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HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR,
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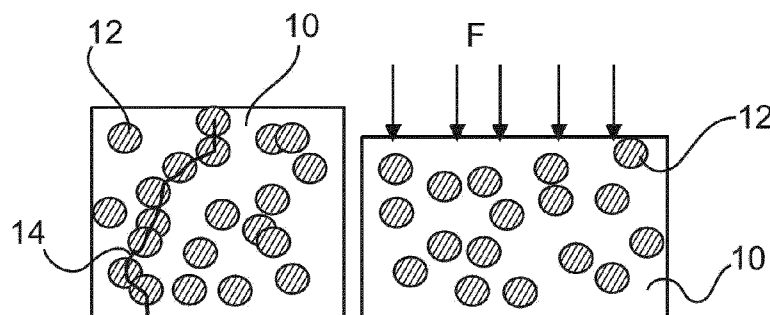
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(54) Title: SILICONE COMPOSITE SENSOR FOR MEASUREMENT OF HEART RATE

**FIG. 2**

(57) **Abstract:** Silicone composite sensor for measurement of heart rate The present invention proposes the use of a silicone composite material for measurement of heart rate or other small changes of pressure or force. The composite material has an electrical resistivity that changes when force is applied on the material. The conductive material may be carbon black or other electrically conductive particles like graphite, carbon nanotubes etc. The material is flexible and stretchable. The material can be made by injection moulding. An optional embodiment consists of a silicon composite material that contains liquid silicone rubber mixed with conductive particles like carbon black.

Silicone composite sensor for measurement of heart rate

FIELD OF THE INVENTION

The invention relates to the field of detectors or sensors for detecting changes
5 in pressure or force, such as – but not limited to – heart rate sensors.

BACKGROUND OF THE INVENTION

A pressure sensor measures pressure which is usually expressed in terms of
force per unit area. Such a sensor usually acts as a transducer and generates a signal as a
10 function of the imposed pressure. Typically, such a signal is an electrical signal.

Pressure sensors are used for control and monitoring in thousands of everyday
applications. Pressure sensors can also be used to indirectly measure other variables such as
fluid/gas flow, speed, water level, and altitude. Pressure sensors can alternatively be called
pressure transducers, pressure transmitters, pressure senders, pressure indicators and
15 piezometers, manometers, among other names. Furthermore, pressure sensors can vary
drastically in technology, design, performance, application suitability, and cost.

In medical areas such as heart rate or blood pressure detection or the like,
sensors typically use optical signals, electrical signals (electrocardiography, ECG) or force
signals (accelerometer) for detection.

20 The US6474367B1 discloses a sensing component made of conductive
polymers which connects to another type of sensor that is used to monitor heart rate. The
conductive polymer can be a composite made of a polymer including conductive organic or
inorganic substances.

US 2013/0218050 A1 describes a sensor and method of sensing dimensional
25 changes, stress changes or pressure changes on a substrate. A piezoresistant sensor is
temporarily and non-destructively attached to a surface. The piezoresistant sensor has an
electrically conductive elastic body having at least one pair of opposed ends, and the elastic
body contains conductive nanotubes homogeneously distributed therein. The elastic body has
at least one surface with two opposed ends and electrodes at each of the opposed ends. A
30 current is passed through the elastic body between the two electrodes. The current passing
through the elastic body is sensed by a Voltmeter. A mechanical step is performed with or on
the substrate, and the sensor measures changes in the current between the electrodes,
indicating strain or pressure on the sensor.

However, conventional types of sensors suffer from disadvantages such as high complexity, high energy consumption, low flexibility and hard skin contact.

SUMMARY OF THE INVENTION

5 It is an object of the present invention to provide a simple and flexible sensor device and a sensing method which can be used for detecting small changes in pressure or force, such as heart rate, blood pressure or the like.

This object is achieved by a sensor device as claimed in claim 1, by a method as claimed in claim 10, by a manufacturing method as claimed in claim 11.

10 Accordingly, a silicone composite material which contains electrically conductive particles is proposed as a material to be used to detect small changes in pressure or force by measuring a resulting change in the electric resistance of the silicone composite material. The silicone composite material contains volume filler in a range between 15 and 23%. In other words, the electrically conductive particles forming the volume filler assume
15 between 15 and 23% of the volume of the silicone composite material. In this range, a good sensitivity of the silicone composite material can be achieved. The composite material provides the further advantage that it can be provided in a soft, flexible and stretchable form which can thus follow curved shapes. Therefore, very low cost and simply structured sensors can be made. Furthermore, the sensor itself can be shaped in any (mouldable) form.

20 According to a first option, the device may be adapted to detect a heart rate of a human or animal based on the measured force or pressure changes on silicone composite material, wherein the force or pressure changes are caused by a blood vessel of the human or the animal. Thereby, the proposed sensor device and sensing method can be used for detecting the heart rate in a simple and flexible manner.

25 According to a second option which can be combined with the first option, a predetermined contact force may be applied to the silicone composite material during measurement.

According to a third option which can be combined with the above first or second option, the silicone composite material comprises liquid silicone rubber. Use of liquid
30 silicone rubber allows easy shaping and high flexibility of the obtained sensor device. In one embodiment, the silicone composite material visco-elastic, whereas normally silicone materials are elastic. Visco-elastic silicone composite material can be achieved by providing the silicone composite material in partially cured form.

According to a fourth option which can be combined with any one of the above first to third options, the conductive particles may comprise at least one of carbon black, metal, graphite, carbon nanotubes and graphene. Thus, a big variety of options is available for selecting suitable conductive particles for the silicone composite to achieve
5 desired characteristics (e.g., sensitivity) of the sensor device.

According to a fifth option which can be combined with any of the above first to fourth options, the concentration of the conductive particles in the silicone composite material may substantially be at percolation level. Thereby, a maximum change of resistance in dependence on the change of the applied pressure or force can be achieved, so as to obtain
10 maximum sensitivity.

According to a sixth option which can be combined with any of the above first to fifth options, the device may comprise a wrist strap on which the silicone composite material is integrated. This provides a straight forward way to measure the heart rate by integrating the silicone composite material to wrist watches or writs straps which can be
15 easily applied and worn by the target person or animal.

According to a seventh option which can be combined with any one of the above first to sixth options, the silicone composite material may arranged on the device as an array of a plurality of sensing elements consisting of the silicone composite material. Thereby, placing precision can be reduced, since the best of all signals generated by sensing
20 elements can be exploited.

Another aspect of the present disclosure is a use of a silicone composite material for detecting a heart rate of a human or animal. In particular, a use of a silicone composite material containing electrically conductive particles forming a volume filler in a range between 15 and 23% for detecting a heart rate of a human or animal via a change of the
25 electric resistance of the silicone composite material is presently disclosed. The silicone composite material used is preferably visco-elastic.

It shall be understood that the device of claim 1, the methods of claims 10 and 11, and the disclosed uses may have similar and/or identical preferred embodiments, in particular, as defined in the dependent claims.

It shall be understood that a preferred embodiment of the invention can also be any combination of the dependent claims or above embodiments with the respective
30 independent claim.

These and other aspects of the invention will be apparent from and elucidated with reference to the embodiments described hereinafter.

BRIEF DESCRIPTION OF THE DRAWINGS

In the following drawings:

Fig. 1 shows a schematic silicone composite sample according to a first
5 embodiment;

Fig. 2 shows an illustrative diagram indicating pressure-dependent behavior of
a conductive path in the silicone composite sample of the first embodiment;

Fig. 3 shows a silicone composite molded sample according to a second
embodiment;

10 Fig. 4 shows a diagram with a heart pulse measurement signal obtained by
silicone composite according to a third embodiment;

Fig. 5 shows a silicone composite placed on a wrist strap according to the third
embodiment; and

15 Fig. 6 shows a sensor arrangement with a matrix of silicone composite sensors
according to a fourth embodiment.

DETAILED DESCRIPTION OF EMBODIMENTS

Embodiments of the present invention are now described based on silicone
composite material with conductive particles, which can be used as a heart rate sensor.

20 A silicone composite, containing conductive particles, like carbon black or the
like, has an electrical resistivity that changes if a force is applied on the material. Such a
material can be used to measure the heart rate. More specifically, since the sensitivity of the
proposed silicone composite to changes of an applied force or pressure is significantly
different to conventional pressure or force sensors, a tactile sensor for heart rate detection,
25 heart rate monitoring or composite force or pressure sensing can be implemented based on
this material.

The conductive material can be carbon black or other electrically conductive
particles like, metals, graphite, carbon, carbon nanotubes graphene etc. The conductive
particle concentration may be close to the percolation level giving maximum response
30 (sensitivity). Furthermore, the silicone composite material can be made by compounding
and/or mixing and by using low cost mass manufacturing technologies, such as injection
moulding and extrusion. The silicone composite material may be based on a liquid silicone
rubber or on other silicones or elastomers. To achieve this, the silicone (e.g., liquid silicone

rubber) may be mixed with carbon black. The material is injection moulded and at least two electrical connections are attached.

Fig. 1 shows a top view (left portion) and a perspective view (right portion) of a schematic structure of a silicone composite sample 10 in a cylindrical shape with electrical connection 20 (left portion) according to a first embodiment. The silicone composite material has a certain electric conductivity achieved by the incorporated electrical particles. Therefore, a predetermined resistance can be measured between the electrical connections. This resistance is dependent on the geometrical structure of the silicone composite material.

Fig. 2 shows illustrative arrangements before and after application of a force F on a block of the silicone composite material 10 with its conductive particles 12. The electrical resistance of the silicone composite material is achieved by conductive paths generated by the conductive particles 12. In the left portion of Fig. 2, an exemplary conductive path 14 in the silicone composite sample 10 is shown before application of the force F. This path leads to a predetermined resistance of the silicone composite material 10. When the force F is applied, the geometric structure of shape of the block of the silicone composite material 10 changes (right portion of Fig. 2), so that the conductive path 14 is broken or changed. Consequently, if the conductive path is broken, the electrical resistance of the material increases.

Fig. 3 shows a silicone composite molded sample according to a second embodiment. Any suitable shape can be moulded as required based on specific applications of the pressure or force sensor.

Fig. 4 shows a diagram with a heart pulse measurement signal obtained by silicone composite material according to a third embodiment, which is shaped as or placed a wrist strap and could be used for a wrist watch or as a separate wrist strap to be worn during physical exercise or the like. As can be gathered from Fig. 4, sufficient sensitivity is achieved for measuring heart pulses and deriving the heart rate. More specifically, the diagram of Fig. 4 may indicate a measured electrical resistance of the silicone composite placed (while some force is applied by pressure changes due to changed blood flow) on the wrist as a function of time. As an example, at a source voltage of 2V, a power consumption of about 2mW may be observed.

Fig. 5 shows a schematic example of a silicone composite material 10 of a circular shape placed on a wrist strap 30 according to the third embodiment. The silicone composite material 10 may be connected via its electrical connection 12 to an integrated chip 50 provided on the wrist strap 30 and comprising a processing unit and a transmission unit for

wireless transmission of measurement data or signals to a remote station (not shown). As an alternative, the electrical connections may be used for a wired connection between the wrist strap 30 with the silicone composite material 10 and a remote or separated station used for analyzing the measurement signal.

Fig. 6 shows a sensor arrangement 40 with a 4x4 matrix of sensors made of the silicone composite material 10 according to a fourth embodiment. This sensor arrangement can be used to provide enhanced sensitivity by multiple sensing locations or by measuring a differential signal between inverted measurement signals of each individual sensor so as to suppress noise caused by electromagnetic interference (EMI) or the like. Of course, another matrix with a larger number of sensors can be used. The best signal of the sensor element that has best contact with the blood vessel can be picked up, so that the sensor does not have to be (perfectly) aligned with the blood vessel or measurement area.

In the above embodiments, very large response can be obtained with only very small force changes, e.g., probably around an equivalent of 1g. The silicon composite material may be manufactured for example by injection moulding. For the test result shown in Fig. 4, a small weight was put on the sensor (e.g. a few hundred of grams on a surface area of 1 cm² of the silicone composite material). Thereby, a mechanical contact between the silicone composite material and the measuring surface is established. The applied weight depends on the surface area of the sensor (e.g., for a sensor of a few mm² a much lower force is required. In principle, for heart rate measurements a weight or force comparable to the force to measure the pulse manually with the finger). In the wrist strap embodiment of Fig. 5 the force generated by the somewhat elastic wrist strap 30 can be sufficient.

The preferred composition of the silicone composite material is close to (around) the percolation level. At that concentration the sensitivity (i.e. resistance change (DR) depending on the change of applied pressure (DP) is maximum (i.e. maximum DR/DP). However, this concentration depends on the type of filler and the shape of the filler particles. Theoretically, with perfectly round particles it is about 16% volume of the filler. Good results have been achieved at around 18%. Experiments have been conducted between 15 and 23%. These levels certainly depend on the filler material used. Graphite is an equally suitable alternative.

To summarize, use of a silicone composite for measurement of heart rate or other small changes of pressure or force has been described. The composite material has an electrical resistivity that changes when force is applied on the material. The conductive material may be carbon black or other electrically conductive particles like graphite, carbon

nanotubes etc. The material is flexible and stretchable. In some embodiments it is viscoelastic. The material can be made by injection moulding. An optional embodiment consists of a silicon composite material that contains liquid silicone rubber mixed with conductive particles like carbon black.

5 While the invention has been illustrated and described in detail in the drawings and foregoing description, such illustration and description are to be considered illustrative or exemplary and not restrictive. The invention is not limited to the disclosed embodiments. The proposed silicone composite may include other types of conductive particles and may be used for heart rate detection, heart rate monitoring, intensive care units (ICUs), home healthcare,
10 sports, activity monitoring, therapy adherence, coaching or generally for measuring other signals which cause changes of pressure or force.

 Other variations to the disclosed embodiments can be understood and effected by those skilled in the art in practicing the claimed invention, from a study of the drawings, the disclosure and the appended claims. In the claims, the word “comprising” does not
15 exclude other elements or steps, and the indefinite article “a” or “an” does not exclude a plurality. A single unit may fulfil the functions of several items recited in the claims. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage.

 The foregoing description details certain embodiments of the invention. It will
20 be appreciated, however, that no matter how detailed the foregoing appears in text, the invention may be practiced in many ways, and is therefore not limited to the embodiments disclosed. It should be noted that the use of particular terminology when describing certain features or aspects of the invention should not be taken to imply that the terminology is being re-defined herein to be restricted to include any specific characteristics of the features or
25 aspects of the invention with which that terminology is associated.

 A single unit or device may fulfill the functions of several items recited in the claims. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage.

CLAIMS:

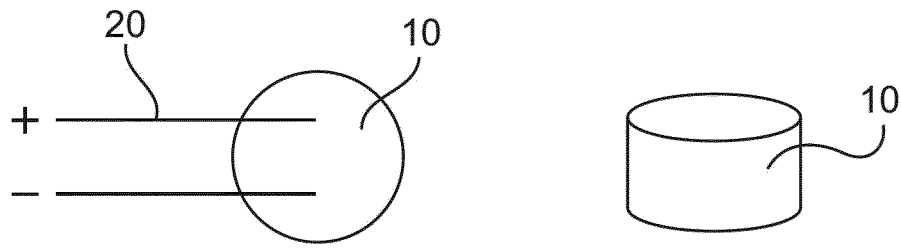
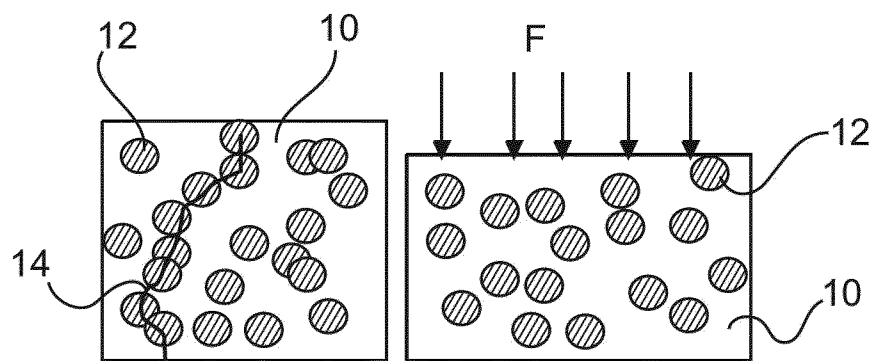
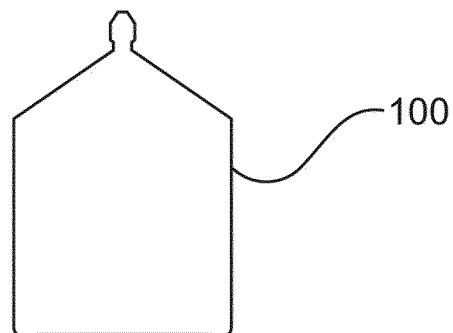
1. A detector device comprising a silicone composite material (10) which contains electrically conductive particles (12) for measuring force or pressure changes on the silicone composite material (10), wherein the detector device is adapted to measure a change of electric resistance of the silicone composite material (10) due to an applied change of pressure or force caused by a blood vessel of a human or an animal and to determine a heart rate of the human or animal based on the measured change of electrical resistance of the silicone composite material (10), wherein the silicone composite material contains volume filler in a range between 15 and 23%.
5
2. The detector device of claim 1, wherein the silicone composite material (10) is visco-elastic.
3. The device of claim 1, wherein a predetermined contact force is applied to the silicone composite material (10) during measurement.
15
4. The device of claim 1, wherein the silicone composite material (10) comprises liquid silicone rubber.
20
5. The device of claim 1, wherein the conductive particles (12) comprise at least one of carbon black, metal, graphite, carbon nanotubes and graphene.
6. The device of claim 1, wherein the concentration of the conductive particles (12) in the silicone composite material (10) is substantially at percolation level.
25
7. The device of claim 1, wherein the silicone composite material (10) is made by injection molding or extrusion.
8. The device of claim 1, further comprising a wrist strap (30) on which the silicone composite material (10) is integrated.
30

9. The device of claim 1, wherein the silicone composite material (10) is arranged on the device as an array of a plurality of sensing elements consisting of the silicone composite material (10).

5 10. A method of detecting a heart rate of a human or animal, the method comprising applying a change of pressure or force caused by a blood vessel to a silicone composite material (10) containing conductive particles (12) forming a volume filler in a range between 15 and 23% of volume, and measuring a change of electric resistance of the silicone composite material (10) caused by the applied change of pressure or force.

10 11. A method of manufacturing a heart rate sensor, the method comprising mixing a silicone material with conductive particles (12) that form a volume filler in a range between 15 and 23% of volume, shaping the obtained silicone composite material (10) by injection molding or extrusion, and attaching electrical connections to the shaped silicone
15 composite material (10).

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**FIG. 1****FIG. 2****FIG. 3**

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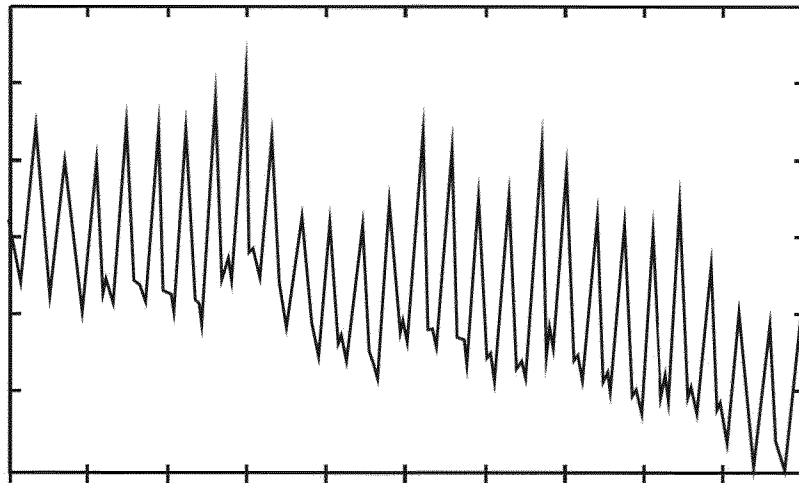


FIG. 4

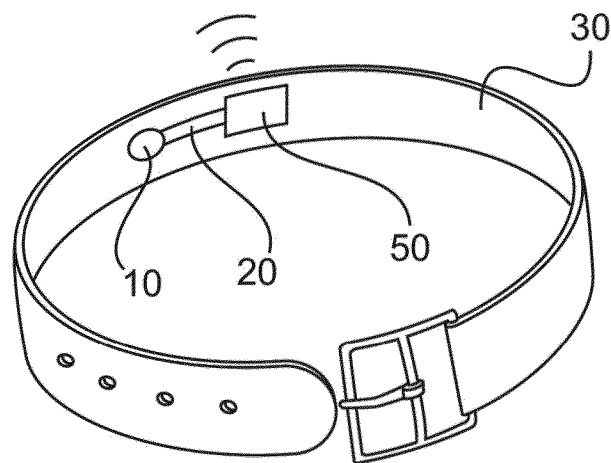


FIG. 5

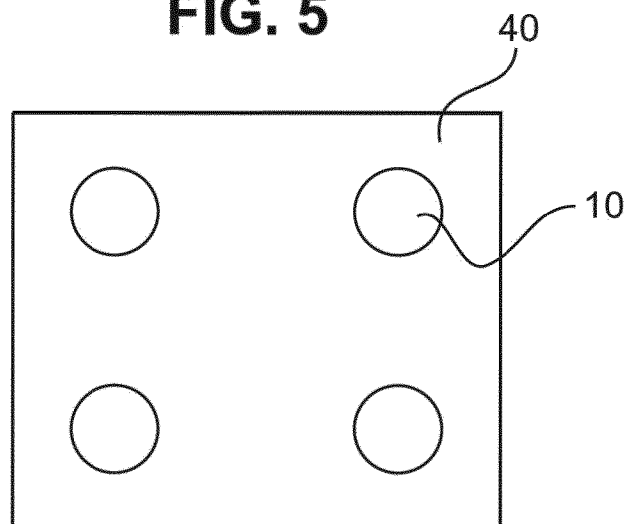


FIG. 6

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2015/052735

A. CLASSIFICATION OF SUBJECT MATTER
INV. A61B5/024 G01L1/18 G01L1/20 H01B1/24
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)
A61B G01L H01B G01B

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

C. 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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Y	paragraphs [0013] - [0020]; figures 1-3 -----	3,8,9
Y	US 2008/307899 A1 (VON LILIENFELD-TOAL HERMANN [DE] ET AL) 18 December 2008 (2008-12-18) paragraphs [0021], [0024] - [0027]; figures 1,3-5 -----	3,8,9
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Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

23 April 2015

Date of mailing of the international search report

04/05/2015

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INTERNATIONAL SEARCH REPORT

International application No

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	KR 2013 0032890 A (PARK SANG GU [KR]) 2 April 2013 (2013-04-02) the whole document -----	1-11

INTERNATIONAL SEARCH REPORT

Information on patent family members

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