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(54) **METHOD FOR MANUFACTURING A SENSORIZED ELASTOMERIC SUPPORT AND SENSORIZED ELASTOMERIC SUPPORT**

VERFAHREN ZUR HERSTELLUNG EINES SENSORISIERTEN ELASTOMEREN LAGERS UND  
SENSORISIERTES ELASTOMERES LAGER

PROCÉDÉ DE FABRICATION D'UN SUPPORT ÉLASTOMÈRE MUNI DE CAPTEURS ET SUPPORT  
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## Description

### TECHNICAL FIELD

[0001] The invention generally belongs to the field of construction, and more particularly to the detection of deformation in elastomeric supports used in construction, such as in bridges.

### STATE OF THE ART

[0002] Several constructions, such as bridges, are conventionally supported on elastomeric supports. An elastomeric support is usually a block made of layers of an elastomeric material alternating with metal plates. Elastomeric supports can be subject to deformations caused by the behaviour of the construction supported thereon, e.g. in response to changes in the load supported by the construction. These deformations must be measured in order to determine the structural condition of the elastomeric support. A number of known elastomeric supports therefore comprise an embedded deformation sensor.

[0003] Document US20180202878A1 discloses a high-damping rubber isolation bearing including a top bearing plate, a bottom bearing plate, a high-damping rubber bearing body, a nano rubber sensor, a base plate, a limit unit and top and bottom anchor bolts.

[0004] Document KR20140001586 discloses a bridge elastomeric support having an embedded sensor for measuring the vertical deformation thereof. The sensor is embedded within the elastomeric support in a vertical direction. A wireless transmission module enables wireless transmission of the data provided by the deformation sensor.

[0005] Document KR20190081052 discloses a bridge elastomeric support having sensors for measuring displacement of the end plates of the support along axes x, y and z. The sensors are installed on opposite surfaces of the upper and lower end plates of the elastomeric support for detecting distance and tilt between the end plates.

[0006] Document DE4402608 discloses an elastomeric support for a bridge having a strain gauge for measuring the force distribution across an upper pressure pad. In particular, the strain gauge is placed along a horizontal direction into a cavity provided within an upper and lower pad of the elastomeric support.

[0007] Prior art elastomeric supports usually require the provision of dedicated placement sites for the installation of the sensors, which are typically embedded within the block, such as parallelepipedic block. Disadvantageously, this entails carrying out a time-consuming sensor installation process. Further, the volume of the sensors provided within the elastomeric supports adversely affects the resistance of the supports. Even further, prior art sensors frequently require complex interrogation electronic circuits for acquiring the relevant signals from the sensor.

## DESCRIPTION OF THE INVENTION

[0008] The present invention solves the aforementioned drawbacks by means of a novel sensorized elastomeric support comprising at least one deformation sensor based on buckypaper and a method for manufacturing a sensorized elastomeric support comprising at least one deformation sensor based on buckypaper.

[0009] Buckypaper is a thin sheet made from an aggregate of carbon nanotubes or carbon nanotube grid paper. The production of buckypaper sheets typically includes making a suspension of carbon nanotubes dispersed in a liquid medium and filtering the suspension by a filter membrane, such that the carbon nanotubes are deposited directly on the filter membrane as the fluid medium flows through the filter membrane. The buckypaper sheet is typically dried and thereafter separated from the filter membrane. Document US7459121 B2 discloses an exemplary method for producing buckypaper. Document EP3524339A1 discloses a method for increasing the thickness of a buckypaper sheet.

[0010] The electrical resistance of a buckypaper strip changes in response to deformation. The applicant advantageously uses this property of buckypaper for employing buckypaper strips as deformation sensors, thus providing a sensorized elastomeric support that overcomes the drawbacks disclosed above. Therefore, in this description, the buckypaper strip is referred to as buckypaper strip sensor or buckypaper strip deformation sensor.

[0011] In the present document, the term "*elastomeric block*" refers to a block made of an elastomeric material and possibly comprising a number of metal plates embedded therein. An elastomeric block may have different shapes, such as parallelepipedic or cylindrical.

[0012] In the present document, the terms "*horizontal*" and "*vertical*" are interpreted with reference to the orientation of the elastomeric support when in normal use. More specifically, when the elastomeric support is in use, the vertical direction corresponds to the direction of the weight supported by said elastomeric support, while the horizontal direction is perpendicular to the vertical direction. Similarly, the terms "*upper*", "*lower*" and the like are interpreted according to said vertical direction.

[0013] In the present document, the term "*face*" refers to each distinct side of the elastomeric support. An elastomeric support, when in use, generally comprises a normally horizontal lower face or base resting on a surface (such as on the ground or on another construction part, such as buttress), a normally horizontal upper face supporting the construction (i.e. bridge or bridge board) and one or more lateral faces. The faces need not be planar, e.g. the lateral faces of a cylindrical elastomeric support are curved.

[0014] In this context, the term "*diagonal*" refers to a direction contained in a lateral face that is neither vertical nor horizontal when the elastomeric block is in use. In other words, a diagonal direction refers to a vector com-

prising a vertical component and a horizontal component.

**[0015]** A first aspect of the present invention is directed to a method for manufacturing a sensorized elastomeric support. The method comprises the following steps:

- Adhering a first sheet of elastomeric material onto a lateral face of an elastomeric block.
- Adhering a buckypaper strip deformation sensor onto said first sheet of elastomeric material. The buckypaper strip deformation sensor is adhered along a diagonal direction of the first sheet of elastomeric material. This enables measuring deformations of the elastomeric block both in a vertical and a horizontal direction.
- Adhering a second sheet of elastomeric material onto the first sheet of elastomeric material, such that the buckypaper strip deformation sensor is sandwiched therebetween.
- Submitting the elastomeric block, with the first sheet, the buckypaper deformation sensor and the second sheet adhered thereto, to a vulcanization process.

**[0016]** The result of this method is a sensorized elastomeric support where the buckypaper deformation sensor is embedded, diagonally, within a lateral face of the elastomeric block. This sensorized elastomeric support can therefore detect deformations both in the vertical and horizontal directions.

**[0017]** The elastomeric block may have parallelepipedic shape. In this case, the buckypaper strip deformation sensor preferably extends diagonally from a lower corner of the lateral face to an upper corner of said lateral face.

**[0018]** The elastomeric block may have cylindrical shape. In this case, the buckypaper strip deformation sensor preferably extends diagonally from a central portion of the lateral face, for example to an upper corner of said lateral face, or to a lower corner thereto, or towards a corner without reaching the corner itself.

**[0019]** In embodiments of the invention, the method comprises an initial step of combining the buckypaper strip with a polymeric material, or soaking the buckypaper strip deformation sensor in a polymeric solution, for increasing its elongation capacity. In a non-limiting example, the polymeric solution is polyvinyl alcohol.

**[0020]** The soaking step may comprise the following steps:

- Obtaining a polyvinyl alcohol solution having between 0.5-15% in weight of polyvinyl alcohol.
- Soaking the buckypaper strip deformation sensor in said polyvinyl alcohol solution for a period of 15-25 hours.
- Drying the buckypaper strip deformation sensor in a vacuum oven.

**[0021]** In embodiments of the invention, electrical wires are then connected to respective opposite ends of

the buckypaper strip deformation sensor. Each wire connection may comprise a protective epoxy layer. The epoxy layer ensures that the connections withstand the pressure and temperature conditions during the vulcanization process disclosed below.

**[0022]** Any appropriate means can be employed for adhering the first sheet and the second sheet of elastomeric material one to the other, as well as to a lateral face of the elastomeric block. In a particular embodiment of the invention, the method further comprises a step of impregnating the first sheet and the second sheet with a viscous bitumen prior to placing the buckypaper strip deformation sensor therebetween. A manual pressure can then be applied on the second sheet of elastomeric material prior to the vulcanization step for ensuring a firm fixation of the first and second elastomeric sheets one to the other with the buckypaper strip deformation sensor sandwiched therebetween.

**[0023]** The method may further comprise adhering another buckypaper strip deformation sensor onto another lateral face of the elastomeric block, sandwiched between corresponding sheets of elastomeric material.

**[0024]** The method may further comprise adhering another pair of buckypaper strip deformation sensors in two other lateral faces of the elastomeric block, sandwiched between corresponding sheets of elastomeric material.

**[0025]** Once the first and second elastomeric sheets and the buckypaper sensor are adhered to the lateral face of the elastomeric block, the vulcanization process can begin. In embodiments of the invention, the vulcanization process comprises submitting the elastomeric block, with the first sheet, the buckypaper deformation sensor, and the second sheet adhered thereto, to a temperature of 120°C-160°C and to a pressure of 15 kg/cm<sup>2</sup>-25 kg/cm<sup>2</sup>.

**[0026]** The application of pressure during the vulcanization process may be carried out by means of a press. The press needs to be modified in order to allow for a uniform application of pressure while ensuring that no damage is caused to the wires. In a particular embodiment the press may comprise two moulds, in which case the method may comprise making holes in at least one of the moulds for the passage of the electrical wires connected to opposite ends of the buckypaper strip deformation sensor towards the outside of said press. Therefore, only a portion of each wire remains within the press during the step of vulcanization, while the main portion thereof exits through the hole made in the at least one mould.

**[0027]** A second aspect of the present invention is directed to a sensorized elastomeric support comprising an elastomeric block and further comprising a buckypaper strip deformation sensor embedded in a diagonal direction of a lateral face of said elastomeric block.

**[0028]** The buckypaper strip deformation sensor is embedded between a first sheet and a second sheet of elastomeric material disposed on (adhered to) said lateral face of the elastomeric block.

**[0029]** The buckypaper strip deformation sensor is provided in a diagonal direction for measuring deformations of the elastomeric block both in a vertical and a horizontal direction.

**[0030]** The elastomeric support may have different shapes. In embodiments of the invention, the support has parallelepipedic shape. In embodiments of the invention, the support has cylindrical shape. Other shapes are also possible depending on the application and its requirements.

**[0031]** When the elastomeric block may have parallelepipedic shape, the buckypaper strip deformation sensor preferably extends diagonally from a lower corner of the lateral face to an upper corner of said lateral face.

**[0032]** When the elastomeric block may have cylindrical shape, the buckypaper strip deformation sensor preferably extends diagonally from a central portion of the lateral face to an upper corner of said lateral face, or to a lower corner thereof, or towards a corner without reaching the corner itself.

**[0033]** In embodiments of the invention, the sensorized elastomeric support comprises one pair of buckypaper strip deformation sensors. For example, the pair of buckypaper strip deformation sensors may be disposed on adjacent lateral faces of the elastomeric block. With this configuration, horizontal deformations caused by both transversal and longitudinal displacement of the support can be measured. This is applicable to parallelepipedic supports and to cylindrical supports.

**[0034]** Alternatively, the pair of buckypaper strip deformation sensors may be disposed on opposite lateral faces of the elastomeric block. This configuration is specially suitable for a support having parallelepipedic shape, and in which in use of the support, one of the directions of displacement -typically the transversal one- is constraint. In other words, because the parallelepipedic shape support can only suffer longitudinal displacement, the two sensors may be disposed on opposite lateral faces of the support (the two longitudinal lateral faces with respect to the displacement to be suffered by the support).

**[0035]** In embodiments of the invention, the sensorized elastomeric support comprises two pairs of buckypaper strip deformation sensors, where the buckypaper strip deformation sensors of each pair are provided on respective opposite lateral faces of the elastomeric block.

**[0036]** These configurations advantageously allow for detecting deformations of the elastomeric block both in the vertical and horizontal directions. Indeed, by embedding the buckypaper strip deformation sensor diagonally within a lateral face of the elastomeric block, both horizontal and vertical deformations of said block cause a change in the length of the buckypaper strip. In turn, said change in the length of the buckypaper strip causes a change in the resistance. This resistance change can be easily detected by using a simple electric circuit. By combining the information obtained from pairs of diagonal buckypaper strip deformation sensors provided in adjacent sides of the elastomeric block, the deformation of

the elastomeric support in both the horizontal and vertical directions is optimized. Further, as disclosed in detail hereinbelow, the installation of this buckypaper strip deformation sensor in the elastomeric block is economic and simple.

**[0037]** This novel sensorized elastomeric support may be specially employed in the construction of bridges.

**[0038]** A third aspect of the present invention is directed to a bridge comprising at least one sensorized elastomeric support comprising an elastomeric block and further comprising at least one pair of buckypaper strip deformation sensors embedded in a corresponding number of lateral faces of said elastomeric block.

## BRIEF DESCRIPTION OF THE DRAWINGS

### [0039]

Fig. 1 shows a schematic flow diagram of the method according to an embodiment of the present invention.

Figs. 2a-2c show the steps of the method of the present invention.

Figs. 3a-3b show closeup views of finished sensorized supports according to embodiments of the invention.

Figs. 4a and 4b show results of tests of a sensorized support when submitted to a vertical load.

Figs. 5a and 5b show results of tests of a sensorized support when submitted to a horizontal load.

Fig. 6 shows a cylindrical sensorized support according to an embodiment of the present invention.

## DESCRIPTION OF A PREFERRED EMBODIMENT

**[0040]** The method of the invention is now disclosed with reference to the attached figures. In particular, the steps of the method shown in Fig. 1 are disclosed in detail below.

**[0041]** As mentioned earlier in the present document, an elastomeric block is a block made of an elastomeric material, possibly having a number of horizontal metal plates embedded therein. The elastomeric material may be, for example, natural rubber (NR), such as chloroprene rubber (CR), also referred to as neoprene. In a particular embodiment, the elastomeric block is made of NR or CR plus a maximum amount of 5% (weight) of other polymers according to EN1337-3.

**[0042]** When in use, an elastomeric block has a horizontal upper face, a horizontal lower face and one or more lateral faces. More specifically, in the particular embodiment herein disclosed (see for example Fig. 2b-2c), the elastomeric block 2 has a parallelepipedic shape hav-

ing six faces, the six faces being parallelograms. The six faces form three pairs of parallel faces. One of the faces is the horizontal lower face, or base, of the elastomeric block 2, the four faces perpendicular to said base are the lateral faces, and the face opposite the base is the horizontal upper face. The base of the elastomeric block 2 usually rests on the ground or on a part or portion of a construction or structure, such as on a buttress, while the horizontal upper face supports a construction, e.g. bridge, or a part thereof. In use of a support made of the elastomeric block 2, for example in a bridge, the support will move horizontally in two possible directions: longitudinally and transversally with respect to the bridge. Therefore, horizontal deformations will be caused by both transversal and longitudinal displacement of the support. In certain conditions, however, the support will move horizontally only in one possible direction, typically longitudinally with respect to the construction (e.g. bridge). This occurs when the other horizontal displacement (transversal to the construction) is physically constraint.

**[0043]** In the following, a method for manufacturing a sensorized elastomeric support 1 as shown for example in Fig. 3a is disclosed. The method comprises steps for embedding a buckypaper strip deformation sensor 3 within a lateral face of an elastomeric block 2, thereby rendering the sensorized elastomeric support 1. As disclosed earlier in the present document, a buckypaper strip deformation sensor 3 is a deformation sensor based on a buckypaper strip.

**[0044]** Firstly, in order to improve the elongation capacity of the buckypaper strip deformation sensor 3, ensuring that the buckypaper strip deformation sensor 3 can stretch together with the elastomeric block 2 when embedded therein, the buckypaper strip deformation sensor is preferably combined with a polymeric material. Preferably, flexible polymers are used. Non-limiting examples of polymers that may be used are: polydimethylsiloxane (PDMS), polyimide (PI), polyethylene terephthalate (PET), polypropylene (PP), polyvinyl, natural rubber and epoxy resins. These polymer substrates can improve the linear response, strain range, and stability of the sensor. For example, a polyvinyl alcohol bath may be applied.

**[0045]** Therefore, step 11 shown in Fig. 1 preferably comprises combining the buckypaper strip with a polymeric material, or soaking the buckypaper strip deformation sensor 3 in a polymeric solution, for increasing its elongation properties. If, for example, a polyvinyl alcohol solution is used, the solution may have between 0.5 and 15% in weight of polyvinyl alcohol. The solution may be prepared by dissolving polyvinyl alcohol powder in distilled water by means of bath ultrasonication for 30 minutes, followed by a magnetic stirring at 600 rpm and 120°C for 2 hours. The buckypaper strip deformation sensor 3 is soaked in this solution for several hours, such as 21 hours. Finally, the buckypaper strip deformation sensor 3 is dried -for example overnight- for example in a vacuum oven at about 60°C. The resulting buckypaper

strip deformation sensor 3 is shown to be more elastic.

**[0046]** Then, according to step 12 of Fig. 1, electrical wires 32 are connected to respective opposite ends of the buckypaper strip deformation sensor 3. Silver resin can be used for this purpose. In addition, epoxy resin can be applied for protecting the connections 31 between the buckypaper strip sensor 3 and the electrical wires 32 during the vulcanization process carried out as the last step of the present method. The result of this step is shown in Fig. 2a.

**[0047]** Then, as shown in step 13 of Fig. 1, a first sheet 41 of elastomeric material is adhered onto a lateral face of the elastomeric block 2. Normally, the first sheet 41 is made of the same elastomeric material as the elastomeric block 2, e.g. NR, CR or the like. In order for the first sheet 41 to firmly adhere to the elastomeric block 2, sheet 41 may first be impregnated with viscous bitumen and then adhered to the lateral face of the elastomeric block 2.

**[0048]** Next, as shown in step 14 of Fig. 1, the buckypaper strip deformation sensor 3 is placed on the first sheet 41 in a diagonal direction. A BP disposed in diagonal direction permits to capture vertical and horizontal deformation as a vectorial decomposition. For example, in the parallelepipedic elastomeric block 2 shown in Fig. 2b, the buckypaper strip deformation sensor 3 may extend diagonally from a lower corner of the lateral face to an upper corner of said lateral face. It has been observed that the longer the buckypaper strip deformation sensor (thus covering a largest diagonal direction of the lateral face on which it is disposed), the more sensible it is to deformations. As disclosed earlier in the present document, a diagonal direction is a direction contained in the lateral face of the elastomeric block 2 -and therefore in the first layer 41 now adhered to a corresponding lateral face of block 2- that is neither horizontal nor vertical when the elastomeric block 2 is in use. The buckypaper strip deformation sensor 3 adheres to the first sheet 41 by means for example of the viscous bitumen. Normally, a horizontal component of the diagonal direction is larger than a vertical component thereof, as shown in Fig. 2b. The sensorized elastomeric support 1 obtained by the present method, and shown for example in Fig. 3a, when in normal use, will therefore be more sensitive to horizontal deformations than to vertical deformations.

**[0049]** Subsequently, as shown in step 15 of Fig. 1, a second sheet 42 of elastomeric material, also preferably impregnated with viscous bitumen, is adhered onto the first sheet 41 (on which sensor 3 has been placed). The buckypaper strip deformation sensor 3 is thus sandwiched between the two sheets 41, 42 with the cables 32 of the buckypaper strip deformation sensor 3 protruding from respective opposite ends of the lateral face of the elastomeric block 2. The result of this step is shown in Fig. 2c. In Fig. 2c, the cables 32 show up at opposite corners of the lateral face of the block 2 on which the sensor 3 is disposed. Alternatively, the cables 32 could show up at different positions on the edges of the lateral face of the elastomeric block 2. In Fig. 2c, dotted traces

represent the embedded sensor 3 and embedded portions of the cables 32, covered by the second sheet 42. It is remarked that the first sheet 41 of elastomeric material is not shown in Fig. 2c because it has been overlapped by the second sheet 42.

**[0050]** Preferably, the former steps for embedding a buckypaper strip deformation sensor 3 within a lateral face of an elastomeric block 2, are repeated at least once. In particular, a second sensor is preferably embedded -following the same steps- within a second lateral face of the elastomeric block 2, as shown in Fig. 3b. For example, the first sheet 41 of elastomeric material surrounds or wraps two adjacent lateral faces of the block, and the second sheet 42 of elastomeric material surrounds or wraps these two adjacent lateral faces of the block once the two sensors 3 are disposed on respective faces (on the first sheet 31). When the elastomeric block 2 is parallelepipedic, this second lateral face is preferably perpendicular (adjacent) to the lateral face within which the first sensor has been embedded. The two sensors 3 are preferably diagonally oriented towards a common corner of the block 2, as shown in Fig. 3b. In use of the final product (support with sensors), at least two BP sensors enable a more optimized measurement of a deformed position of the block, because two sensors permit to extract the vector components (vertical and horizontal) of the deformation suffered by the sensor in use of the support. As already mentioned, in use of a support made of the elastomeric block 2, for example in a bridge, the support will typically move horizontally in two possible directions: longitudinally and transversally with respect to the bridge. Therefore, horizontal deformations will be caused by both transversal and longitudinal displacement of the support. In this case, the two BP sensors are preferably disposed on adjacent lateral faces of the block 2. The deformation obtained by each sensor is combined. Thus, the deformation suffered by the support in the two horizontal directions (longitudinal and transversal) is obtained. In certain conditions, however, the support will move horizontally only in one possible direction, typically longitudinally with respect to the construction (e.g. bridge). This occurs when the other horizontal displacement (transversal to the construction) is physically constrained. In this case, the two BP sensors may be disposed on opposite lateral faces of the block 2.

**[0051]** In a another embodiment, the former steps for embedding a buckypaper strip deformation sensor 3 within a lateral face of an elastomeric block 2, are repeated three times, such that four sensors 3 are embedded within four lateral faces of the block 2, thus enabling a most optimized measurement of a deformed position of the parallelepipedic block 2. Again, a single first sheet 41 of elastomeric material may be used, surrounding the four lateral faces of the block, and a single second sheet 42 of elastomeric material may be used, surrounding the four lateral faces of the block once the four sensors have been placed. Because two position vectors of two different points of the upper face of the support are obtained,

a more precise knowledge of the behaviour of the support is therefore obtained.

**[0052]** As shown in step 16 of Fig. 1, the elastomeric block 2 having the sheets 41, 42 and the deformation sensor 3 adhered thereon (or more than one sensor and corresponding pairs of sheets, in respective lateral faces of the block 2) is then vulcanized using a press having mould clamps 100. For example, lateral mould clamps are made of several metallic parts configured to laterally confine the block 2, in such a way that an upper press applies pressure on the mould clamps and block 2 confined therein. In particular, the press may apply a pressure of between 15 kg/cm<sup>2</sup>-25 kg/cm<sup>2</sup> to the elastomeric block 2. In order to prevent the cables 32 from being damaged, they exit the press through dedicated holes 5 provided in the mould clamps 100. The epoxy layer disclosed above ensures that the cable connections, which remain within the press during the vulcanization process, are not damaged by the high temperature and pressure. Fig. 2d shows the elastomeric block 2 introduced in the press (mould clamps) with the cables 32 exiting through the holes 5 provided in the mould clamps 100. Subsequently, compression is carried out by means of an upper plate moving downwards from above.

**[0053]** Fig. 3a shows the final result of this method. A finished sensorized elastomeric support 1 comprising an elastomeric block 2 having a buckypaper strip deformation sensor 3 embedded on a lateral face thereof is produced. During use, a two-wire data acquisition equipment connected to the wires 32 suffices for obtaining the resistance of the buckypaper strip deformation sensor 3. No amplifiers or signal conditioners are necessary. This novel sensorized elastomeric support 1 can be used in any type of supports used in construction, e.g. type A, B, etc., as defined for example in UNE-EN 1337-3:2005. As already explained, the final support 1 may have more than one embedded sensor 3. For example, it may have 2 embedded sensors in perpendicular (adjacent) lateral faces of the block 2, as shown in Fig. 3b. Or it may have 4 embedded sensors, each sensor being embedded in each of the four lateral faces of the parallelepipedic block 2.

**[0054]** Finally, Figs. 4a-b and 5a-b show the result of tests carried out when the sensorized elastomeric support 1 having one sensor (Fig. 3a) is submitted respectively to vertical and horizontal loads. The change in the electrical resistance of the buckypaper strip deformation sensor 3 during the tests is determined. Fig. 4a-b respectively show sensor resistance (R, in Ohms) and vertical displacement (VD, in millimetres) versus time (t, in seconds), while Fig. 5a-b respectively show sensor resistance (R, in Ohms) and horizontal displacement (HD, in millimetres) versus time (t).

**[0055]** As explained, the method disclosed above can be employed for producing a sensorized elastomeric support having one or two pairs of buckypaper strip deformation sensors 3 embedded on opposite lateral sides of the elastomeric block 2. By combining the information

obtained from each of the buckypaper strip deformation sensors 3, this configuration allows for detecting the deformation of the elastomeric block 2.

**[0056]** Fig. 6 shows a sensorized elastomeric support 1 comprising a cylindrical elastomeric block 2 and two pairs of buckypaper strip deformation sensors 3. Therefore, the lateral cylindrical surface of the cylindrical elastomeric block 2 is divided into four similar portions. In order to maintain the wording used so far, each of said portions is referred to herein as a lateral face. In particular, each lateral face is a section of the lateral cylindrical surface of the cylindrical elastomeric block 2 having a curvature of approx. 90°. A respective buckypaper strip deformation sensor 3 is provided diagonally, for example from substantially a center of each lateral face to an upper corner of said lateral face. The buckypaper strip deformation sensors 3 are provided in the same geometrical position on all four lateral faces. None of the four buckypaper strip deformation sensors 3 contacts any other buckypaper strip deformation sensor 3. Note that only three of the buckypaper strip deformation sensors are visible in the figure, the fourth buckypaper strip deformation sensor being hidden behind the elastomeric block 2. These buckypaper strip deformation sensors 3 can be embedded on the lateral faces of this elastomeric block 2 by means of the method of the invention disclosed earlier in the present document.

**[0057]** When this sensorized elastomeric support 1 is submitted to a load, the cylindrical elastomeric block 2 deforms. The characteristics of the deformation suffered by the elastomeric block 2 depend on the direction, magnitude and localization of the load. In any case, in response to said deformation of the elastomeric block 2, each of the four buckypaper strip deformation sensors 3 provided on the lateral faces thereof also deform. As previously disclosed with respect to the support 1 of Fig. 3a-3b, the deformation causes a change in the resistance of the buckypaper strip deformation sensors 3, and this change in resistance is detected by the respective acquisition equipment. A vector analysis of the electrical signal received from the four buckypaper strip deformation sensors 3 then allows for obtaining the deformation of the elastomeric block 2.

**[0058]** Although the support 1 shown in Fig. 6 has four embedded BP sensors, in a more general embodiment, the cylindrical block 2 may comprise a single BP sensor embedded in one of its lateral faces. Alternatively, it may comprise two BP sensors embedded in different lateral faces thereof.

**[0059]** The invention is obviously not limited to the specific embodiment(s) described herein, but also encompasses any variations that may be considered by any person skilled in the art (for example, as regards the choice of materials, dimensions, components, configuration, etc.), within the general scope of the invention as defined in the claims.

## Claims

1. A method for manufacturing a sensorized elastomeric support (1), **characterized by** comprising the following steps:

adhering a first sheet (41) of elastomeric material onto a lateral face of an elastomeric block (2);  
adhering a buckypaper strip deformation sensor (3) along a diagonal direction of said first sheet (41) of elastomeric material for measuring deformations of the elastomeric block (2) both in a vertical and a horizontal direction;  
adhering a second sheet (42) of elastomeric material onto the first sheet (41) of elastomeric material, such that the buckypaper strip deformation sensor (3) is sandwiched therebetween;  
submitting the elastomeric block (2), with the first sheet (41), the buckypaper strip deformation sensor (3) and the second sheet (41) adhered thereto, to a vulcanization process.

2. The method of claim 1, wherein when the elastomeric block (2) has parallelepipedic shape, the buckypaper strip deformation sensor (3) extends diagonally from a lower corner of the lateral face to an upper corner of said lateral face.

3. The method of claim 1, wherein when the elastomeric block (2) has cylindrical shape, the buckypaper strip deformation sensor (3) extends diagonally from a central portion of the lateral face.

4. The method of any one of claims 1-3, further comprising an initial step of soaking the buckypaper strip deformation sensor (3) in a polymeric solution or combining the buckypaper strip deformation sensor (3) with a polymeric material, for increasing its elongation capacity.

5. The method of claim 4, wherein the buckypaper strip deformation sensor (3) is soaked in a polymeric solution, wherein the soaking step further comprises:

obtaining a polyvinyl alcohol solution having between 0.5-15 % in weight of polyvinyl alcohol;  
soaking the buckypaper strip deformation sensor (3) in said polyvinyl alcohol solution for a period of 15-25 hours; and  
drying the buckypaper strip deformation sensor (3) in a vacuum oven.

6. The method of any one of claims 1-5, further comprising connecting electrical wires (32) to respective opposite ends of the buckypaper strip deformation sensor (3).

7. The method of any one of claim 1-6, further compris-

ing impregnating the first sheet (41) and the second sheet (42) with a viscous bitumen prior to placing the buckypaper strip deformation sensor (3) therebetween.

8. The method of any one of claim 1-7, further comprising adhering another buckypaper strip deformation sensor onto another lateral face of the elastomeric block, sandwiched between corresponding sheets of elastomeric material.

9. The method of any one of claims 1-8, wherein the vulcanization step comprises submitting the elastomeric block (2), with the embedded buckypaper deformation sensor or sensors (3), to a temperature of 120°C-160°C and to a pressure of 15 kg/cm<sup>2</sup>-25 kg/cm<sup>2</sup>.

10. A sensorized elastomeric support (1) comprising an elastomeric block (2), **characterized in that** the sensorized elastomeric support (1) comprises a buckypaper strip deformation sensor (3) embedded in a diagonal direction of a lateral face of the elastomeric block (2), wherein the buckypaper strip deformation sensor (3) is embedded between a first sheet (41) and a second sheet (42) of elastomeric material adhered to said lateral face of the elastomeric block (2).

11. The sensorized elastomeric support (1) of claim 10, wherein the elastomeric block (2) has parallelepipedic shape, the buckypaper strip deformation sensor (3) extending diagonally from a lower corner of the lateral face to an upper corner of said lateral face.

12. The sensorized elastomeric support (1) of claim 10, wherein the elastomeric block (2) has cylindrical shape, the buckypaper strip deformation sensor (3) extending diagonally from a central portion of the lateral face.

13. The sensorized elastomeric support (1) of any one of claims 10-12, comprising one pair of buckypaper strip deformation sensors (3).

14. The sensorized elastomeric support (1) of any one of claims 10-12, comprising two pairs of buckypaper strip deformation sensors (3), the buckypaper strip deformation sensors (3) of each pair being provided on respective opposite lateral faces of the elastomeric block (2).

#### Patentansprüche

1. Verfahren zur Herstellung eines sensorisierten Elastomerlagers (1),  
**gekennzeichnet durch** folgende Schritte:

Anbringen einer ersten Bahn (41) eines elastomeren Werkstoffs auf einer Seitenfläche eines Elastomerblocks (2);

Anbringen eines Buckypapierstreifen-Verformungssensors (3) entlang einer diagonalen Richtung der ersten Bahn (41) eines elastomeren Werkstoffs, um Verformungen des Elastomerblocks (2) sowohl in vertikaler als auch in horizontaler Richtung zu messen;

Anbringen einer zweiten Bahn (42) eines elastomeren Werkstoffs auf der ersten Bahn (41) eines elastomeren Werkstoffs derart, dass der Buckypapierstreifen-Verformungssensor (3) dazwischen angeordnet ist,

Durchführung eines Vulkanisationsverfahrens bei dem Elastomerblock (2), einschließlich der daran anhaftenden ersten Bahn (41), des Buckypapierstreifen-Verformungssensors (3) und der daran anhaftenden zweiten Bahn (41).

2. Verfahren nach Anspruch 1, bei dem der Elastomerblock (2) die Form eines Parallelepipeds hat und der Buckypapierstreifen-Verformungssensor (3) sich diagonal von einer unteren Ecke der Seitenfläche zu einer oberen Ecke der Seitenfläche erstreckt.

3. Verfahren nach Anspruch 1, bei dem der Elastomerblock (2) eine zylindrische Form hat und der Buckypapierstreifen-Verformungssensor (3) sich von einem mittigen Bereich der Seitenfläche diagonal erstreckt.

4. Verfahren nach einem der Ansprüche 1-3, das außerdem einen anfänglichen Schritt aufweist, bei dem der Buckypapierstreifen-Verformungssensor (3) mit einer Polymerlösung getränkt wird oder der Buckypapierstreifen-Verformungssensor (3) mit einem polymeren Werkstoff kombiniert wird, um seine Längänderungskapazität zu erhöhen.

5. Verfahren nach Anspruch 4, bei dem der Buckypapierstreifen-Verformungssensor (3) mit einer Polymerlösung getränkt wird, wobei der Schritt des Tränkens außerdem aufweist:

Erstellen einer Polyvinylalkohollösung mit 0,5-15 Gew.% Polyvinylalkohol;

Tränken des Buckypapierstreifen-Verformungssensors (3) mit der Polyvinylalkohollösung über einen Zeitraum von 15-25 Stunden; und

Trocknen des Buckypapierstreifen-Verformungssensors (3) in einem Vakuumtrockenofen.

6. Verfahren nach einem der Ansprüche 1-5, das außerdem das Verbinden elektrischer Drähte (32) mit jeweils entgegengesetzten Enden des Buckypapier-

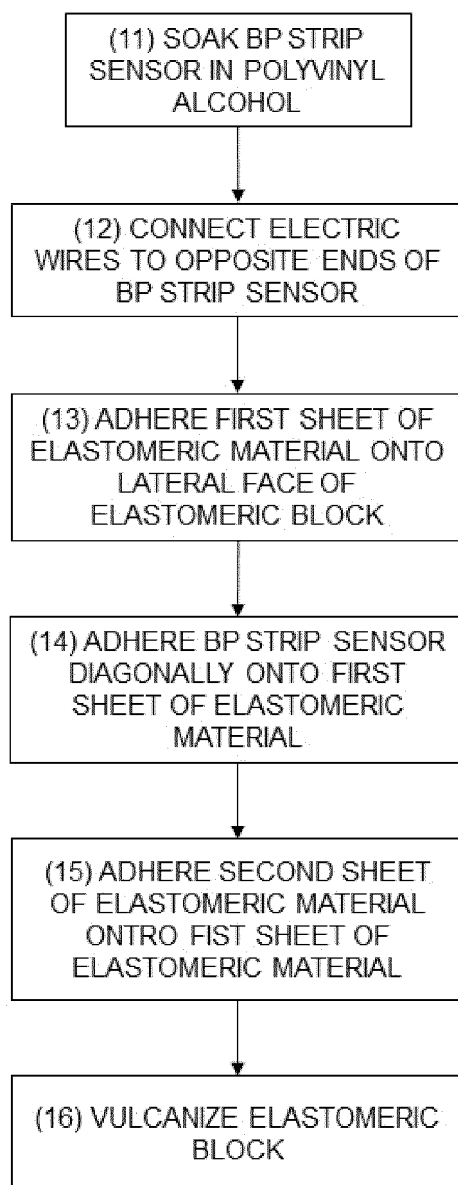
streifen-Verformungssensors (3) aufweist.

7. Verfahren nach einem der Ansprüche 1-6, das außerdem das Imprägnieren der ersten Bahn (41) und der zweiten Bahn (42) mit einem viskosen Bitumen vor dem Platzieren des Buckypapierstreifen-Verformungssensors (3) zwischen den Bahnen aufweist. 5
8. Verfahren nach einem der Ansprüche 1-7, das außerdem aufweist, einen weiteren Buckypapierstreifen-Verformungssensor auf einer weiteren Seitenfläche des Elastomerblocks anzubringen, angeordnet zwischen entsprechenden Bahnen eines elastomeren Werkstoffs. 10
9. Verfahren nach einem der Ansprüche 1-8, bei dem der Schritt der Vulkanisation aufweist, den Elastomerblock (2) mit dem eingebetteten Buckypapierstreifen-Verformungssensor oder den -sensoren (3) einer Temperatur von 120°C-160°C und einem Druck von 15 kg/cm<sup>2</sup>-25kg/cm<sup>2</sup> auszusetzen. 15 20
10. Sensorisiertes Elastomerlager (1), das einen Elastomerblock (2) aufweist, **dadurch gekennzeichnet, dass** das sensorisierte Elastomerlager (1) einen Buckypapierstreifen-Verformungssensor (3) aufweist, der in einer diagonalen Richtung einer Seitenfläche des Elastomerblocks (2) eingebettet ist, wobei der Buckypapierstreifen-Verformungssensor (3) zwischen einer ersten Bahn (41) und einer zweiten Bahn (42) eines elastomeren Werkstoffs eingebettet ist, die an der Seitenfläche des Elastomerblocks (2) angebracht sind. 25 30
11. Sensorisiertes Elastomerlager (1) nach Anspruch 10, bei dem der Elastomerblock (2) die Form eines Parallelepipedes hat und der Buckypapierstreifen-Verformungssensor (3) sich diagonal von einer unteren Ecke der Seitenfläche zu einer oberen Ecke der Seitenfläche erstreckt. 35 40
12. Sensorisiertes Elastomerlager (1) nach Anspruch 10, bei dem der Elastomerblock (2) eine zylindrische Form hat und der Buckypapierstreifen-Verformungssensor (3) sich von einem mittigen Bereich der Seitenfläche diagonal erstreckt. 45
13. Sensorisiertes Elastomerlager (1) nach einem der Ansprüche 10-12, das ein Paar Buckypapierstreifen-Verformungssensoren (3) aufweist. 50
14. Sensorisiertes Elastomerlager (1) nach einem der Ansprüche 10-12, das zwei Paar Buckypapierstreifen-Verformungssensoren (3) aufweist, wobei die Buckypapierstreifen-Verformungssensoren (3) eines jeden Paares auf jeweils gegenüberliegenden Seitenflächen des Elastomerblocks (2) vorgesehen sind. 55

## Revendications

1. Méthode de fabrication d'un support élastomère muni de capteurs (1), **caractérisée en ce qu'elle** comprend les étapes suivantes :  
 le collage d'une première feuille (41) de matériau élastomère sur une face latérale d'un bloc élastomère (2) ;  
 le collage d'un capteur de déformation en bande de feuille de nanotubes (3) le long d'une direction diagonale de ladite première feuille (41) de matériau élastomère pour mesurer les déformations du bloc élastomère (2) à la fois dans une direction verticale et une horizontale ;  
 le collage d'une seconde feuille (42) de matériau élastomère sur la première feuille (41) de matériau élastomère, de telle sorte que le capteur de déformation en bande de feuille de nanotubes (3) soit pris en sandwich entre les deux ;  
 la soumission du bloc élastomère (2), avec la première feuille (41), le capteur de déformation en bande de feuille de nanotubes (3) et la seconde feuille (41) collés dessus, à un procédé de vulcanisation.
2. Méthode selon la revendication 1, dans laquelle quand le bloc élastomère (2) a une forme parallélépipédique, le capteur de déformation en bande de feuille de nanotubes (3) s'étend en diagonale depuis un coin inférieur de la face latérale vers un coin supérieur de ladite face latérale.
3. Méthode selon la revendication 1, dans laquelle quand le bloc élastomère (2) a une forme cylindrique, le capteur de déformation en bande de feuille de nanotubes (3) s'étend en diagonale depuis une partie centrale de la face latérale.
4. Méthode selon l'une quelconque des revendications 1 à 3, comprenant en outre une étape initiale d'immersion du capteur de déformation en bande de feuille de nanotubes (3) dans une solution polymérique ou de combinaison du capteur de déformation en bande de feuille de nanotubes (3) avec un matériau polymère, pour augmenter sa capacité d'allongement.
5. Méthode selon la revendication 4, dans laquelle le capteur de déformation en bande de feuille de nanotubes (3) est immergé dans une solution polymérique, dans laquelle l'étape d'immersion comprend en outre :  
 l'obtention d'une solution d'alcool polyvinylique ayant entre 0,5 et 15 % en poids d'alcool polyvinylique ;  
 l'immersion du capteur de déformation en bande

- de feuille de nanotubes (3) dans ladite solution d'alcool polyvinylique pendant une durée de 15 à 25 heures ; et  
le séchage du capteur de déformation en bande de feuille de nanotubes (3) dans un four à vide. 5
6. Méthode selon l'une quelconque des revendications 1 à 5, comprenant en outre la connexion de fils électriques (32) à des extrémités opposées respectives du capteur de déformation en bande de feuille de nanotubes (3). 10
7. Méthode selon l'une quelconque des revendications 1 à 6, comprenant en outre l'imprégnation de la première feuille (41) et de la seconde feuille (42) avec un bitume visqueux avant de placer le capteur de déformation en bande de feuille de nanotubes (3) entre les deux. 15
8. Méthode selon l'une quelconque des revendications 1 à 7, comprenant en outre le collage d'un autre capteur de déformation en bande de feuille de nanotubes sur une autre face latérale du bloc élastomère, pris en sandwich entre des feuilles correspondantes de matériau élastomère. 20  
25
9. Méthode selon l'une quelconque des revendications 1 à 8, dans laquelle l'étape de vulcanisation comprend la soumission du bloc élastomère (2), avec le ou les capteurs de déformation en bande de feuille de nanotubes (3) intégrés, à une température de 120°C à 160°C et à une pression de 15 kg/cm<sup>2</sup> à 25 kg/cm<sup>2</sup>. 30
10. Support élastomère muni de capteurs (1) comprenant un bloc élastomère (2), **caractérisé en ce que** le support élastomère muni de capteurs (1) comprend un capteur de déformation en bande de feuille de nanotubes (3) intégré dans une direction diagonale d'une face latérale du bloc élastomère (2), 35  
40  
dans lequel le capteur de déformation en bande de feuille de nanotubes (3) est intégré entre une première feuille (41) et une seconde feuille (42) de matériau élastomère collées à ladite face latérale du bloc élastomère (2). 45
11. Support élastomère muni de capteurs (1) selon la revendication 10, dans lequel le bloc élastomère (2) a une forme parallépipédique, le capteur de déformation en bande de feuille de nanotubes (3) s'étendant en diagonale depuis un coin inférieur de la face latérale vers un coin supérieur de ladite face latérale. 50
12. Support élastomère muni de capteurs (1) selon la revendication 10, dans lequel le bloc élastomère (2) a une forme cylindrique, le capteur de déformation en bande de feuille de nanotubes (3) s'étendant en diagonale depuis une partie centrale de la face latérale. 55
13. Support élastomère muni de capteurs (1) selon l'une quelconque des revendications 10 à 12, comprenant une paire de capteurs de déformation en bande de feuille de nanotubes (3).
14. Support élastomère muni de capteurs (1) selon l'une quelconque des revendications 10 à 12, comprenant deux paires de capteurs de déformation en bande de feuille de nanotubes (3), les capteurs de déformation en bande de feuille de nanotubes (3) de chaque paire étant disposés sur des faces latérales opposées respectives du bloc élastomère (2).



**FIG. 1**

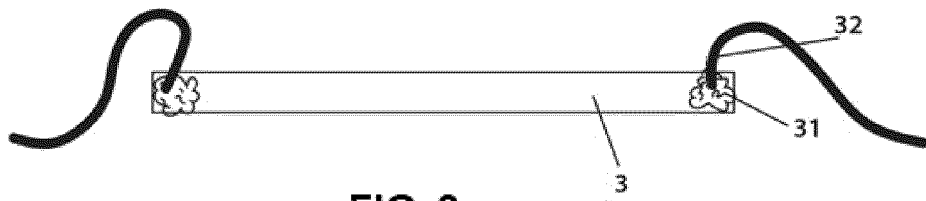


FIG. 2a

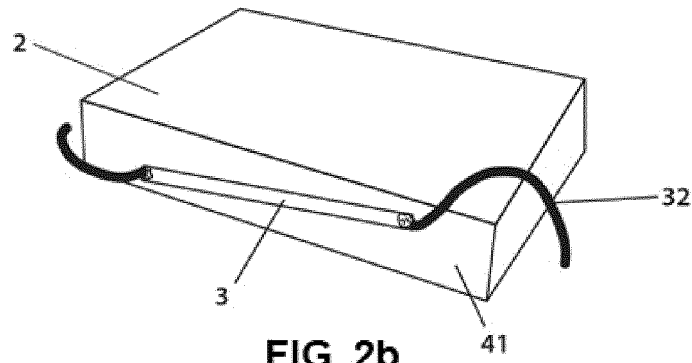


FIG. 2b

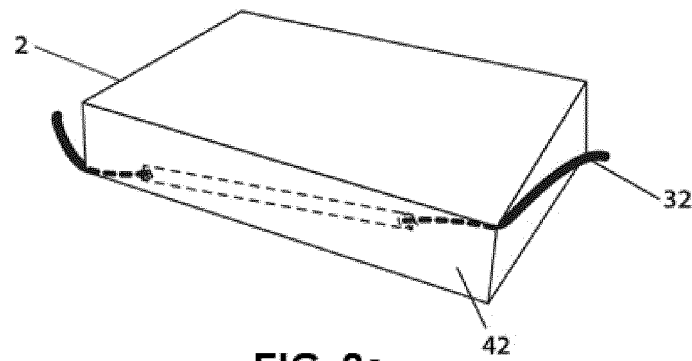


FIG. 2c

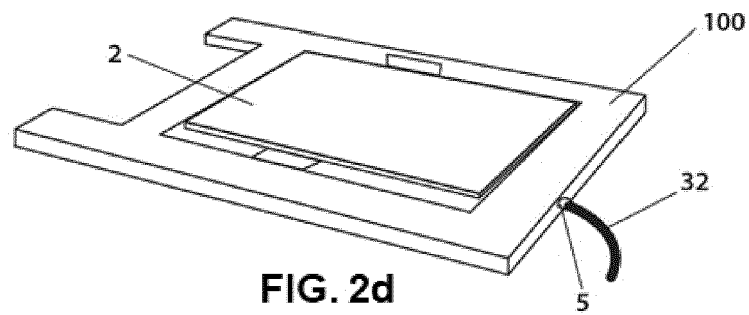


FIG. 2d

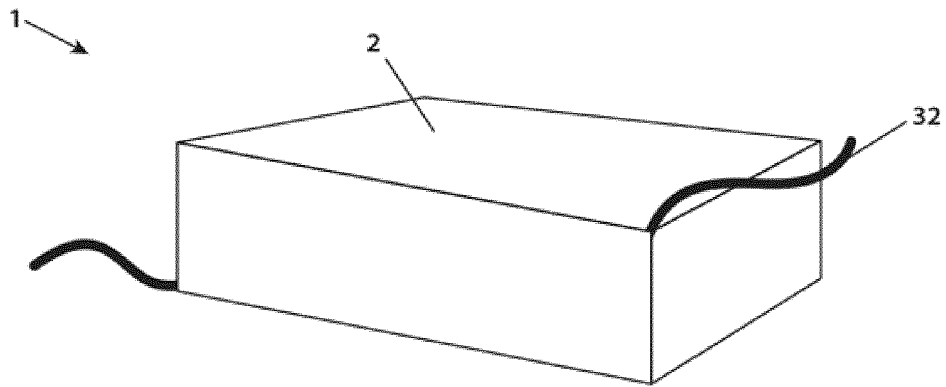


FIG. 3a

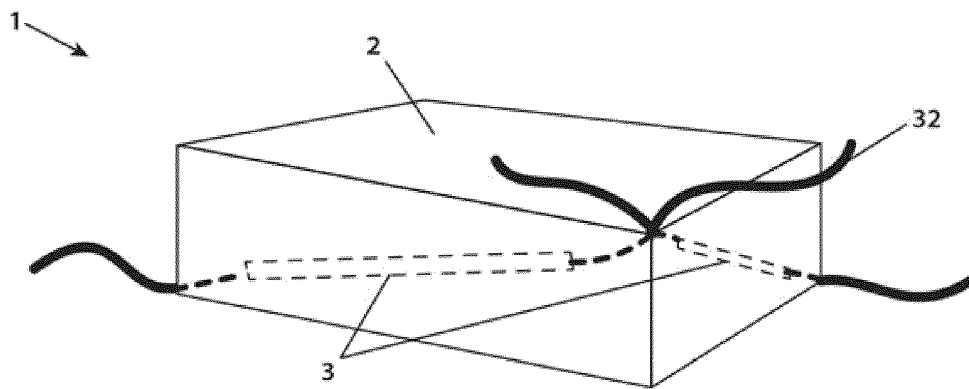


FIG. 3b

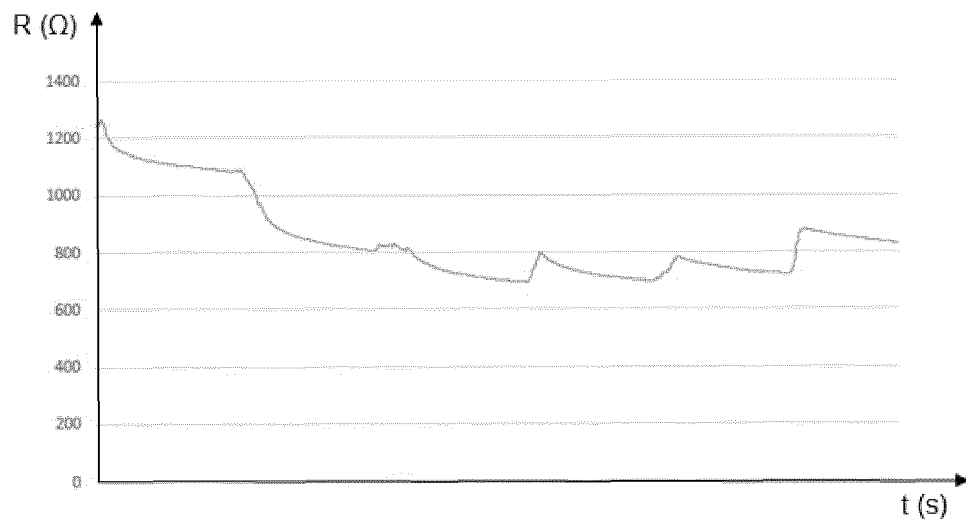


FIG. 4a

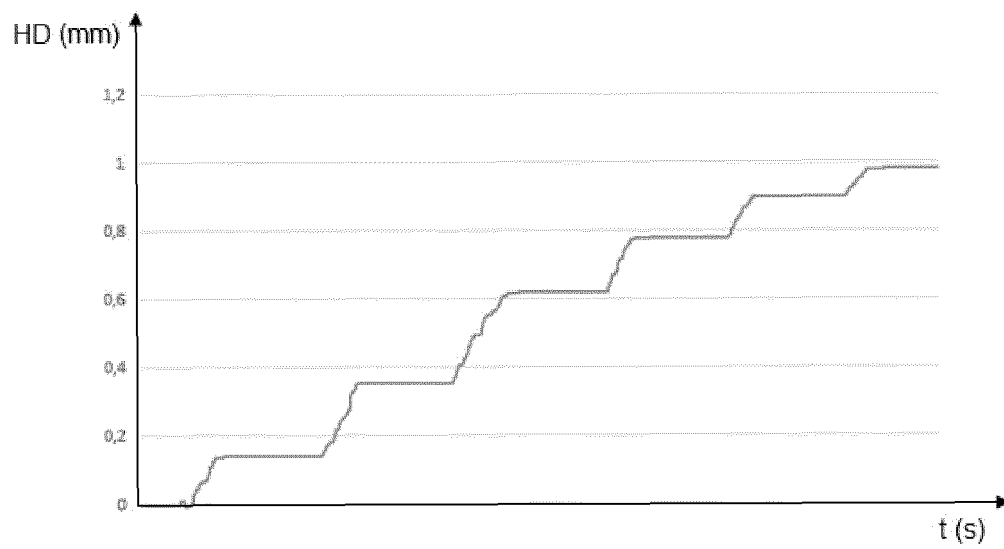


FIG. 4b

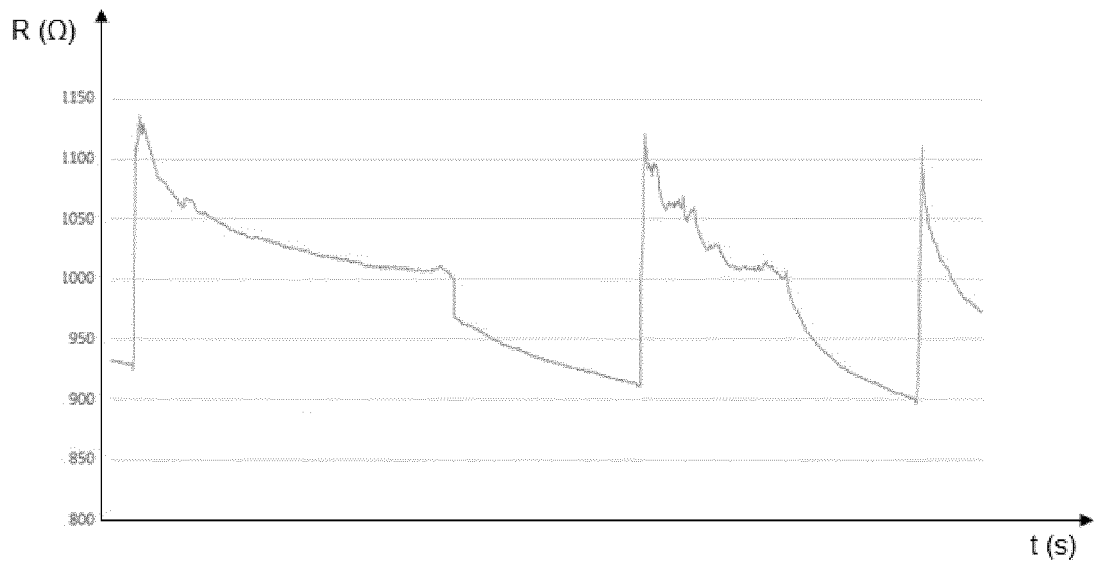


FIG. 5a

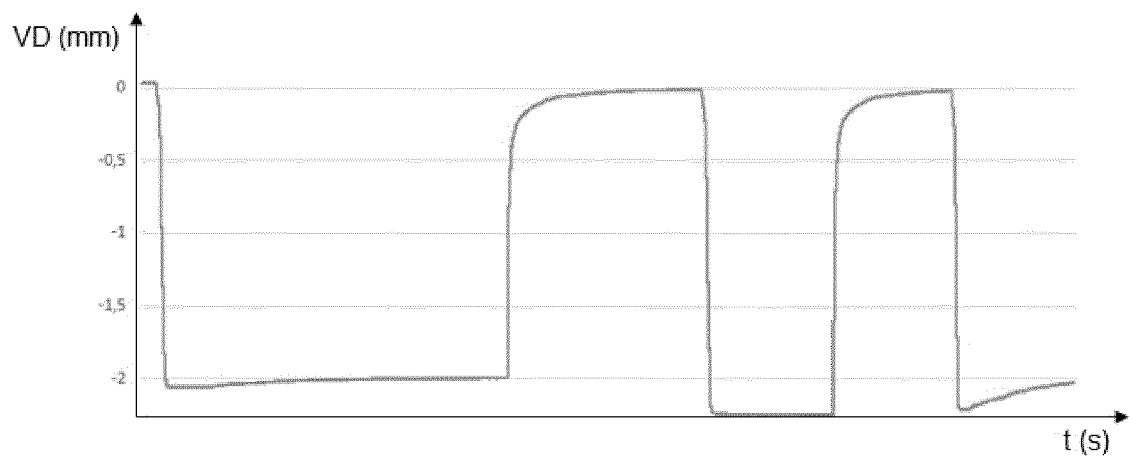


FIG. 5b

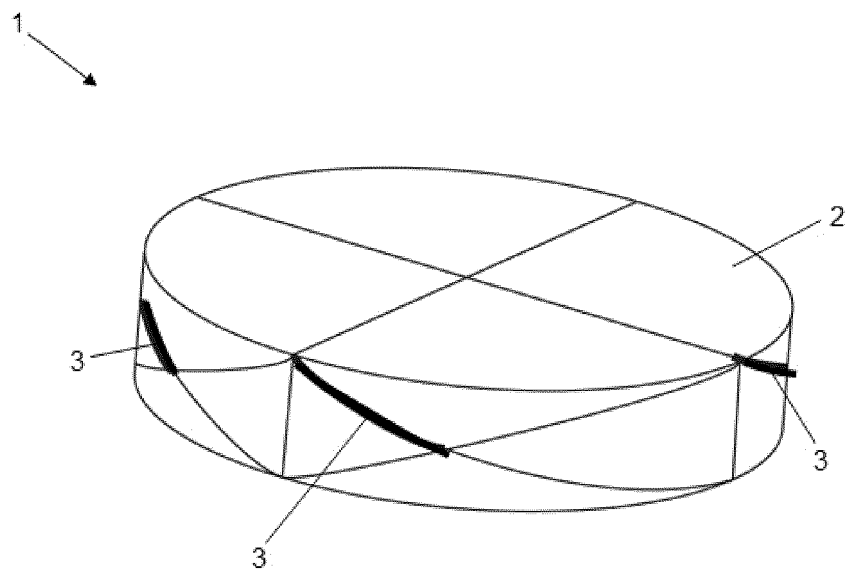


FIG. 6

**REFERENCES CITED IN THE DESCRIPTION**

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