$$

when the refractive index n_1 of the transparent material is less than the refractive index n_2 of the silicon oil, the incident angle θ of the laser beam (L) with respect to the side surface (111) is selected to satisfy a following expression (2):

$$\arcsin(1/n_1) = \theta_{c1} \leq \theta < 90^\circ \quad (2),$$

wherein,

θ_{c1} refers to a critical angle at which the laser beam (L) directed into the transparent material occurs the total reflection on the interface between the transparent material and the air,

θ_{c2} refers to a critical angle at which the laser beam (L) directed into the transparent material occurs the total reflection on the interface between the transparent material and the silicon oil, and

the refractive index of the air is equal to 1.

3. The silicon oil sensor according to claim 2,

wherein the refractive index n_1 of the transparent material and the incident angle θ of the laser beam (L) with respect to the side surface (111) are selected so that:

when the recess (110) is filled with water, the laser beam (L) occurs the total reflection on the side surface (111) and exits out of the transparent member (100) in the total reflection path (L1)

4. The silicon oil sensor according to claim 3, wherein

when the refractive index n_1 of the transparent material is larger than the refractive index n_2 of the silicon oil, the incident angle θ of the laser beam (L) with respect to the side surface (111) is selected to satisfy the following expression (3):

$$\arcsin(n_3/n_1)= \theta_{c3} \leq \theta < \theta_{c2} \qquad (3), \text{ and}$$

when the refractive index n_1 of the transparent material is less than the refractive index n_2 of the silicon oil, the incident angle θ of the laser beam (L) with respect to the side surface (111) is selected to satisfy the following expression (4):

$$\arcsin(n_3/n_1)= \theta_{c3} \leq \theta < 90^\circ \qquad (4),$$

wherein,

θ_{c3} refers to a critical angle at which the laser beam (L) directed into the transparent material occurs the total reflection on the interface between the transparent material and the water, and

n_3 refers to the refractive index of water, and the refractive index n_3 of water is less than the refractive index n_1 of the transparent material and the refractive index n_2 of the silicon oil.

5. The silicon oil sensor according to any one of claims 1-4,

wherein the side surface (111) of the recess (110) facing the incident laser beam (L) is configured as a slope side surface or a vertical side surface with respect to a horizontal direction.

6. The silicon oil sensor according to any one of claims 1-4,

wherein an observor determines whether the silicon oil is leaked into the recess (110) by directly observing the path in which the laser beam (L) exits out of the transparent member (100) with his/her eyes.

7. The silicon oil sensor according to any one of claims 1-4, further comprising:

a first light detection device (300) disposed at a first position corresponding to the total

reflection path (L1) so as to receive the light of the laser beam led out the transparent member (100) in the total reflection path (L1),

wherein when the first light detection device (300) receives the light of the laser beam, it can determine that the silicon oil is not leaked into the recess (110) of the transparent member (100), and

when the first light detection device (300) does not receive the light of the laser beam, it can determine that the silicon oil is leaked into the recess (110) of the transparent member (100).

8. The silicon oil sensor according to any one of claims 1-4, further comprising:

a second light detection device (400) disposed at a second position corresponding to the refractive path (L2) so as to receive the light of the laser beam led out the transparent member (100) in the refractive path (L2),

wherein when the second light detection device (400) receives the light of the laser beam, it can determine that the silicon oil is leaked into the recess (110) of the transparent member (100), and

when the second light detection device (400) does not receive the light of the laser beam, it can determine that the silicon oil is not leaked into the recess (110) of the transparent member (100).

9. The silicon oil sensor according to any one of claims 1-4, further comprising:

a first light detection device (300) disposed at a first position corresponding to the total reflection path (L1) so as to receive the light of the laser beam led out the transparent member (100) in the total reflection path (L1); and

a second light detection device (400) disposed at a second position corresponding to the refractive path (L2) so as to receive the light of the laser beam led out the transparent member (100) in the refractive path (L2),

wherein when the first light detection device (300) receives the light of the laser beam and when the second light detection device (400) does not receive the light of the laser beam, it can determine that the silicon oil is not leaked into the recess (110) of the transparent member (100), and

when the first light detection device (300) does not receive the light of the laser beam and when the second light detection device (400) receives the light of the laser beam, it can determine that the silicon oil is leaked into the recess (110) of the transparent member (100).

10. The silicon oil sensor according to any one of claims 1-4,

wherein a plurality of recesses (110) are formed in the transparent member (100), and the plurality of recesses (110) are separated from each other and arranged in a row.

11. The silicon oil sensor according to any one of claims 1-4,
wherein the recess (110) is shaped as an elongated groove.

12. The silicon oil sensor according to any one of claims 1-4,
wherein the transparent member (100) of the silicon oil sensor is disposed below an outdoor electric power terminal (500) filled with the silicon oil so as to detect whether the silicon oil is leaked out of the outdoor electric power terminal (500).

13. The silicon oil sensor according to claim 12,
wherein the transparent member (100) of the silicon oil sensor is uncovered and directly exposed in an outdoor environment.

14. The silicon oil sensor according to claim 12,
wherein the size of the transparent member (100) and the size/the number of the recess(es) are determined based on the size of the outdoor electric power terminal.

15. The silicon oil sensor according to claim 14,
wherein the recess (110) is formed in a trumpet shape and has a flared opening toward the outdoor electric power terminal (500) to receive the silicon oil leaked out of the outdoor electric power terminal (500).

16. The silicon oil sensor according to claim 1,
wherein the transparent material comprises at least one of glass, methyl methacrylate, polycarbonate, polystyrene, fluorinated ethylene propylene, epoxy resin and polyester.

17. An electric power terminal assembly, comprising:
an electric power terminal (500) filled with silicon oil; and
a silicon oil sensor, according to any one of claims 1-16, disposed below the electric power terminal (500).

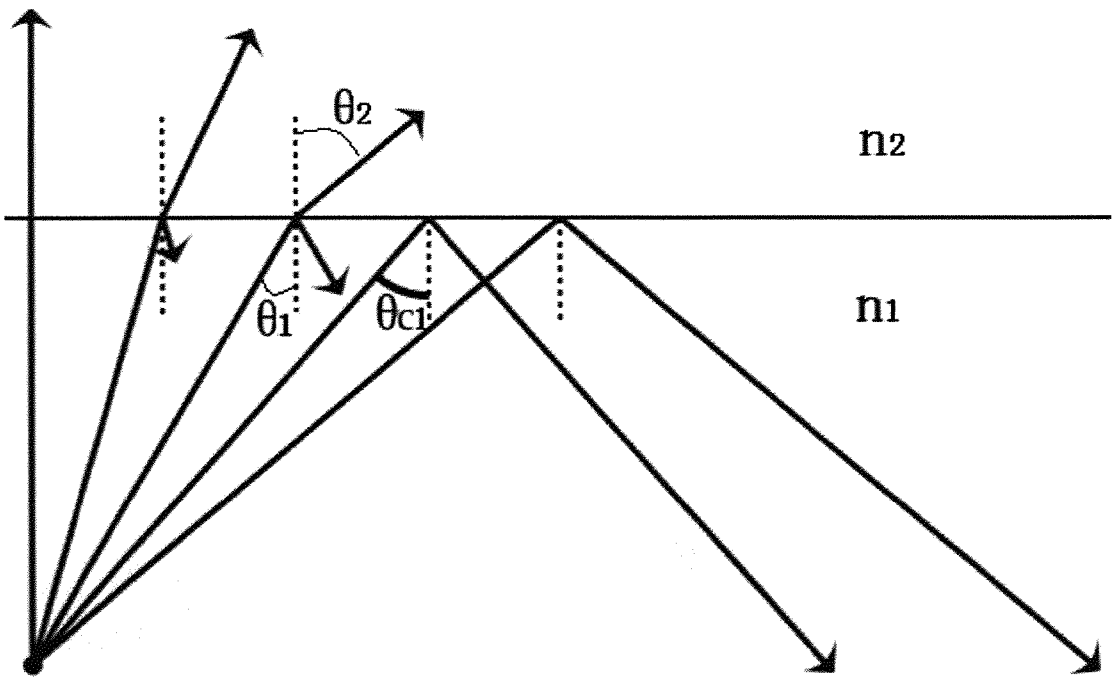


Fig.1

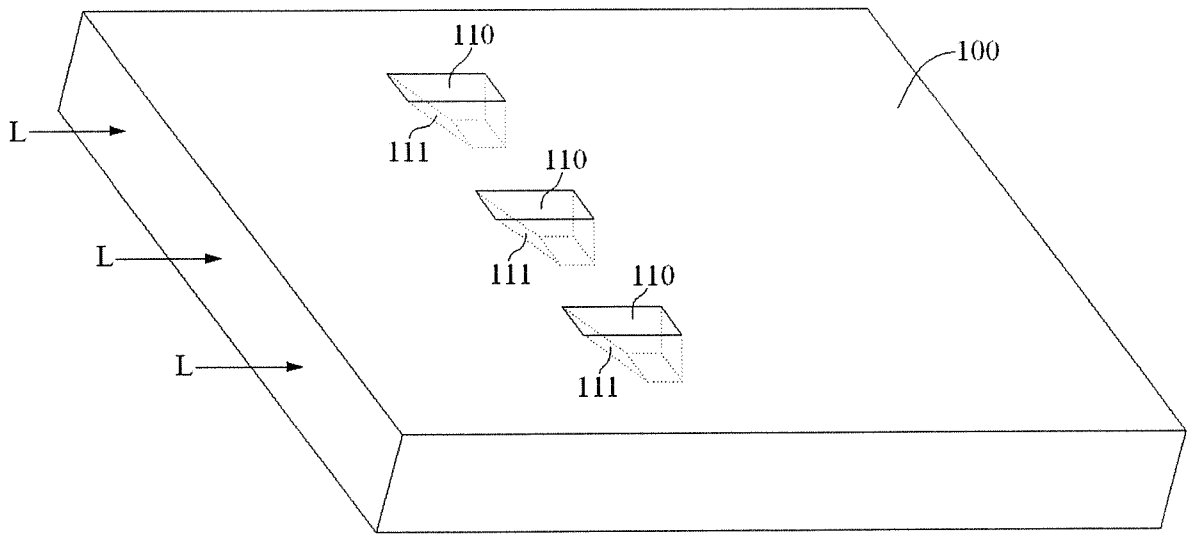


Fig.2

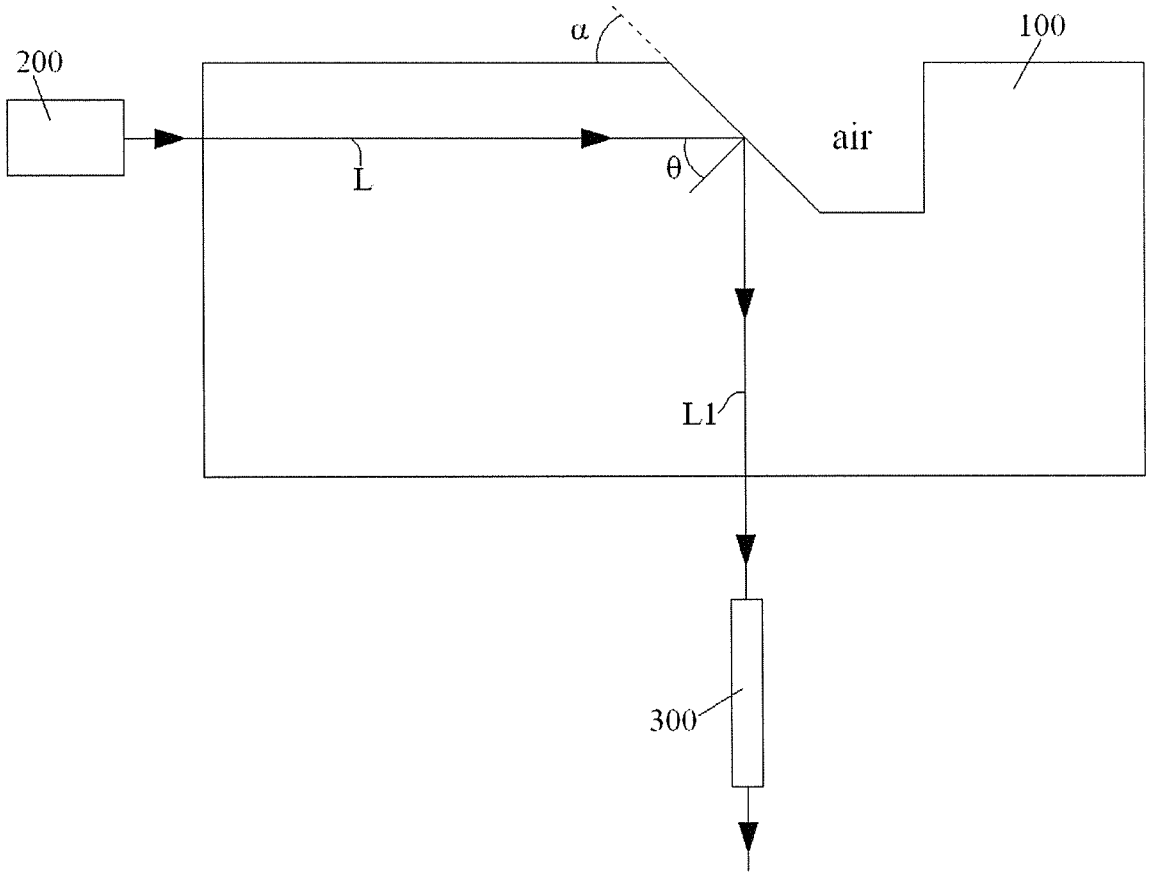


Fig.3

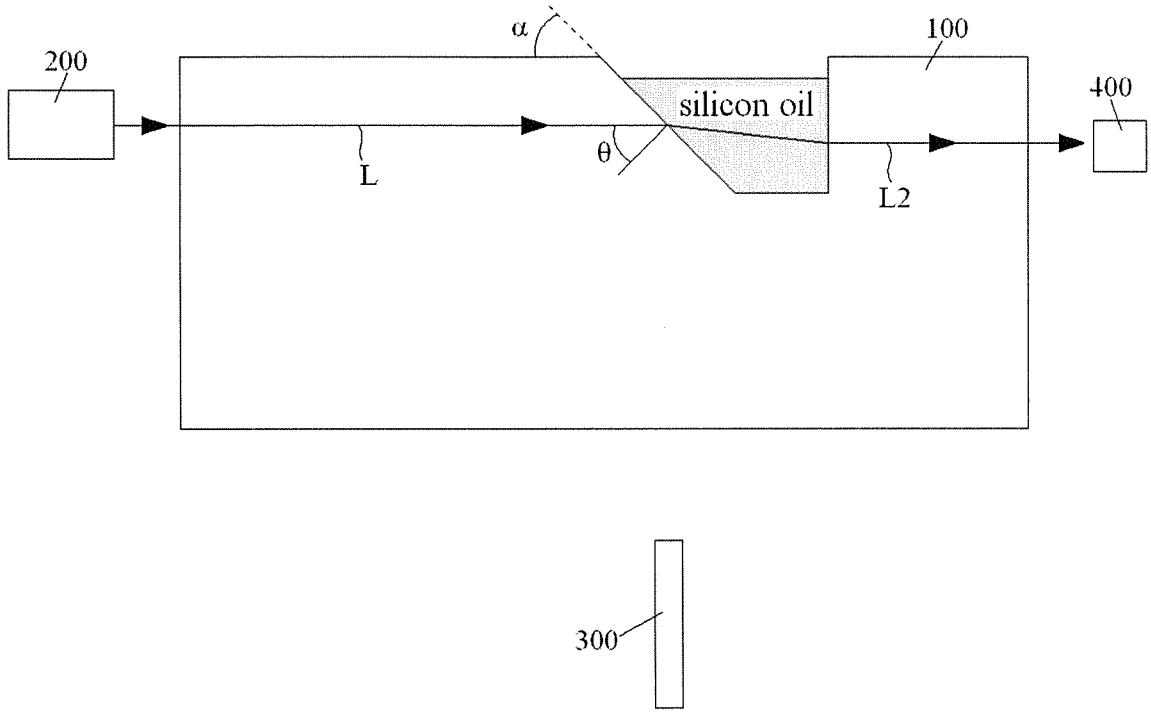


Fig.4

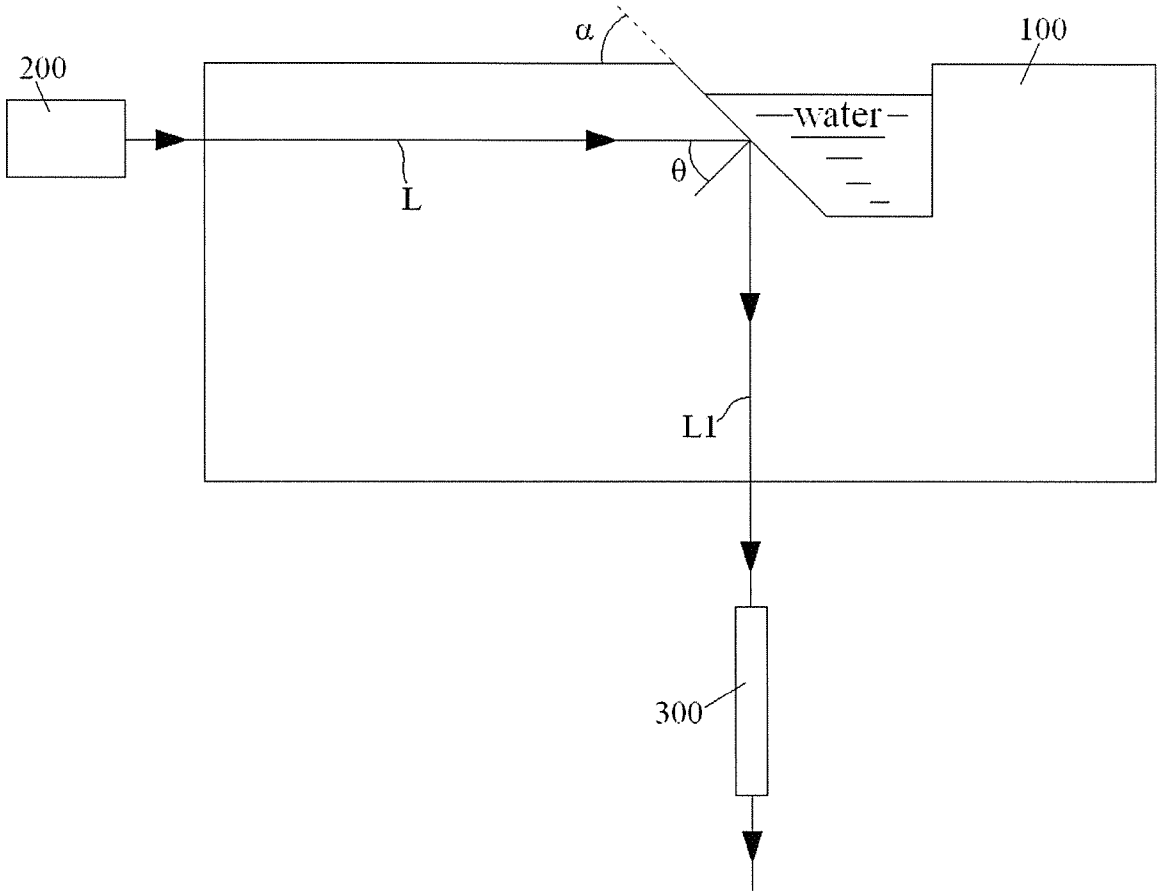


Fig.5

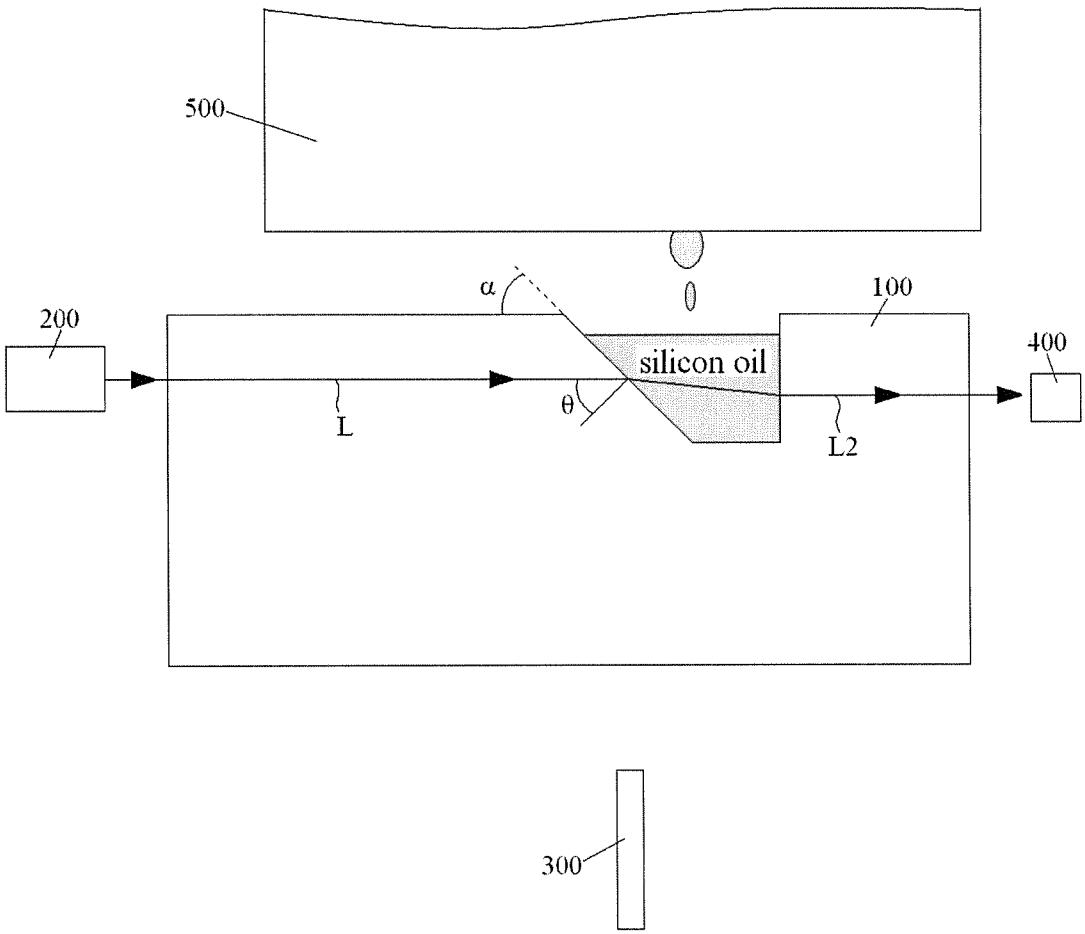


Fig.6

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2014/058429

A. CLASSIFICATION OF SUBJECT MATTER
INV. G01F23/292 G01M3/04 G01M3/38
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)
G01F G01M

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)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2009/039296 A1 (RICHARD MATTHIEU [FR]) 12 February 2009 (2009-02-12)	1,2,5-17
A	paragraph [0034] - paragraph [0040]; figures 3,4 paragraph [0052]; figure 12	3,4
X	JP S55 75620 A (SHINKO ELECTRIC CO LTD) 7 June 1980 (1980-06-07)	1,2,5-9, 11-17
A	abstract; figures 1-5	3,4,10
X	JP H06 28715 U (?) 15 April 1994 (1994-04-15)	1,2,5-17
A	abstract; figures 1,2	3,4

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
16 June 2014	23/06/2014

Name and mailing address of the ISA/	Authorized officer
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INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2014/058429

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	paragraph [0016] - paragraph [0029]; figures 1,2	3,4,10

A	US 2013/016357 A1 (CHEIM LUIZ A V [US]) 17 January 2013 (2013-01-17) paragraph [0012] - paragraph [0015]; figure 2	10

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Information on patent family members

International application No
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