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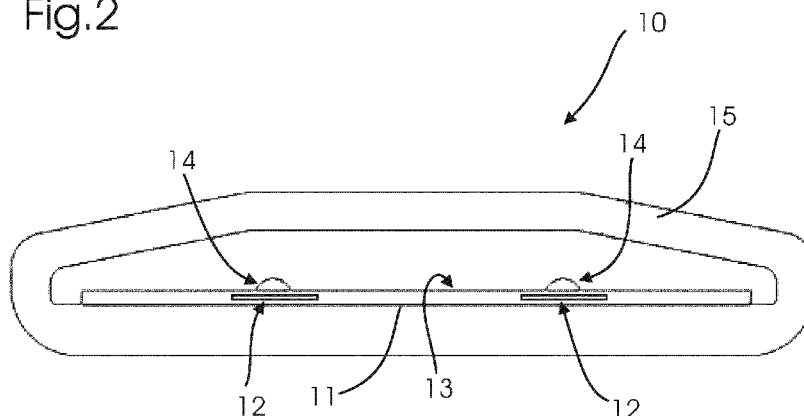
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(54) Title: PRESSURE-RESPONSIVE SENSOR UNIT

Fig.2



(57) Abstract: The invention relates to a pressure-responsive sensor unit (10). In order to provide means for detecting pressure fast and reliably which allow for design flexibility and easy assembly, the sensor unit (10) comprises at least one membrane switch sensor (11), which comprises a first carrier foil and a second carrier foil spaced from each other by a spacer foil, said spacer foil having therein at least one opening defining a pressure-responsive sensor cell (12), and at least two electrodes arranged in facing relationship with each other in said cell (12) on said first and said second carrier foil, respectively, in such a way that they are brought closer together when pressure is applied to the membrane switch sensor (11), wherein at least one activator element (14), adhered to an outer surface (13) of the membrane switch sensor (11), forms a raised structure of substantially stable form on said outer surface (13), at least partially over one sensor cell (12).



Pressure-Responsive Sensor Unit

Technical Field

[0001] The invention relates to a pressure-responsive sensor unit, to an impact detection system, to a seat occupancy detection system and to a method for producing a pressure-responsive sensor unit.

Background Art

[0002] Due to more restrictive safety regulation requirements and general market development trends, automotive industry have to establish more efficient passenger protection systems by means of improved active safety devices (e.g. multiple air-bag solutions, more sophisticated restraint systems, adapted system deployment strategies, etc.). In general, such techniques need more lead time to be activated in order to provide the full protection capability and/or additional data to be deployed in a more dedicated way according to the crash situation. In case of a collision event it is therefore essential to identify strong impacts as early as possible, i.e. in best case at the time of first contact with the car bumper.

[0003] Up to now, impact characterisation is accomplished by so-called up-front sensors (also known as "g-sensors") located in the bumper area of the car, which detect crash-related acceleration effects caused by deformation and vibration. Although such sensor elements are well proven in various automotive applications, their detection efficiency is meanwhile hampered due to mechanically softer materials and design constraints of modern car front-ends in order to fulfil requirements related to pedestrian protection or energy savings.

[0004] Further, it is known to employ membrane switch sensors, which are usually integrated into the front or rear bumper of the car. These sensors are effective in fast detection of an impact and have a high sensitivity, but are characterised by an activation threshold. If a force or pressure acting on the sensor exceeds the threshold, the sensor is activated. It is known to protect the membrane switch sensor itself by placing it in a housing, which is commonly made of an elastic material like rubber. In an impact situation, the housing is deformed and presses onto the sensor. Usually, the membrane switch sensor is not susceptible to an activating pressure over its entire surface, but only in the region

of so-called sensor cells. These cells essentially consist of two electrodes that are spaced apart as long as no pressure is acting. They are brought into contact when an external pressure is present, whereby the resistance of the sensor cell drops significantly. In order to assure a reliable activation of the sensor cells, it is known to provide rib-like extensions on the inside of the housing, which face the respective sensor cells. When the housing is deformed by pressure, the aforementioned extensions contact the sensor cells first and help to concentrate the pressure in this region. These extensions may be referred to as "activators" or "activator elements".

[0005] While this technical solution has proved to be effective, it brings about several difficulties. On the one hand, the rubber housing is usually an extruded part having a hose-like structure, and therefore has the same cross-section everywhere along an axis corresponding to the direction of extrusion. Although being relatively cheap to produce, the hose-like structure of the housing with the activators largely dictates the shape of the sensor and the position of the sensor cells. This reduces the freedom of design significantly. In case of a sensor that is integrated into a bumper, the sensor is normally mounted essentially along the Y-axis of the vehicle and it is impossible to vary the positions of the cells along the Z-axis. This in turn can lead to integration problems if, for instance, a certain part of the bumper region has to be kept clear for a towing hook or air inlets.

[0006] On the other hand, to allow for a reliable activation of the sensor cells, the activator elements must be positioned relatively precisely with respect to the respective cell. Moreover, the activator elements have to be relatively close to the sensor switch in order to reduce the risk of missing a sensor cell. This leads to the requirement that the hose-like housing has to fit relatively closely around the sensor switch, which in turn makes the assembly more difficult.

Technical Problem

[0007] It is thus an object of the present invention to provide means for detecting pressure fast and reliably which allow for design flexibility and easy assembly. This object is solved by a pressure-responsive sensor unit according to claim 1, an impact detection system according to claim 9, an occupancy detection system

according to claim 10 and a method for producing a pressure-responsive sensor unit according to claim 11.

General Description of the Invention

[0008] The application provides a pressure-responsive sensor unit, comprising at least one membrane switch sensor, which comprises a first carrier foil and a second carrier foil spaced from each other by a spacer foil, said spacer foil having therein at least one opening defining a pressure-responsive sensor cell, and at least two electrodes arranged in facing relationship with each other in said cell on said first and said second carrier foil, respectively, in such a way that they are brought closer together when pressure is applied to the membrane switch sensor.

[0009] The membrane switch sensor is a usually flat, foil-like sensor. The carrier foils and the spacer foil are normally made of a polymeric material. When the carrier foils are deformed by a pressure acting on the sensor, the two electrodes get closer to each other and finally get into contact with each other. The contact occurs when a pressure threshold is exceeded, which threshold can be predetermined by the elasticity of the carrier foils, the geometry of the recess etc. Normally, the electrodes are connected to a pair of terminals, to which a voltage may be applied. As long as the electrodes are separated, the current flow is negligible, but when the electrodes contact each other, the resistance drops significantly and the current increases correspondingly. A sensor of this type is disclosed in WO 2006/111558 A1, the disclosure of which is hereby included by reference. As described in this document, sensors of this type can also be used to derive information on the location and the width of a contact between the electrodes, if these are configured as a linear potentiometer. Needless to say, the membrane switch sensor may comprise a plurality of sensor cells, which may be connected in series, in parallel or even independently.

[0010] According to the invention, at least one activator element, arranged on an outer surface of the membrane switch sensor, forms a raised structure of substantially stable form on said outer surface, at least partially over one sensor cell. In this context, the term "outer surface" refers to the surface which is facing away from the sensor cell(s). Preferably this is the outer surface of the first carrier foil, which faces towards the outside of the membrane switch sensor. "Over the

sensor cell" refers to a position relative to the cell in a direction perpendicular to the plane of the membrane switch sensor. "At least partially over the sensor cell" means that a portion of activator element may not be positioned over the sensor cell and/or the activator element may not be positioned over the entire area of the cell. Finally the expression "stable form" or "substantially stable form" means that the raised structure has a stable form and is not substantially deformed under normal operating conditions of the membrane switch sensor.

[0011] The activator element is configured to facilitate or enable the activation of at least one sensor cell. Since the activator element is a raised structure with respect to the outer surface, it will likely be the first structure to make contact with any object that touches the membrane switch sensor, and, due to the substantially stable form of the activator element, the pressure on the sensor will increase rapidly in the region of the activator element. The activator element may be integrally formed on the outer surface of the membrane switch sensor. Alternatively the activator element may be adhered to the outer surface either directly or indirectly by an intermediate layer that acts as adhesive. The adhesion mechanism is not limited and may be mechanical, chemical or other. The material of the activator elements is generally not limited, but it preferably comprises a polymeric material. This polymeric material may even be identical to a polymeric material from which the first carrier foil is formed, although the activator element and the carrier foil are not necessarily formed as single piece in the same process.

[0012] The inventive sensor unit provides several advantages. While still relying on the activator concept which is known to be effective in connection with a membrane switch sensor, it allows for an (almost) arbitrary positioning of the sensor cells, because the activator element is placed directly on the membrane switch sensor (usually directly on the carrier foil) and is independent of the shape and the forming process of a protective housing (if present). Therefore, the overall design of the membrane switch sensor can be varied widely. Furthermore, as the activator element is applied directly on the sensor, the invention allows to minimize the (usually quite big) tolerance of positioning between the activator element and the sensor. Also, since a housing is no longer needed to provide the function of activating the sensor cells, it can be produced cheaper and/or smaller and in some cases may even be unnecessary. Furthermore, it is easier to position

the activator elements in relation to the sensor cell, which allows for less strict positioning tolerances. Also, a housing (if present) does not have to fit very tightly around the membrane switch sensor, which makes the assembly much easier.

[0013] It should further be noted that the inventive concept of the present invention allows to tune or adjust the response of the sensor unit. In fact by varying the height and/or the positioning of the actuator element the response of an individual sensor cell to a force acting on the sensor can be finely tuned. Hence, for a sensor unit comprising different sensor cells, the height of the individual actuator elements could be varied during casting or dispensing process (on a single sensor) in order to generate different cell responses.

[0014] Acting on the height and/or the position of the actuator element also allows for the compensation of other tolerances. By varying the configuration and/or the position of the activator element allows for instance to compensate for production tolerances of the membrane switch. As an example, the spacer opening tolerance may be checked, for example by a camera. Reacting on that, the position or thickness of the dispensed activator may be changed and adapted to compensate this tolerance.

[0015] There are several possibilities how the activator elements can be adhered to the outer surface. According to one embodiment, at least one activator element has been primary formed on the outer surface. As is known in the art, the term "primary forming" refers to forming from a shapeless, usually liquid mass. The primary forming takes place "in situ", i.e. in the final position of the activator element, which is on the outer surface. For example, the activator element may be cast or dispensed onto this surface. Alternatively, it may be printed, painted, sprayed etc. onto the surface. In each of these cases, an application process is followed by a setting or curing process. The latter process may be induced by exposure to the atmosphere, by radiation (e.g. ultraviolet radiation), by elevated temperatures or other. In the application process, a curable composition is applied, which may comprise one or several binder components, a solvent (which evaporates later on) and/or additional components. It is also conceivable that a molten or semi-molten material is applied to the surface, which solidifies on the surface and adheres thereto.

[0016] According to another embodiment, at least one activator has been laminated to the outer surface. In this case, any lamination technique known in the art can be used. In particular, the lamination process may employ an intermediate adhesive layer between the activator element and the carrier foil. Some lamination processes may also be characterised as primary forming processes.

[0017] Especially, but not exclusively, in the above-mentioned cases, at least one activator element may consist of a plurality of layers. Especially if the application process does not allow for a sufficient thickness, several layers may be applied consecutively in order to achieve a sufficient height of the activator element.

[0018] In order to effectively concentrate the pressure onto a sensor cell and to allow for an accurate activation, it is preferred that at least one activator element forms a ridge-like or knob-like structure. A ridge-like structure may be curved, straight or angled. A knob-like structure normally has a width in any direction that is in the order of its height (perpendicular to the outer surface), or even less than its height. That is, a knob-like structure may be employed to vary sharply concentrate the pressure on certain region, e.g. the center of a sensor cell. A knob-like structure could possibly be created by applying a single drop of liquid composition to the outer surface of the sensor and subsequently curing the composition.

[0019] According to a preferred embodiment, at least one activator element is localised over a sensor cell. In other words, this activator element does not extend beyond the sensor cell. In most cases this embodiment saves material for the activator element and helps to concentrate the pressure on the sensor cell. In other embodiments, the activator element may extend beyond the sensor cell, thereby applying some of the pressure to the non-sensitive parts of the membrane switch sensor, which may help to raise the activation threshold without changing the inner structure of the membrane switch sensor itself.

[0020] The sensor unit may also comprise a cover disposed to mechanically protect at least the outer surface. As known in the art, the cover may be made of an elastic material like rubber, but other, even non-elastic materials are also conceivable. In a state where no pressure is applied, the cover can be spaced-part from the outer surface. It may, however, also touch the outer surface, especially in those regions that are not located above a sensor cell and therefore are not

sensitive to pressure. Normally, the cover is disposed to be deformed when an external pressure is applied so that the cover presses onto at least one activator element.

[0021] The cover may be positioned only over the outer surface of the first carrier foil, while the second carrier foil is protected by other measures or even unprotected. Alternatively, the membrane switch sensor can be enclosed or encapsulated in the cover. In this case, the cover can also be described as a housing or a sleeve in which the membrane switch sensor is positioned. As mentioned above, the cover does not need to be placed very tightly around the sensor, because the activator elements are not part of the cover, wherefore no strict positioning tolerances have to be kept. In one embodiment, the cover and at least one activator element are disposed spaced-apart. I.e., there is a space between the activator element and the cover when no external pressure is applied. If pressure is applied, however, the cover is pressed down on the activator element, which in turn exerts pressure on the membrane switch sensor. It is understood that even if the cover is a housing that surrounds the membrane switch sensor, electrical connections for the electrodes of the sensor cell(s) penetrate the housing.

[0022] The inventive sensor unit may in particular be employed as a sensor unit for impact detection. Accordingly, the invention also provides an impact detection system for a vehicle, which system comprises at least one pressure-responsive sensor unit as described above. Of course, it may comprise additional sensors, support elements, wiring and other components, some of which are discussed below. The vehicle may in particular be a motor vehicle like a car, e.g. a passenger car or a truck. Other types of vehicles are also within the scope of the invention, though, if impact detection is relevant for them. The term "impact detection system" refers to a system which may be used to at least detect whether an impact, i.e. a collision with another object like a pedestrian, another vehicle, a pole etc., has occurred. The system may also give additional information on the intensity of the impact or the like.

[0023] Of course, the system may comprise several inventive sensor units, possibly along with other types of sensors. An inventive sensor unit may be disposed inside an exterior component of the vehicle, e.g. a front or rear bumper.

Usually, a component like a bumper comprises a solid outer plastic skin, under which a foam layer is disposed. In this case, an inventive sensor unit may be positioned above, inside or underneath the foam layer.

[0024] In a preferred embodiment, the crash detection system comprises a processing unit, which is connected to the at least one pressure-responsive sensor unit and is configured to identify an impact situation based on a variation of the electrical resistance of the at least one pressure-responsive sensor unit. Of course, this refers to the electrical resistance of the sensor cell(s), the electrodes of which are connected via a pair of terminals to the processing unit. The processing unit can be a dedicated device or it may be an on-board computer of the vehicle, which also handles other, e.g. non-safety operations. Such processing units are known in the art and will not be described in detail here. It is understood that the processing unit may further be connected to at least one safety device and to be configured to deploy this safety device upon detection and identification of a crash situation. This may refer to activating belt tensioner, deploying an airbag, adjusting a seat position or the like.

[0025] Apart from impact detection, there are numerous other applications for the inventive sensor unit. One application is a seat occupancy detection system for a vehicle, which comprises at least one inventive pressure-responsive sensor unit. The sensor unit could be placed inside or underneath the seat cushion. Needless to say, the detection system may also comprise a processing unit connected to the at least one sensor unit. As known in the art, the processing unit may be configured to activate a seat belt reminder or the like depending on the activation of the sensor unit.

[0026] The invention finally provides a method for producing a pressure-responsive sensor unit. According to one step of the method, at least one membrane switch sensor is provided. The membrane switch sensor comprises a first carrier foil and a second carrier foil spaced from each other by a spacer foil, said spacer foil having therein at least one opening defining a pressure-responsive sensor cell, and at least two electrodes arranged in facing relationship with each other in said cell on said first and said second carrier foil, respectively, in such a way that they are brought closer together when pressure is applied to the

membrane switch sensor. The membrane switch sensor may be produced by methods known in the art.

[0027] In another step of the method, at least one activator element is adhered to an outer surface of the membrane switch sensor, so that the activator element forms a raised structure of substantially stable form on the outer surface, at least partially above one sensor cell.

[0028] Preferred embodiments of the inventive method correspond to those of the inventive sensor unit and will not be described again in detail. In the step of adhering the activator element, at least one activator element may be primarily formed on the outer surface. Also, at least one activator element may be laminated onto the outer surface.

[0029] According to one embodiment, a cover is provided after adhering the activator element, which cover is disposed to mechanically protect at least the outer surface. Normally, the cover is connected to the membrane switch sensor or both elements are connected to another element like a mounting plate.

[0030] In one embodiment, the membrane switch sensor is placed inside the cover (or the cover is placed around the membrane switch sensor, respectively). In this case, the cover is a housing or a sleeve which surrounds the sensor. If a rubber sleeve is used, the ends are usually closed by vulcanising. It is, however, conceivable to use other techniques like ultrasonic welding. It is also possible that the cover/housing is made of several (normally two) parts which are assembled around the membrane switch sensor and subsequently connected.

Brief Description of the Drawings

[0031] Preferred embodiments of the invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Fig. 1 is a schematic cross-section view of a sensor unit according to prior art; and

Fig. 2 is a schematic cross-section view of an inventive sensor unit.

Description of Preferred Embodiments

[0032] Fig.1 shows a cross-section view of a prior-art sensor unit 1, which may be used as an impact sensor in a front bumper of a car. The sensor unit 1 comprises a membrane switch sensor 2, which is disposed inside a sleeve-like housing 4. The membrane switch sensor 2 comprises a first carrier foil and a second carrier foil which are separated by the spacer foil. The spacer foil has two openings which define sensor cells 3. For sake of simplicity, details of the foils and the sensor cells 3 are not shown in the figures. Each sensor cell 3 has pair of electrodes (also not shown), which are adhered to the opposing first and second carrier foil. When a voltage is applied to the electrodes, the current flow is minimal as long as no pressure acts on the sensor cell 3.

[0033] The housing 4 is made of rubber by an extrusion process. Its general shape therefore corresponds to a hose or sleeve. In the assembly process, the membrane switch sensor 2 is placed inside the housing 4, whereafter the ends of the housing 4 are vulcanised and closed. As can be seen in fig.1, the housing 4 comprises two ridge-like activator elements 5, which are formed in the course of the extrusion process. When a pressure acts on the sensor unit 1, the housing is deformed and the activator elements 4 move towards the membrane switch sensor 2. Finally, the activator elements press down on the sensor cells 3, which leads to their activation.

[0034] Thus, the housing 4 has two functions. On the one hand, it mechanically protects the membrane switch sensor 2. On the other hand, it activates the sensor cells 3 by means of the activator elements 5. Therefore, the housing 4 has to be positioned carefully with respect to the membrane switch sensor 2 in order to ensure a reliable activation of the sensor cells 3.

[0035] Fig. 2 shows a cross-section view of an inventive pressure-responsive sensor unit 10. This sensor unit 10, too, comprises a membrane switch sensor 11 having two sensor cells 12. This membrane switch sensor 11 is similar to the one shown in fig. 1 and therefore will not be described again in detail. It is enclosed in a rubber housing 15 similar to the one shown in fig. 1. However, the rubber housing 15 has no activator elements. Instead, two knob-like activator elements 14 of substantially stable form are disposed on an outer surface 13 of the first carrier foil of the membrane switch sensor 11. In this example, each activator element 14

has been formed by applying a UV-curable composition to the outer surface 13, which is subsequently cured by UV light. They are positioned over the centre of a respective sensor cell 12 and therefore ensure its accurate activation. Since the protective housing 15 does not comprise activator elements, its position relative to the membrane switch sensor 11 is not critical. Therefore, the assembly process of the sensor unit 10 is much easier compared to the one shown in fig. 1. Also, as a variation, it is possible to use other materials for the housing 15 or to use a smaller/thinner housing. Also, it is possible that the housing 15 is not closed by vulcanising, but by ultrasonic welding or other techniques.

Legend of Reference Numbers:

1, 10	sensor unit	5, 14	activator element
2, 11	membrane switch sensor	13	outer surface
3, 12	sensor cell		
4, 15	housing		

Claims

1. Pressure-responsive sensor unit (10), comprising at least one membrane switch sensor (11), which comprises a first carrier foil and a second carrier foil spaced from each other by a spacer foil, said spacer foil having therein at least one opening defining a pressure-responsive sensor cell (12), and at least two electrodes arranged in facing relationship with each other in said cell (12) on said first and said second carrier foil, respectively, in such a way that they are brought closer together when pressure is applied to the membrane switch sensor (11),
wherein at least one activator element (14), arranged on or adhered to an outer surface (13) of the membrane switch sensor (11), forms a raised structure of substantially stable form on said outer surface (13), at least partially over one sensor cell (12).
2. Sensor unit according to claim 1, characterised in that at least one activator element (14) has been primary formed on the outer surface (13), in particular by printing or dispensing.
3. Sensor unit according to claim 1 or 2, characterised in that at least one activator element (14) has been laminated to the outer surface.
4. Sensor unit according to any of the preceding claims, characterised in that at least one activator element (14) consists of a plurality of layers.
5. Sensor unit according to any of the preceding claims, characterised in that at least one activator element (14) forms a ridge-like or knob-like structure.
6. Sensor unit according to any of the preceding claims, characterised in that at least one activator element (14) is localised over a sensor cell (12).
7. Sensor unit according to any of the preceding claims, characterised by a cover (15) disposed to mechanically protect at least the outer surface (13).

8. Sensor unit according to claim 7, characterised in that the membrane switch sensor (11) is enclosed in the cover (15).
9. Impact detection system for a vehicle, comprising at least one pressure-responsive sensor unit (10) according to any of claims 1 to 8.
10. Seat occupancy detection system for a vehicle, comprising at least one pressure-responsive sensor unit (10) according to any of claims 1 to 8.
11. Method for producing a pressure-responsive sensor unit (10), comprising the following steps:
 - providing at least one membrane switch sensor (11), which comprises a first carrier foil and a second carrier foil spaced from each other by a spacer foil, said spacer foil having therein at least one opening defining a pressure-responsive sensor cell (12), and at least two electrodes arranged in facing relationship with each other in said cell (12) on said first and said second carrier foil, respectively, in such a way that they are brought closer together when pressure is applied to the membrane switch sensor (11), and
 - adhering at least one activator element (14) to an outer surface (13) of the membrane switch sensor (11), so that the activator element (14) forms a raised structure of substantially stable form on the outer surface (13), at least partially above one sensor cell (12).
12. Method according to claim 11, characterised in that at least one activator element (14) is primarily formed on the outer surface (13).
13. Method according to claim 11 or 12, characterised in that at least one activator element (14) is laminated onto the outer surface (13).
14. Method according to any of claims 11 to 13, characterised in that, after adhering the activator element (14), a cover (15) is provided, which is disposed to mechanically protect at least the outer surface (13).

15. Method according to claim 14, characterised in that the membrane switch sensor (11) is placed inside the cover (15).

Fig.1

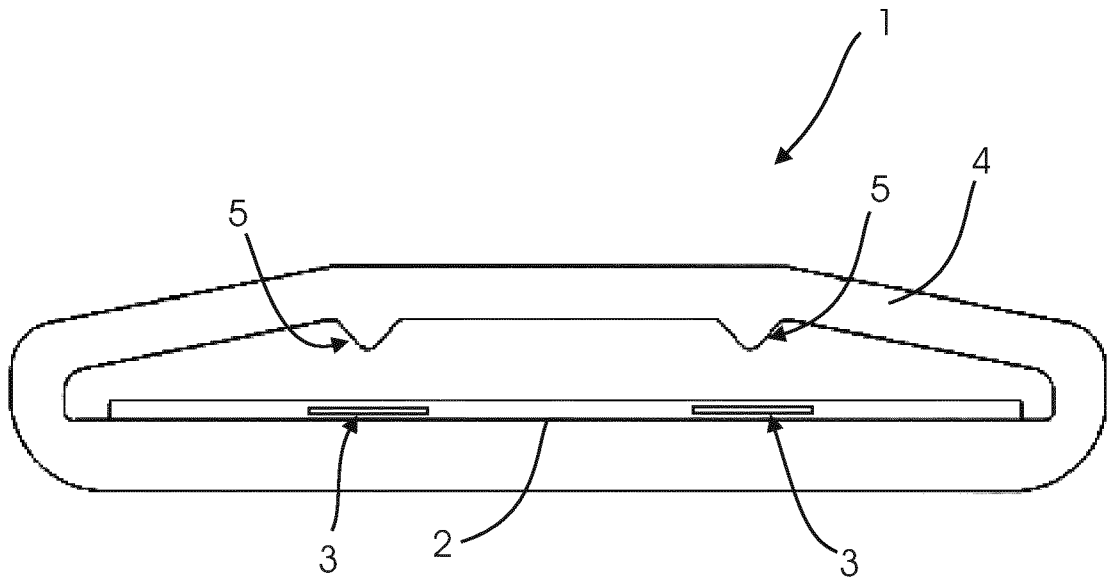
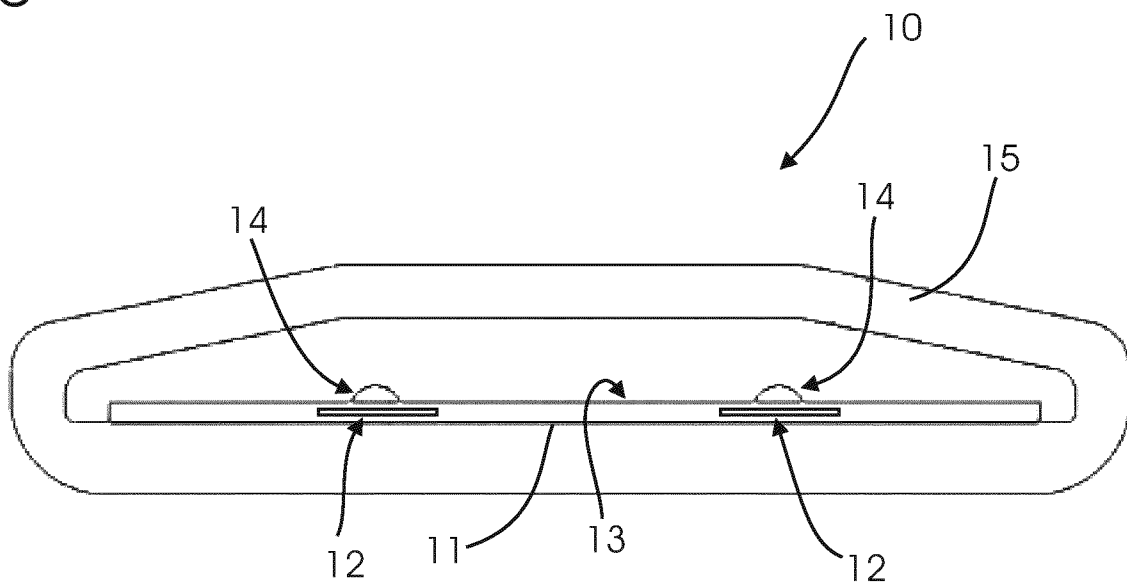


Fig.2



INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2016/060293

A. CLASSIFICATION OF SUBJECT MATTER

INV. H01H3/14 B60R21/0136 B60R21/015 H01H13/702
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)

H01H B60R B60N G06F

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	LU 91 702 A1 (IEE SARL [LU]) 22 December 2011 (2011-12-22) paragraph [0001] paragraph [0013] - paragraph [0015] paragraph [0025] - paragraph [0028] figure 3	1-3,5-15
X	JP 5 587477 B1 (FUJIKURA LTD) 10 September 2014 (2014-09-10)	1,5,6, 10,11
Y	paragraph [0001] paragraph [0026] - paragraph [0039] paragraph [0042] paragraph [0059] - paragraph [0060] paragraph [0120] - paragraph [0133] paragraph [0167] - paragraph [0168] figures 1, 2, 5, 14, 15 ----- -/-	9



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"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

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Date of the actual completion of the international search

12 July 2016

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22/07/2016

Name and mailing address of the ISA/

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Hristov, Stefan

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2016/060293

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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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

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