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(71) Applicant: **CSEM Centre Suisse d'Electronique et de Microtechnique SA - Recherche et Développement**
2002 Neuchâtel (CH)

(72) Inventors:
- **STERGIOU, Ioannis**
  8854 Siebnen-Galgenen (CH)
- **PARKEL, Thomas**
  8645 Jona (CH)

(74) Representative: **P&TS SA (AG, Ltd.)**
Avenue J.-J. Rousseau 4
P.O. Box 2848
2001 Neuchâtel (CH)

(54) CUSHION ELEMENT

(57) Cushion element (1) comprising a polymeric material, the cushion element (1) having an interface surface (2) for contacting a human and a free surface (3) opposite to the interface surface (2),wherein a) the cushion element (1) has a through-going open-cell structure which allows air-circulation between the interface surface (2) and the free surface (3); and b) the through-going open-cell structure is obtained by a 3D printing manufacturing process. The cushion element (1) permits to place different softness zones wherever needed within the design and achieve pressure relief on neuralgic prominent anatomical pressure sensitive zones. Optionally, the cushion element (1) can further comprise two electrode plates (7), which comprise an electrically conductive material, the two electrode plates (7) are arranged essentially parallel to the interface surface (2) at a given distance from each other and electrically isolated from each other by the polymeric cellular material between the two electrode plates (7) and wherein the electrode plates (7) are obtained via the 3D printing manufacturing process.

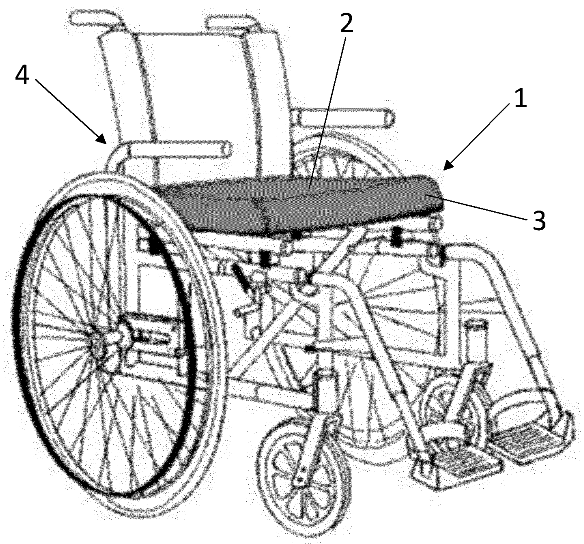

Fig. 1

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Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The invention relates to a cushion element according to the preamble of claim 1 and to a method for its manufacture according to the preamble of claim 16.

2. Description of the Related Art

[0002] As paralyzed people are compelled to be seated in their wheelchair for many hours, an optimal seat interface is essential. By individually shaping seat cushions, wheelchair specialists try to build the best possible seat interface, to provide good comfort and avoid decubitus skin defects caused by pressure overload on prominent anatomical spots (ischial tuberosity/ sitting bone and coccyx). In addition, skin temperature and transpiration have a big impact on healthy skin condition. Therefore air circulation at the body interface, which is the key to control skin temperature and skin moisture, is an essential requirement, which however is not met by today’s standard cushions. Today’s seat cushion designs still haven’t found a solution to reducing body heat build-up on the seating interface.

[0003] A monitoring cushion for persons at risk of developing pressure ulcers is known from GB 2558614 A. It comprises a pressure sensor consisting of two conductive sheets separated by several insulating layers made of resilient polymeric foam. The insulating layers comprise a plurality of through apertures, through which the two conductive layers can come into contact when sufficient pressure is applied to the cushion. The disadvantages of this known cushion are manifold, namely:

- the pressure sensor can only detect the exceeding of a certain pre-chosen pressure value, but does not allow the measurement of the pressure as such;
- the cushion is composed of a multitude of components (conductive sheets, insulating layers and wires) manufactured separately and necessitating their assembly and ultimate fixation relative to each other (e.g. by gluing);
- it does not allow for air-circulation through the cushion.

BRIEF SUMMARY OF THE INVENTION

[0004] It is an object of the invention to provide an improved cushion element to be used as an interface to a human which can be manufactured easily in one step and which does not need any assembling of components. The optional incorporation of a sensor should not complicate the manufacture of the device and should allow more sophisticated measurement of compression or humidity.

[0005] The invention solves the posed problem with a cushion device comprising the features of claim 1 and with a method for its manufacture comprising the features of claim 16.

[0006] The advantages of the cushion element according to the invention are commented below.

[0007] Air and liquid can flow through the open celled structure of the cushion element with the following benefits:

- Less moisture build up on the body-cushion interface;
- Skin temperature build up is reduced due to less skin encapsulation;
- In case of urinary liquid loss, the surface and its structure are not retained;
- Cushion can be easily cleaned
- Freedom to place different softness zones wherever needed within the design and achieve pressure relief on neuralgic prominent anatomical pressure sensitive zones; and
- Possibility to integrate corrective wedges into the cushion element to achieve better patient alignment in statics or even corrective body positions (scoliosis pelvis misalignments).

[0008] On top of the above stated advantages the special embodiment of the cushion element with integrated sensors provides the following additional advantages:

- Integrating sensors into the material of soft seat cushions today is not possible without destroying the structures and with it changing the properties of the seat cushion. By means of the multi-material additive manufacturing process a solution has been found to directly integrate a capacitive sensor by using conductive printable material;
- The sensors are not detectable by palpation (applying manual force) thereby eliminating decubitus risk;
- The sensor connectors are accessible directly on the surface of the cushion element for wire or socket connectors;

- The sensors can be integrated into the cushion element where it is not possible to insert a sensor to an existing functional structure without destroying its functionality;
- The entire cushion element can be washed including the sensor.
- It is possible to measure weight distribution on the sitting interface with several sensors/zones;
- The sensors always remain fixed to the cushion and cannot dislocate by usage.
- Data measured by the sensors allow monitoring sitting posture and warning of the patient if the position has remained too long in the same position. It is possible to generate a signal to "re-seat" in a new position; and
- Sensing of humidity/temperature for a controlled skin environment controlling a ventilation system is possible.

[0009] The cushion element according to the invention has the following further advantages: It is adapted to the patient anatomy, leading to a better pressure distribution, and improves air circulation due to its open cell structure. In a special embodiment - in order to prevent pressure ulcers - the cushion element is equipped with a compression sensor, which is seamlessly integrated into the seat cushion by FFF 3D printing using conductive material. The sensor can provide valuable information on statics, sitting too long in one posture (risk of skin defects) and helps reducing or preventing pressure ulcers.

[0010] Further advantageous embodiments of the invention can be commented as follows:

In a special embodiment the through-going open-cell structure allows air-circulation through further surfaces of the cushion element.

[0011] In a further embodiment the cushion element comprises several zones, two of which at least are exhibiting different physical properties.

[0012] In a further embodiment at least two of the several zones and preferably all of the several zones consist of the same polymeric material.

[0013] In a further embodiment the polymeric material is a thermoplastic material. Preferably, the thermoplastic material is thermoplastic polyurethane.

[0014] In another embodiment the Young's modulus of the several zones is minimum $2x10^{-4}$ MPa and maximum 10^{-1} MPa.

[0015] In another embodiment the thickness of the walls of the open cells is minimum 0.4 mm and preferably maximum 1.2 mm.

[0016] In another embodiment at least two of the several zones, and preferably all of them, differ in one or more of the following physical properties: (i) density; (ii) geometrical structure; (iii) uni-, di-, ortri- directional orientation of the cell structure; (iv) mean size of the open cells; and (v) mean thickness of the walls of the open cells.

[0017] In a further embodiment the cushion element having a through-going open-cell structure has been obtained by an Additive Manufacturing (AM) technology and preferably by Fused Filament Fabrication (FFF).

[0018] In yet a further embodiment the cushion element comprises a polymeric material with a melting point of minimum 150° C, preferably of minimum 200° C.

[0019] In another embodiment the cushion element comprises a polymeric material with a melting point of maximum 240°.

[0020] In another embodiment the cushion element comprises a polymeric material with a Shore A hardness of minimum 60, preferably of minimum 80.

[0021] In another embodiment the cushion element comprises a polymeric material with a Shore A hardness of maximum 100, preferably of maximum 90.

[0022] In a further embodiment the cushion element further comprises two electrode plates which comprise an electrically conductive material seamlessly positioned within the cushion element, the two electrode plates being arranged essentially parallel to the interface surface at a given distance from each other and electrically isolated from each other by the polymeric cellular material between the two electrode plates.

[0023] In a further embodiment the polymeric cellular material between the two electrode plates is resilient so that upon exertion of pressure to the interface surface the distance between the two electrode plates is reduced thereby allowing a capacity measurement in response to the magnitude of the pressure exerted.

[0024] In another embodiment the polymeric cellular material between the two electrode plates is stiff so that upon exertion of pressure to the interface surface the distance between the two electrode plates remains essentially constant thereby allowing a capacity measurement in response to the humidity in the open-cell structure.

[0025] In another embodiment the electrode plates have an open-cell structure.

[0026] In again another embodiment the electrode plates are perforated.

[0027] In again another embodiment the electrode plates are obtained via the 3D printing manufacturing process.

In a further embodiment the electrode plates are wired to the outer surface by means of 3D printed conductive ribbons.

[0028] In another embodiment electronic near field communication (NFC) components are attached to the surface of the electrode plates. These electronic NFC components, powered wirelessly, allow the measurement of the capacitance and the transmittal of the capacitance values to an external device.

[0029] In another embodiment the electrode plates comprise thermoplastic material or filaments, preferably polyurethane resins and additionally one or more of the following substances: carbon black, silica cristobalite and silver particles. Preferably, the electrode plates are obtained via the 3D printing manufacturing process.

[0030] In a further embodiment the cushion element additionally comprises an air ventilator which is either integrated in the open-cell structure or arranged exterior of the cushion element with an air inlet at the cushion element.

[0031] In a further embodiment the electrode plates have a surface area of 480 mm^2 to 4'800 mm^2.

[0032] In again a further embodiment the electrode plates have a thickness of 0.8 mm to 1.6 mm.

[0033] Preferably, the electrode plates are arranged at a distance of 10 mm - 80 mm from each other.

[0034] It is another object of the present invention to provide a method for manufacturing a cushion element comprising a polymeric material and having an interface surface for contacting a human and a free surface opposite to the interface surface, comprising the following steps:

a) determining the functional outer surface of the cushion element with its prominent body including the interface surface for contacting a human and the free surface opposite to the interface surface suitable as a wheelchair interface in shape and dimensions;
b) determining multiple zones and designs of the inner open-cell cellular structure of the cushion element permitting air-circulation through all surfaces of the cushion element;
c) merging all CAD data and generating a machine code for multi-material printing;
d) printing the cushion element by using a 3D printing and manufacturing process.

[0035] According to a special embodiment of the method before step c) the following step is performed: b2) selecting points of interest to place and designing one or more capacitive sensors (10).

[0036] According to a further embodiment of the method electronic NFC components are introduced inside the cushion element during step d).

A BRIEF DESCRIPTION OF THE DRAWINGS

[0037] Several embodiments of the invention will be described in the following by way of example and with reference to the accompanying drawings in which:

Fig. 1 illustrates a perspective view of a wheelchair with the cushion element according to the invention as a sitting platform;

Fig. 2 illustrates a schematic perspective view on a first embodiment of an open-cell cellular structure of the cushion element of fig. 1;

Fig. 3 illustrates a schematic perspective view on a second embodiment of an open-cell cellular structure of the cushion element of fig. 1;

Fig. 4 illustrates a schematic perspective view on a third embodiment of an open-cell cellular structure of the cushion element of fig. 1;

Fig. 5 illustrates a schematic perspective view on a fourth embodiment of an open-cell cellular structure of the cushion element of fig. 1;

Fig. 6 illustrates a cross-sectional view of another embodiment of the cushion element according to the invention;

Fig. 7 illustrates a perspective view of a special embodiment of the cushion element according to the invention with four sensors integrated in the open-cell cellular structure of the cushion element;

Fig. 8 illustrates a perspective cut-out of the region including the integrated electrode plates in the cushion element of a further embodiment according to the invention;

Fig. 9 illustrates a perspective cut-out of the region including the integrated electrode plates in the cushion element of again a further embodiment of the cushion element according to the invention;

Fig. 10 illustrates a top view on an electrode plate according to another embodiment of the cushion element according to the invention;

Fig. 11 illustrates a schematic view of the integrated 3D printed sensor within the open-cell cellular structure of a further embodiment of the cushion element according to the invention;

Fig. 12 illustrates a perspective view on a humidity sensor integrated in a cushion element of another embodiment of the cushion element according to the invention; and

Fig. 13 illustrates a cross-sectional view showing the air tubes between the two electrode plates of the humidity sensor of fig. 12.

DETAILED DESCRIPTION OF THE INVENTION

[0038] Fig. 1 illustrates an embodiment of the cushion element 1 according to the invention, which comprises a polymeric material and which has an interface surface 2 for contacting a human and a free surface 3 opposite to the interface surface 2. Exemplarily, but not limiting, the cushion element 1 is configured as the interface between the backside of the driver and the wheelchair 4. The cushion element 1 has a through-going open-cell cellular structure which allows air-circulation between the interface surface 2 and the free surface 3, wherein the through-going open-cell structure is obtained by a 3D printing manufacturing process. The entire seat cushion element 1 is printed with a fused filament fabrication (FFF) technology with TPU (Thermoplastic Polyurethane) material in the shore hardness of 85A. Alternatively, the cushion element 1 can be realized with other 3D printing technologies or Additive Manufacturing (AM) technology_and with other materials.

Definition of the term "Open-Cell Cellular Structure":

[0039] Cellular structures are omnipresent as a building block in nature. Adapting their principles into product design optimizes resulting properties, such as the weight-to-strength ratio, and energy absorption. The design of cellular structures is a unit cell-based periodic design that is arranged in two- or three-dimensional (3D) arrays. Not having the unit cells completely encapsulated, but deliberately designed to be opened.

[0040] Particular types of open-cell cellular structures are illustrated in figs. 2 - 5, wherein fig. 2 illustrates a lattice comprising cubic algebraic structure of cylinders with the parameters: "cylinders' diameter, cylinders' length, nodes' shape and size, orientation", fig. 3 illustrates a 3D re-entrant auxetic with the parameters "height h, length l and angle θ, whereas fig. 4 illustrates a configuration of tiled spheres having a set of spheres on a regular grid, being subtracted from a specified volume with the prerequisite "spheres' diameter" > "Spheres' center distance from each other" and with the parameters "spheres' diameter, spheres' center distance from each other, orientation" and fig. 5 illustrates a gyroid (TPMs gyroid) with the parameters "unit-cell size or fill ratio, and thickness". In alternative embodiments other open celled cellular structures with a low Young's modulus, resulting to damping/soft-foam properties can be used as well. (Examples are: Stochastic foam, Body-centered cubic (BCC), TPMS P-type, TPMS I-WP type).

[0041] Open-cell cellular structures allow air-circulation with low fluidic resistance across the material. To illustrate this property, an air-flow-resistance measurement was carried out with a Ventilator (turbine), an AWM720P1 Flowmeter, and a Frame. The Frame was a cubic construction of 50mm side, with one face opened to atmospheric pressure and the opposite face featuring a central cylindrical opening, with a diameter of 19 mm for air connection to the vent. The air-flow measurement is taken between the vent and the Frame. When the Frame is empty, the air flow was measured and represented 100 liters per minute. Filling the Frame with a 50 mm cubic-shaped open-cell cellular structure as used in one embodiment of the present invention, resulted in a limited reduction of the airflow of less than 2 liters per minute.

[0042] A further embodiment of the cushion element 1 according to the invention is illustrated in fig. 6 which differs from the embodiment of fig. 1 only therein that the cushion element 1 comprises a perforated surface 6 and an inner structure. The perforated surface 6 creates a pattern of holes while the inner structure includes four zones 5a - 5d, which are exhibiting different physical properties. These different zones 5a - 5d are realized by different open-cell cellular structures types with different dimensions, wherein zone 5a (lower front part of the cushion element 1) forms the most dense area, zones 5b (adjoining zone 5a towards a rear part and at the rear part of the cushion element 1) forms a dense frame area, zone 5c (lower central part of the cushion element 1) forms a soft zone (Ischium) and zone 5d (upper front part of the cushion element 1) forms a very soft zone (15 mm Stimulite). The four zones 5a - 5d consist of the same polymeric material. Further, exemplarily, but not limiting, the holes of the perforated surface 6 have a smaller diameter than the open cells of the open-cell cellular structure of zone 5d.

[0043] Dimensions for these zones 5a - 5d are as follows:

	Zone 5a	Zone 5b	Zone 5c	Zone 5d
Min. element thickness in mm	1.55	0.89-1.00	0.85-1.10	0.93-1.00

(continued)

	Zone 5a	Zone 5b	Zone 5c	Zone 5d
Cellular size in mm^3	5.31^3	5^3	6^3	7^3

[0044] Figs. 7 - 11 illustrate a further embodiment of the cushion element 1 according to the invention which differs from each of the embodiments of figs. 1 - 6 only therein that the cushion element 1 additionally comprises a plurality of electrode plates 7 in the form of 3D printed capacitive sensors 10 which are provided with ribbon connectors 8 (signal roots) that are directly integrated into the open-celled design of the cushion element 1. These ribbon connectors 8 each comprise an interface to a desired output area of the cushion element 1 so as to provide access points 9 for all sensors for signal transmission which are accessible from the outer surface of the cushion element 1 (fig. 11). The sensor signals are processed and interpreted in a separate mobile device (not shown) to provide add-on information to the driver and or to the medical team for further sitting optimization.

[0045] The electrode plates 7 are made of a conductive material seamlessly positioned within the cushion element 1, wherein each two electrode plates 7 are arranged at a given distance from each other and electrically isolated from each other by the polymeric cellular material between the two electrode plates 7. The polymeric cellular material between each two electrode plates 7 is resilient (fig. 9) so that upon exertion of pressure to the interface surface 2 the distance between respective two electrode plates 7 is reduced thereby allowing a capacity measurement in response to the magnitude of the pressure exerted that is causing the difference in distance of the electrode plates.

[0046] In the cushion element 1 the sensors 10 are integrated into the open-celled structure of the cushion element on point of interest locations as illustrated in fig. 7. Principle description of integration (figs. 8 and 9): the sensor electrode surfaces consist of conductive areas (electrode plates 7) which are 3D printed with conductive FFF filaments. The electrode plates 7 are surrounded by open-celled non-conductive TPU material, not facing the surface of the cushion element 1. Each electrode plate 7 has one or more ribbon connectors 8 that lead from the electrode plate 7 to the desired output area on the surface of the cushion element 1. In Fig.7 the electrode plates 7 are located directly below the surface of the cushion element 1, but the essence is the same even if there was some distance from the surface. Alternatively, there is some open-cell cellular structure between the electrode plates 7 and the perforated surface 6 of the cushion element 1.

[0047] Fig. 8 illustrates a particular embodiment of a sensor 10 with a TPU flexible structure between the two electrode plates 7.

[0048] Each two 3D printed electrode plates 7 are aligned with a fair distance to each other within the cushion element 1. Exemplarily, but not limiting, the shape of the electrode plates 7 is square and the electrode plates 7 are perforated (fig. 10). Alternatively, the electrode plates 7 can be non-perforated and the shape of the electrode plates 7 can be round or any other shape. In further alternative embodiments the electrode plates 7 can be contoured. Exemplarily, the electrode plates 7 are made from a thermoplastic polyurethane resin and comprise as an electrically conductive material carbon black. Alternatively or additionally, as electrically conductive material silica cristobalite and/or silver particles can be added.

[0049] The dimensions of the electrode plates were 50 x 50 x 1.2 mm. The electrode plates were covered up with one non-conductive layer and the distance between the electrode plates 7 was 30 mm. In alternative embodiments the distance between the electrode plates 7 can be between 15 mm and 100 mm.

[0050] In the example of fig. 8 each electrode plate 7 comprises one printed ribbon connector 8 which is made of an electrically conductive material and which extends from the electrode plate 7 to the surface of the cushion element 1. In alternative embodiments, each electrode plate 7 can comprise a plurality of ribbon connectors 8.

[0051] Following is an optional design to replace the ribbon connectors 8: Instead of having physical connection routes from the electrodes to the surface of the seat cushion, an alternative way is to use NFC (near field communication) technology to charge electrodes and transmit the signal of the electrodes wireless to the receiver. The manufacturing process of using additive manufacturing remains the same. Applying the NFC to the electrode within the printing process can be done by pick&place robot. Other ways of NFC circuits are possible.

Sensor working principle

[0052] The printed integrated sensors 10 function as capacitive sensors. A capacitor is a device that stores electrical energy in an electric field. The capacitance is a measurable property of a capacitor, which is a function of the geometry of the device (e.g. area of the plates and the distance between them) and of the permittivity of the dielectric material between the plates of the capacitor. By measuring any change in the capacitance value, and knowing what parameter was the cause of it, we can quantify this parameter, thus making a sensor for measuring distance, and humidity.

Distance measurement

[0053] By changing the distance between the two electrode plates 7 of the capacitor, while keeping the dielectric permittivity relatively unchanged, and measuring the change in capacitance, then effectively distance is measured.

[0054] Figs. 12 and 13 illustrate another embodiment of the cushion element 1 according to the invention which differs from the embodiment of figs. 7 - 11 only therein that the polymeric cellular structure between each two electrode plates 7 is stiff so that upon exertion of pressure to the interface surface the distance between each two electrode plates 7 remains essentially constant thereby allowing a capacity measurement in response to the humidity in the open-cell structure. By changing only the dielectric permittivity by changing the air humidity and measuring the change in capacitance, then effectively humidity is measured.

Data interpretation:

[0055] A device, e.g. a standard Arduino (open-source electronics platform), is monitoring the capacitive change over time in [pF] picofarad. Its values can be translated in mm distance. A multi-channel capacitive measurement device can show all sensor information and interpret a shift of compression values into change of position (fig. 7). It can also detect a certain time period without any weight dislocation (distance change) and send out a warning signal to prevent pressure skin defects.

Cushion ventilation

[0056] As the open celled cushion element design already allows air circulation within the inner structure to the surrounding ambient, an air ventilator to actively control the temperature and humidity can be integrated. Ambient air is transferred through the cushion structure to transport body temperature and moisture from the open celled cushion body interface back to the ambient (exhaust). Exemplarily, the ventilator is integrated into the seat cushion whereby the air streams through the inner structure along the body interface surface till it exits the cushion element. Alternatively, the ventilator can be arranged exteriorly of the cushion element, e.g. integrated in a wheelchair, wherein in this case a main air inlet is positioned at a surface of the cushion element.

Implementation examples

Seat without sensors:

[0057] A customized multi soft zone open celled cushion element that can be placed on any sitting/rest device functioning as a soft interface for weight load distribution: This can be on mobile or static devices like any type of wheelchair, rest-beds, couch. It will be used to prevent skin and musculoskeletal defects on patients that are at least partially immobilized or have the tendency to be forced to rest longer period on certain body areas (paralyzed, coma patient, handicapped people, professional drivers).

Seat with sensors:

[0058] A customized multi soft zone open celled cushion element that can be placed on any sitting/rest device functioning as a soft interface for weight load distribution. The integrated sensor(s) are used to monitor the weight distribution but can also sense temperature and humidity. The sensor data can be computed and useful information to prevent skin and musculoskeletal defects can be provided to the users: This interface can be integrated on mobile or static devices like any type of wheelchair, rest-beds, and couch.

Seat cushion with ventilator:

[0059] Temperature and moisture control during long period of inactive sitting laying interfacing. Used on wheelchairs, couches, in cushion, in matraces.

[0060] Although the invention has been described in conjunction with specific embodiments thereof, it is evident that many alternatives, modifications and variations will be apparent to those skilled in the art. Accordingly, it is intended to embrace all such alternatives, modifications and variations that fall within the scope of the appended claims.

[0061] It is appreciated that certain features of the invention, which are, for clarity, described in the context of separate embodiments, may also be provided in combination in a single embodiment. Conversely, various features of the invention, which are, for brevity, described in the context of a single embodiment, may also be provided separately or in any suitable subcombination or as suitable in any other described embodiment of the invention. Certain features described in the context of various embodiments are not to be considered essential features of those embodiments, unless the embodiment is inoperative without those elements.

Claims

1. Cushion element (1) comprising a polymeric material, the cushion element (1) having an interface surface (2) for contacting a human and a free surface (3) opposite to the interface surface (2),
characterized in that

   a) the cushion element (1) has a through-going open-cell structure which allows air-circulation between the interface surface (2) and the free surface (3); and
   b) the through-going open-cell structure is obtained by a 3D printing manufacturing process.

2. Cushion element (1) according to claim 1, **characterized in that** the through-going open-cell structure allows air-circulation through further surfaces of the cushion element (1).

3. Cushion element (1) according to claim 1 or 2, **characterized in that** the cushion element (1) comprises several zones (5a-5d), two of which at least are exhibiting different physical properties.

4. Cushion element (1) according to claim 3, **characterized in that** at least two of the several zones (5a-5d) and preferably all of the several zones (5a-5d) consist of the same polymeric material.

5. Cushion element (1) according to one of the claims 1 to 3, **characterized in that** the polymeric material is a thermoplastic material.

6. Cushion element (1) according to one of the claims 1 to 5, **characterized in that** the thickness of the walls (12) of the open cells is minimum 0.4 mm and preferably maximum 1.2 mm.

7. Cushion element (1) according to one of the claims 3 to 6, **characterized in that** at least two of the several zones (5a-5d), and preferably all of them, differ in one or more of the following physical properties:

   (i) density;
   (ii) geometrical structure;
   (iii) uni-, di-, or tri- directional orientation of the cell structure
   (iv) mean size of the open cells; and
   (v) mean thickness of the walls of the open cells.

8. Cushion element (1) according to one of the claims 1 to 7, **characterized in that** the cushion element (1) having a through-going open-cell structure has been obtained by an Additive Manufacturing (AM) technology and preferably by Fused Filament Fabrication (FFF).

9. Cushion element (1) according to one of the claims 1 to 8, **characterized in that** it further comprises two electrode plates (7) which comprise an electrically conductive material seamlessly positioned within the cushion element (1), the two electrode plates (7) being arranged essentially parallel to the interface surface (2) at a given distance from each other and electrically isolated from each other by the polymeric cellular material between the two electrode plates (7).

10. Cushion element (1) according to claim 9, **characterized in that** the polymeric cellular material between the two electrode plates (7) is stiff so that upon exertion of pressure to the interface surface the distance between the two electrode plates (7) remains essentially constant thereby allowing a capacity measurement in response to the humidity in the open-cell structure.

11. Cushion element (1) according to claim 9 or 10, **characterized in that** the electrode plates (7) are wired to the outer surface by means of 3D printed conductive ribbons (8).

12. Cushion element (1) according to claim 9 or 10, **characterized in that** electronic NFC components are attached to the surface of the electrode plates (7).

13. Cushion element (1) according to one of the claims 9 to 12, **characterized in that** the electrode plates (7) comprise thermoplastic material, preferably polyurethane resins and additionally one or more of the following substances: carbon black, silica cristobalite and silver particles.

14. Cushion element (1) according to one of the claims 1 to 13, **characterized in that** it comprises an air ventilator which is either integrated in the open-cell structure or arranged exterior of the cushion element (1) with an air inlet at the cushion element (1).

15. Cushion element (1) according to one of the claims 9 to 14, **characterized in that** the electrode plates (7) are obtained via the 3D printing manufacturing process.

16. Method for manufacturing of a cushion element (1) comprising a polymeric material and having an interface surface (2) for contacting a human and a free surface (3) opposite to the interface surface (2), comprising the following steps:

a) determining the functional outer surface of the cushion element (1) with its prominent body including the interface surface (2) for contacting a human and the free surface (3) opposite to the interface surface (2) suitable as a wheelchair interface in shape and dimensions;
b) determining multiple zones (5a-5d) and designs of the inner open-cell cellular structure of the cushion element (1) permitting air-circulation through all surfaces of the cushion element (1);
c) merging all CAD data and generate a machine code for multi-material printing;
d) printing the cushion element (1) by using a 3D printing and manufacturing process.

17. Method according to claim 16, **characterized in that** before step c) the following step is performed:
b2) selecting points of interest to place and designing one or more capacitive sensors (10).

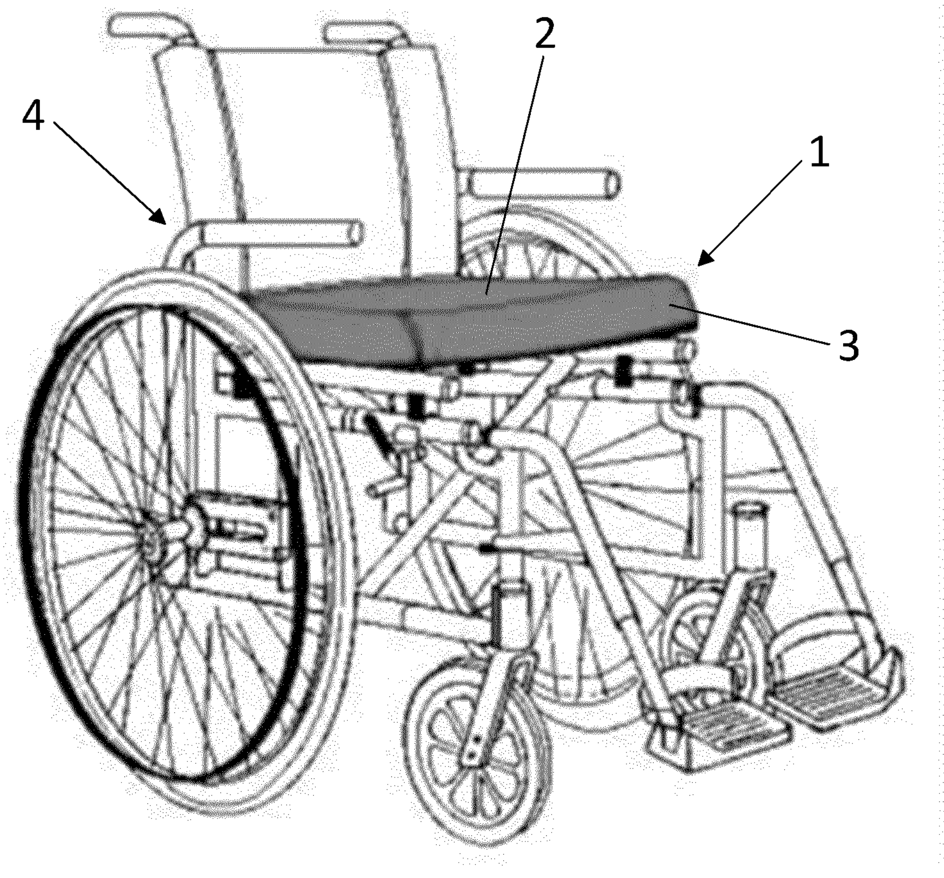


Fig. 1

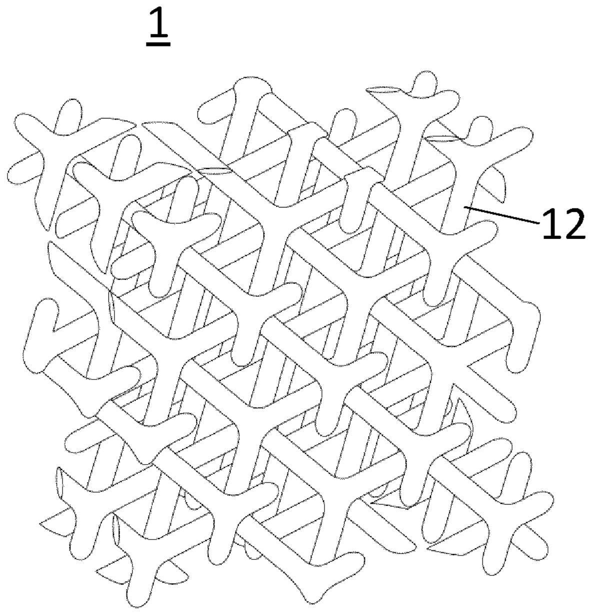


Fig. 2

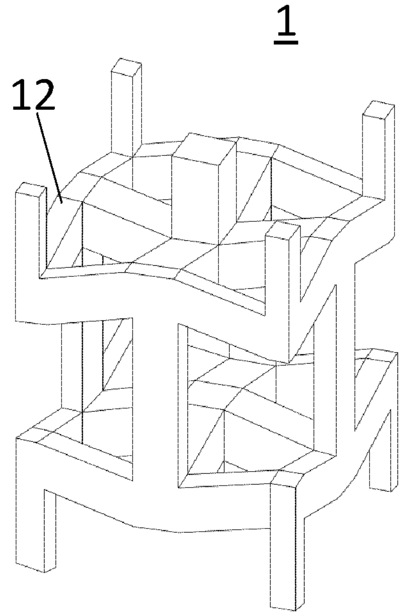


Fig. 3

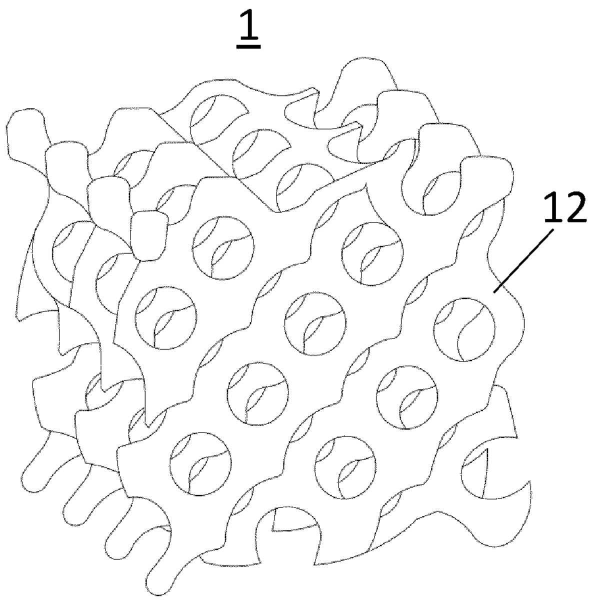
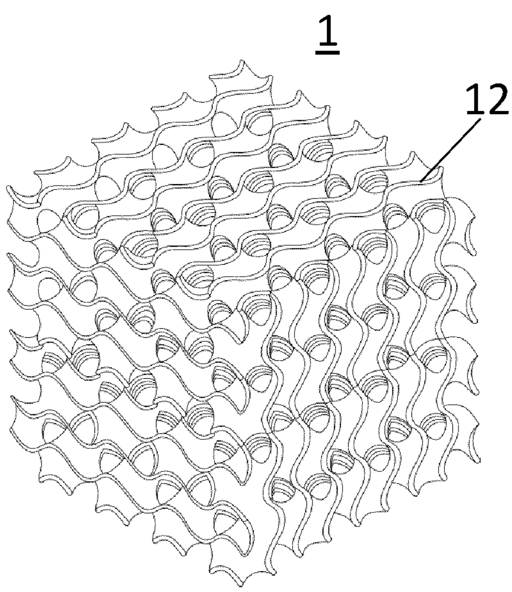


Fig. 4



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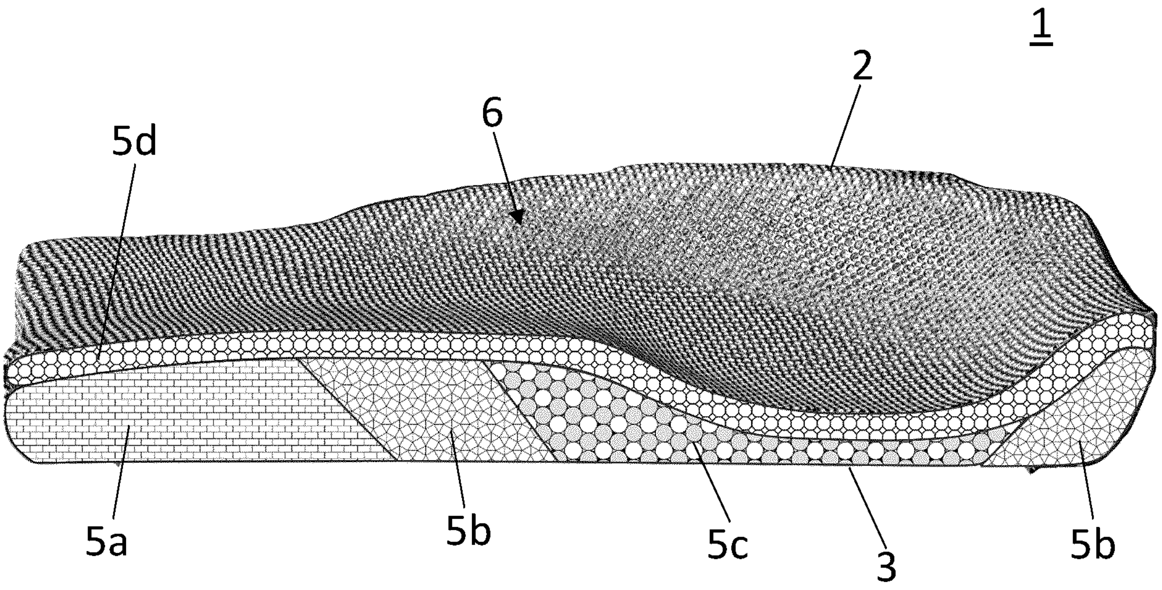

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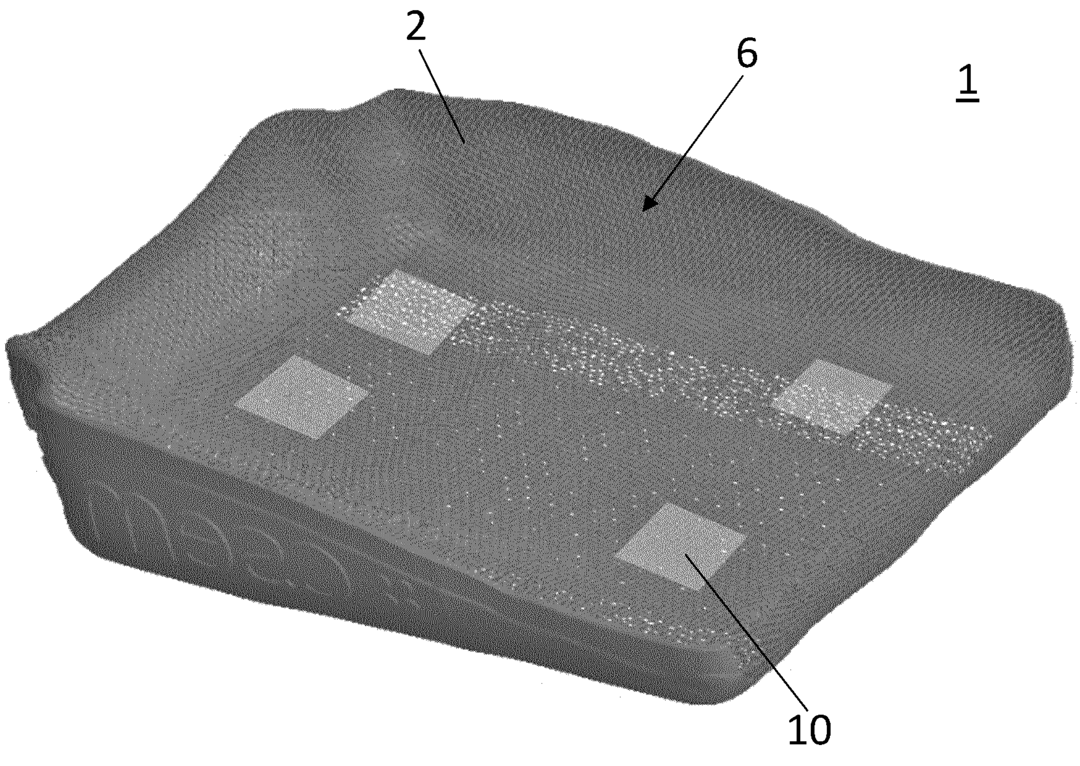

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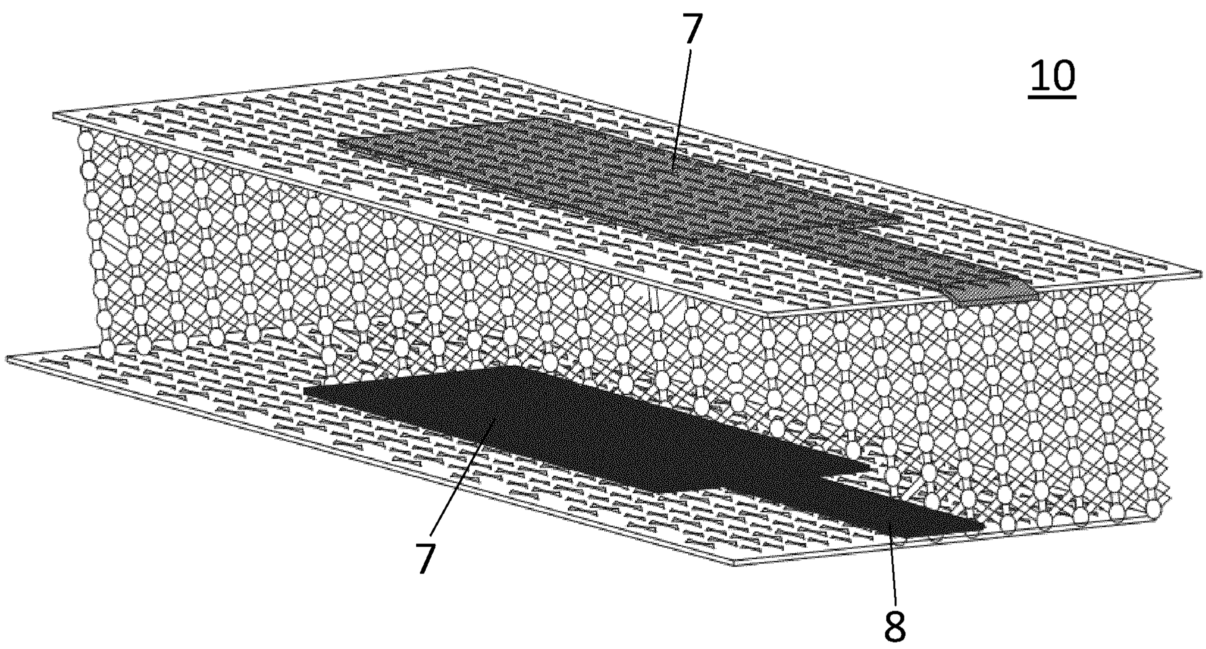

Fig. 8

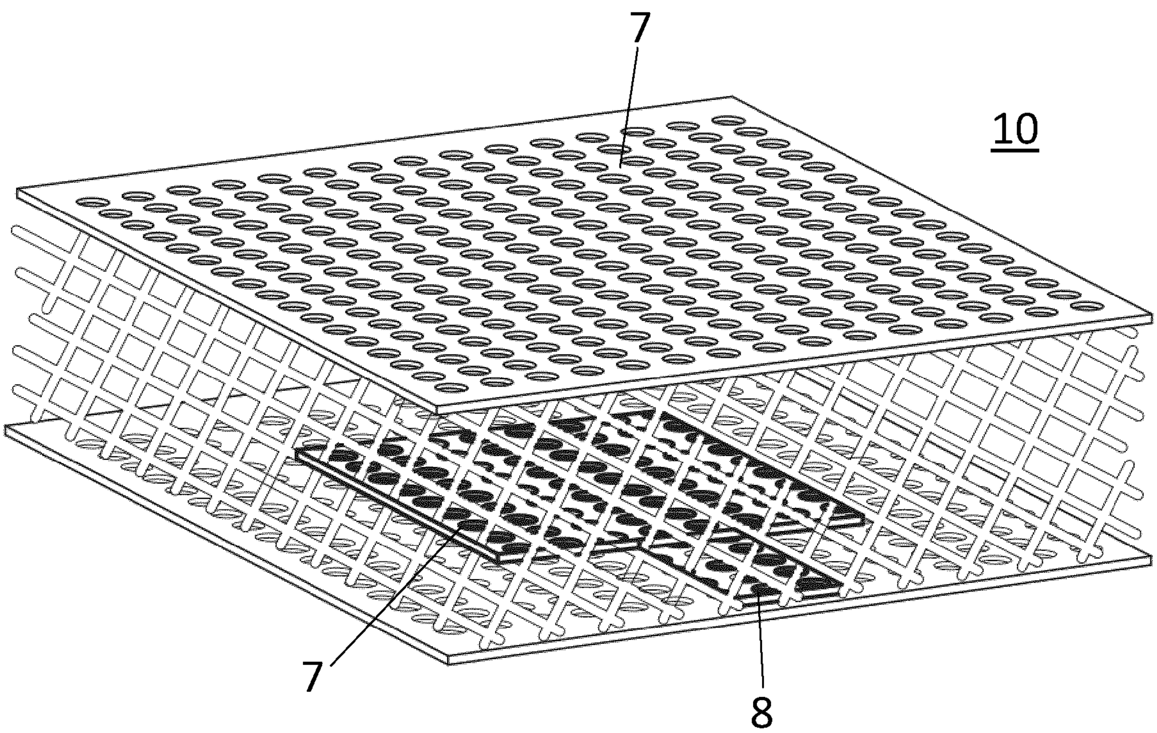

Fig. 9

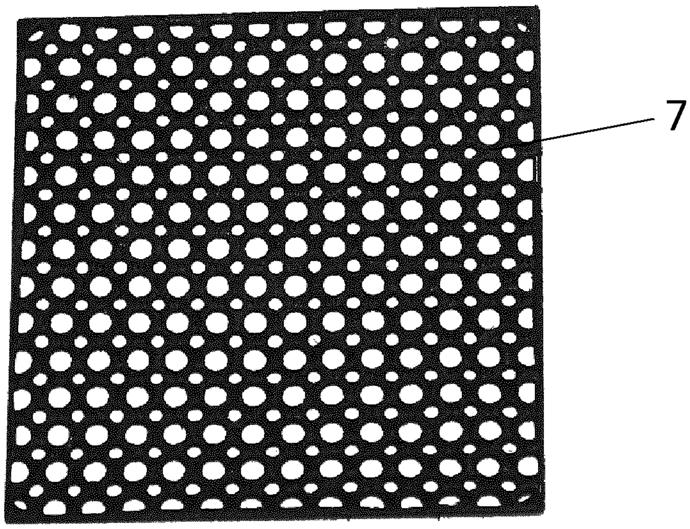

Fig. 10

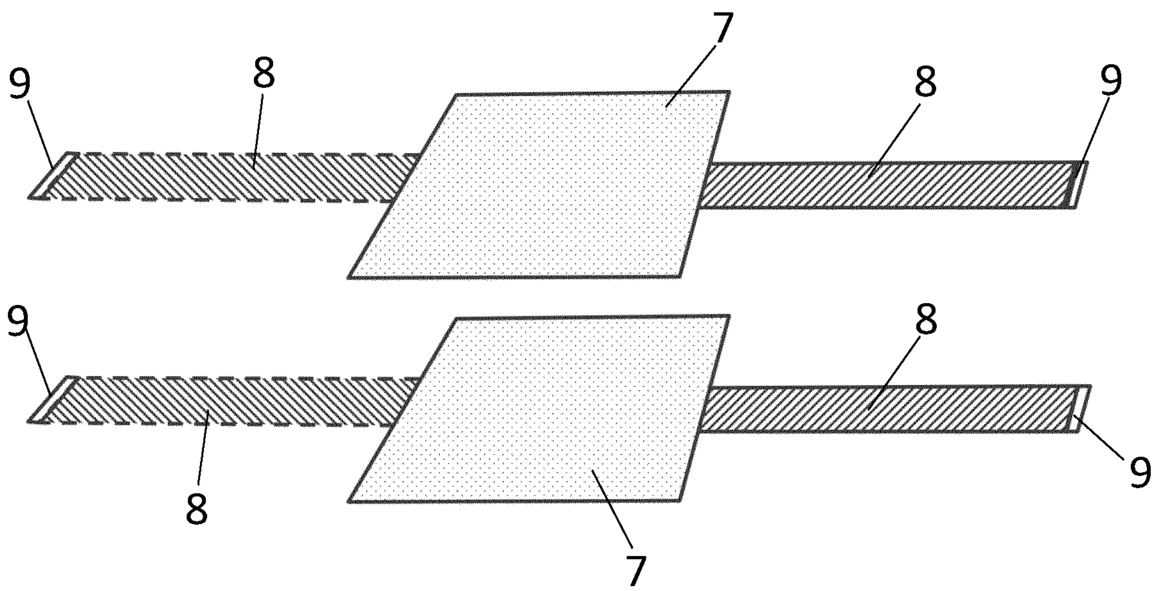

Fig. 11

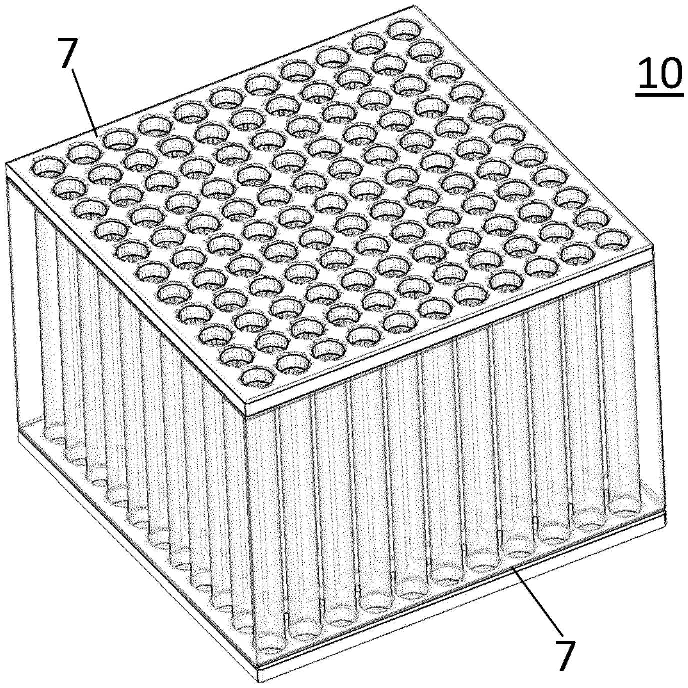

Fig. 12

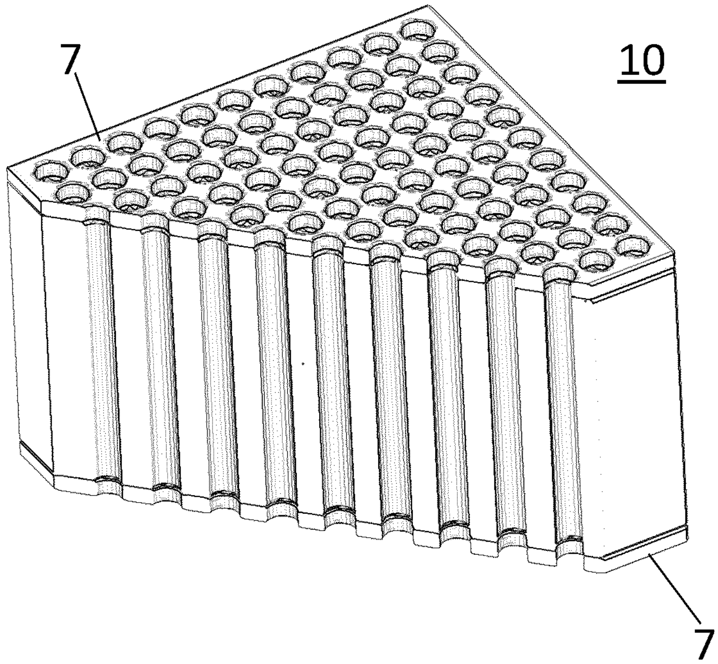

Fig. 13

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EUROPEAN SEARCH REPORT

Application Number
EP 20 15 2487

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X	US 2019/054847 A1 (LANG STEVEN C [US] ET AL) 21 February 2019 (2019-02-21) * paragraph [0031] - paragraph [0034] * -----	1-17	INV. A61G5/10 B60N2/70
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A61G
B60N

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	24 June 2020	Kousouretas, Ioannis

CATEGORY OF CITED DOCUMENTS

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