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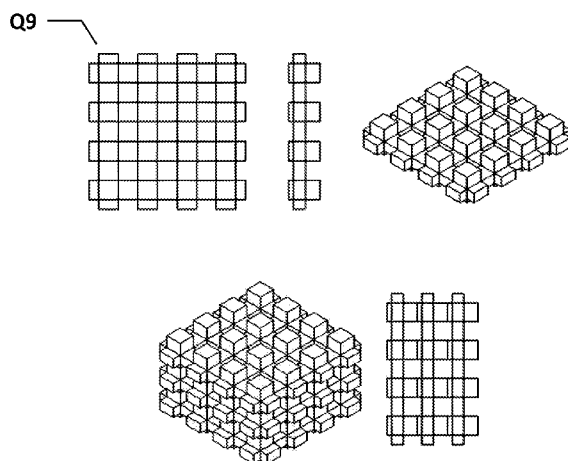


Fig. 12

(57) Abstract: Three-dimensional porous structures comprising multiple moulded layer modules with interconnected channels in all 3D, in particular substantially axial and/or radial directions. The three-dimensional porous moulded-multilayer product (2) comprises an assembly of a plurality of moulded layer modules (1) which in turn comprise a plurality of through-holes between the layer surfaces of said moulded layer module (1); and a plurality of longitudinal recesses on at least one of the layer surfaces of said moulded layer module (1), along at least two different directions, such that when assembled with the layer surface of another moulded layer module (1) longitudinal channels are formed; wherein said through-holes and recess channels are interconnected. The production method comprises assembling of the moulded layer modules (1) by sintering, welding, ultrasonic welding, or applying rigid junctions, screws, spikes, rivets, snap fits, or combinations thereof.

D E S C R I P T I O N
“3D POROUS MOULDED-MULTILAYER PRODUCT
AND PRODUCTION METHOD THEREOF”

Technical field

[0001] The disclosure relates to the production of three-dimensional porous structures comprising multiple moulded layer modules with interconnected channels in all 3D substantially axial and/or radial directions namely for medical, automotive, construction or electronic applications.

Background Art

[0002] Three-dimensional porous structures with interconnected channels are made through three leading methods. These are foaming, foam replication, and solid free forming, or 3D printing, processes.

[0003] In foaming or replication processes, non-uniform structures are achieved. The geometry of the channels is dictated by the formation, growth and impingement of gaseous cells (pore). In general, pores are spherical in shape. Level of pores interconnectivity is only possible to be determined with special techniques, and is highly influenced by process parameters.

[0004] In 3D printing processes or solid free forming processes, three-dimensional porous structures are produced by deposition of materials, layer by layer, using one or several nozzles at once. These methods allow the manufacture of exclusive parts, but are still slow and expensive for mass production.

[0005] Patent document US2009/0061127A1 (Entezarian et al) describes the manufacture of porous structures through injection moulding. In this document, a very complex injection moulding tool is described in which several straight elements are organized in a way that allows the manufacture in a single step of simple geometric

structures with interconnected channels. The section of the channels is defined by the section of the pins that are organized and aligned in two different directions. The channel in the third direction is obtained as a consequence of the tangency of the previous described inserts (e.g. Fig. 7B). For this reason, the interconnectivity section of the channels is limited by the tangent surface of the moulding pins.

[0006] Other prior art, namely described in document EP0672395A1 (Salvatore et al) describes a method specially conceived for the production of medical application parts in order to improve osteointegration. This method allows the production of complex shape parts in a system of layer-by-layer powder deposition, allowing the production of complex free form parts, dispensing the use of a mold to conform the materials. However, this system does not allow the mass production of parts in a systematic approach, since it is based in a slow method of individual part production, that need to be previously generated in a Computer Assisted Design system.

[0007] The method claimed in the above cited document EP0672395A1 is suited for individually specific parts, with precise properties and does not allow the easy flexibility of form and chain production ability of the described invention. Moreover, said method has strong limitation on the type of materials that can be used to produce the final part, being dependent on the powder suspension formulations available for the technology. Thus, document EP0672395A1 cannot be reduced to practice using a wide range of materials.

[0008] Document EP0647439A2 refers the use of layer modules to obtain three-dimensional porous moulded-multilayer products. Its layers are symmetrical in the Z axis and require two subsequently reversed layers for channels in all 3D directions to be formed. Thus it requires a substantial amount of joints between layers, which increases the probability of layer adhesion problems and, thus, structural faults. It also requires that subsequent layers must be 'turned upside down' and the complexity of turning such small scale objects is considerable. Furthermore, for aligning protrusions with protrusions, the alignment of the layers before joining must be rather precise, with corresponding higher costs. In fact, the disclosure does not seem enabling as a mandrel is mentioned for recovering the alignment between through-holes of different

layers, which is neither practically feasible nor economic, depending on the through-hole diameter. This document also refers that the layers are stacked by rolling up multiple times a sheet layer – but as different roll layers have different roll perimeters, the through-holes will only align infrequently and thus through-holes will not be formed through the material.

Summary

[0009] It is disclosed a three-dimensional porous moulded-multilayer product (2) comprising a stack assembly of a plurality of a moulded layer module (1), said module (1) comprising:

- a. a plurality of through-holes between the layer surfaces of said moulded layer module (1);
- b. a plurality of longitudinal recesses on at least one of the layer surfaces of said moulded layer module (1), along at least two different directions, such that when assembled with a layer surface of another moulded layer module (1) longitudinal channels are formed;

wherein said through-holes and recess channels are interconnected.

[0010] In an embodiment, the plurality of modules (1) is assembled with all layer faces of said modules (1) positioned in the same direction.

[0011] In an embodiment, said module (1) comprises alignment features on both layer surfaces of said moulded layer module (1), in particular protrusions and recesses for receiving protrusions, said features being such that, when a moulded layer module is assembled with another moulded layer module, a partial or full overlap of the through-holes of said moulded layer modules is obtained.

[0012] In an embodiment, the moulded layer module (1) is obtainable by powder injection moulding, thermoplastic injection, powder pressing or machining, or combinations thereof.

[0013] In an embodiment, the moulded layer module (1) comprises plastic, thermoplastic polymer, thermoset resin, metal, or ceramic, or combinations thereof.

[0014] In an embodiment, the moulded layer module (1) comprises bioresorbable polymer, bioresorbable ceramic, bio-inert polymer, bio-inert ceramic, bio-inert metallic, or heat-conductive material, or combinations thereof.

[0015] In an embodiment, the cross-section of the through-holes and longitudinal channels of the moulded layer module (1) is hexagonal (Q1), square (Q2, Q7), circular (Q3, Q5, Q8), and/or cross-shaped (Q4).

[0016] In an embodiment, the through-holes of the of the moulded layer module (1) are laid out in a grid (Q1, Q2, Q4, Q5, Q6), or concentrically (Q3, Q8), or both in a grid and concentrically (Q7).

[0017] In an embodiment, the through-holes of the moulded layer module (1) are perpendicular to the layer surfaces of said moulded layer module (1) or are tilted relative to the layer surfaces of said moulded layer module (1).

[0018] It is also disclosed that the moulded-multilayer products (Q1, Q2, Q3, Q4, Q5, Q6, Q7, Q8, Q9 and Q10) are aligned based on the alignment features principles represented in (Q11, Q12). The referred features are added to the design definition of the moulded layer module (1) to guaranty the alignment and precision of the moulded-multilayer products (2). Controlling the alignment between layers is relevant for controlling the overall porosity of the product. It should be noted that this porosity is not strictly porosity in the sense of the proportion between voids and solid in the product. For example, for numerous applications, porosity is better evaluated as effective porosity, i.e. not considering voids that are not interconnected. Furthermore, for example, for biocompatibility, the interconnections must be reasonably accessible, i.e. relatively straight, or with a precisely controllable meandering aspect. Thus the importance of controlling the alignment of the layers and thus the overall product characteristics.

[0019] In an embodiment, the three-dimensional porous moulded-multilayer product (2) assembly is obtainable by sintering, welding, ultrasonic welding, rigid junctions, screws, spikes, rivets or snap fits, or combinations thereof.

[0020] In an embodiment, the assembled plurality of moulded layer modules (1) of the three-dimensional porous moulded-multilayer product (2) is offset between adjacent

moulded layer modules (1), in particular such that adjacent moulded layer modules (1) are translationally, rotationally or randomly offset, in order that adjacent moulded layer modules (1) through-holes are partially overlapping.

[0021] In an embodiment, the three-dimensional porous moulded-multilayer product (2) is for use in medicine.

[0022] In an embodiment, the three-dimensional porous moulded-multilayer product (2) is for use in bone implants.

[0023] In an embodiment, it is described the use of the three-dimensional porous moulded-multilayer product (2) is as a fluid filter, catalytic converter, heat exchanger, or heat sink.

[0024] It is also disclosed a mould for the moulded layer module (1) according to any one of the previous embodiments comprising the inverse features for obtaining said moulded layer module (1) features.

[0025] It is also disclosed a method for producing a three-dimensional porous moulded-multilayer product (2) comprising the steps of:

- a. moulding a plurality of moulded layer modules (1) according to any of the previously described;
- b. assembling said plurality of moulded layer modules (1) in a stack.

[0026] In an embodiment, the moulding of the moulded layer module (1) comprises powder injection moulding, thermoplastic injection moulding, powder pressing or machining, or combinations thereof.

[0027] In an embodiment, the assembling of the moulded layer modules (1) comprises applying rigid junctions, screws, spikes, rivets or snap fits, sintering, welding, ultrasonic welding, or combinations thereof.

[0028] In an embodiment, the method further comprises, in the moulding step of the moulded layer modules (1), moulding with a binder, and further comprising, before or during the assembly step, removing said binder, in particular thermally removing said binder during the assembly operation, said assembly operation by sintering.

[0029] In an embodiment, said binder is polymeric and the removal of said binder is thermal, catalytic or by solubility.

[0030] The disclosure relates to the production of three-dimensional porous structures comprising multiple moulded layer modules with interconnected channels in all 3D substantially axial and/or radial directions. The directions may be orthogonal or may be not orthogonal but with also 3 different directions obtained in a 3D space. The two directions in each layer may be perpendicular or not. The through-holes, when considered from the through-hole axis, may be perpendicular to each layer, may be perpendicular to a part of the layers, or may not be perpendicular to any layer.

[0031] One of the objects of the disclosure is a high porosity three-dimensional multi-layer, or multi-module, device comprising interconnected three-dimensional channels and controlled (geometric and dimensional) cross-sections (constant or variable) obtained by the assembly of several modular parts and the process to produce said device namely for medical, automotive, construction or electronic applications.

[0032] The modular or layer parts can be plastic, metallic, ceramic or any compound comprising some and/or all the cited materials and obtained through moulding techniques, namely powder injection moulding (metallic or ceramic materials), thermoplastic injection, powder pressing or machining techniques.

[0033] The modular or layer parts include design features to allow the assembly alignment (Q11, Q12). These features will guaranty the channel concentricity and, for example, consequent improved biocompatibility in orthopaedic applications.

[0034] The final devices may be assembled by different techniques namely by powder sintering techniques, ultrasonic welding, rigid junctions (screws, spiking, rivets), snap fits in order to obtain multiple product shapes.

[0035] The combination of any of the previous described techniques may also be used.

Brief Description of Drawings

[0036] The following figures provide preferred embodiments for illustrating the description and should not be seen as limiting the scope of invention.

[0037] **Erro! A origem da referência não foi encontrada.:** Schematic representation of the coordinate system which serves as reference for the disclosure.

[0038] **Erro! A origem da referência não foi encontrada.:** Schematic representation of the assembly of three layer modules (1) into an assembled three-dimensional porous structure comprising interconnected channels in all 3D axial directions.

[0039] **Erro! A origem da referência não foi encontrada.:** Schematic representation of a layer module, and respective assembled 3D porous structure comprising interconnected channels in all 3D axial directions, with hexagonal cross-section (Q1).

[0040] **Erro! A origem da referência não foi encontrada.:** Schematic representation of a layer module, and respective assembled 3D porous structure comprising interconnected channels in all 3D axial directions, with square cross-section (Q2). The channel cross-sections are formed 50% in one of the layer module XY surfaces being the other 50% formed through the opposite XY surface of the same layer module.

[0041] **Erro! A origem da referência não foi encontrada.:** Schematic representation of a layer module, and respective assembled 3D porous structure comprising interconnected channels in all 3D cylindrical directions (longitudinal, radial, concentric), with circular cross-section (Q3).

[0042] **Erro! A origem da referência não foi encontrada.:** Schematic representation of a layer module, and respective assembled 3D porous structure comprising interconnected channels in all 3D axial directions, with cross-shaped cross-section (Q4).

[0043] **Erro! A origem da referência não foi encontrada.:** Schematic representation of a layer module, and respective assembled 3D porous structure comprising interconnected channels in all 3D axial directions, with circular cross-section (Q5).

[0044] **Erro! A origem da referência não foi encontrada.:** Schematic representation of a layer module, and respective assembled 3D porous structure comprising interconnected channels in all 3D axial directions, with X-Y square cross-section and non-rectilinear centreline and distorted Z square cross-section and rectilinear centreline (Q6).

[0045] **Erro! A origem da referência não foi encontrada.:** Schematic representation of a layer module, and respective assembled 3D porous structure comprising interconnected channels in all 3D axial directions, with square cross-section and further channels at both 45 degrees relative to the X-Y axis (Q7).

[0046] **Erro! A origem da referência não foi encontrada.:** Schematic representation of a layer module, and respective assembled 3D porous structure comprising interconnected channels in all 3D cylindrical directions (longitudinal, radial, concentric), with circular cross-section which increases towards the longitudinal centre of the assembly (Q8).

[0047] **Fig. 11:** Schematic representation of the moulded-multilayer product (2) with channels slanted along the Z axis. a) The moulded-multilayer module has slanted channels with the Z axis. b) The moulded-multilayer module has channels parallel to the Z axis. In both cases, the channel continuity along the Z axis can be obtained by translations (in the XY plan), rotations (along the Z axis) or both of the previous movements of the different moulded multilayer modules.

[0048] **Fig. 12:** Schematic representation of a layer module and respective assembled 3D porous structure comprising interconnected channels in all 3D axial directions with square cross-sections (Q9). The channel cross-sections are formed 25% in one of the layer module XY surfaces being the other 75% formed through the opposite XY surface of the same layer module.

[0049] **Fig. 13:** Schematic representation of a layer module and respective assembled 3D porous structure comprising interconnected channels in all 3D axial directions with square cross-sections (Q10). The channels cross-sections are formed 100% in one of the layer module XY surface.

[0050] **Fig. 14:** Schematic representation of a layer module and respective 3D porous structure comprising interconnected channels in all 3D axial directions with square cross-sections and XY alignment features (Q11). The channel cross-sections as well as the alignment features are formed 50% in one of the layer module XY surfaces being the other 50% formed through the opposite XY surface of the same layer module.

[0051] **Fig. 15:** Schematic representation of a layer module and respective 3D porous structure comprising interconnected channels in all 3D cylindrical directions (longitudinal, radial, and concentric) with circular cross-sections and XY alignment features (Q12). The channel cross-sections as well as the alignment features are formed 50% in one of the layer module XY surfaces being the other 50% formed through the opposite XY surface of the same layer module.

[0052] The devices represented in each figure are obtained by the replicated use of the respective modules.

[0053] In some embodiments, combinations of different modules may be used to create a complex multi-shape part or device.

[0054] The previous represented devices are fully interconnected. Some embodiments may be partially interconnected to allow for example the creation of customized and precise channels or tracks.

[0055] The represented Figures consider that the channels in the plan defined by the XY axis (surface contact plan between modules) are generally defined 50% in the upper surface and 50% in the bottom surface (upper and lower modules). Nevertheless, some embodiments can be customized in a range from 0% up to 100% (Q9, Q10) in each of the referred surfaces (upper and lower modules). In the case of 100% (Q10) of the channel being in one of the layer module surfaces, then no channel is required on the opposite side of the layer module surface simplifying design and construction. However, if the channel has a convex cross-section, namely circular or hexagonal, it may be preferable to provide part of the channel in both surfaces of the layer module such that ejection from the mould can be facilitated.

[0056] The represented Figures consider the assembly of the several modules only along the Z-axis.

[0057] Some embodiments can also consider the assembly in any direction over the plan defined by the XY axis. For example, previously assembled layer modules Q1, Q2 and Q4 may be easily assembled laterally with other similar previously assembled layer modules.

[0058] Slanted assemblies are also possible where the stack assembly angle is not at perpendicular angles to the layer surfaces of the layer module.

Detailed Description of the Invention

[0059] The disclosure comprises a high porosity three-dimensional multi-layer device comprising interconnected three-dimensional channels and controlled (geometric and dimensional) cross-sections (constant or variable) obtained by the assembly of several modular parts and the processes to produce said device namely for medical, automotive, construction or electronic applications.

[0060] For medical applications, such devices may be used specially as bone implants, taking in consideration the exceptional condition provided by the high exposed area, which will facilitate the bone implant absorption and osteointegration. Moreover the ability to conceive and produce any shape in mass production represents a huge advance in the approach that can be used to setup new standard shapes and models for this field of application.

[0061] In the construction area, such devices may be used as shells in the manufacture of building structural pillars.

[0062] In electronic or electrical applications such devices may be used as cooling units, namely heat sinks or heat exchangers, or fluid distribution boxes, taking advantage of the multichannel ability that is easily obtained with this disclosure.

[0063] In automotive applications such devices may be used as parts for exhaust systems, namely catalytic converters, climatization, namely air or fluid filters.

[0064] The disclosure is generally suited for all applications with the requirement to maximize the exposed area of a material to increase the functionality provided by the surface area, or whenever the internal shape tends to be very complex (like multichannel of variable design) which might limit the final shape design of the parts, due to the production technique constraints.

[0065] The materials to be used can be any mouldable or machined material, namely plastic, metallic, ceramic or any compound comprising some and/or all the cited materials.

[0066] In some embodiments, the material includes one or more of a thermoplastic polymer, a thermoset resin, a ceramic or a metal. Metals or ceramics can be supplied in a polymer matrix solution, namely powder injection moulding feedstock's (market available or customized for any particular use and/or embodiment).

[0067] In some embodiments, the material can include (at least partially, more than half, substantially, or essentially) a biocompatible material such as a bioresorbable polymer or a bioresorbable ceramic. In some of these embodiments, the material may comprise a bio-inert polymer, a bio-inert ceramic, or a bio-inert metallic.

[0068] In some embodiments the material may comprise a heat-conductive material.

[0069] The modular parts produced may have porosity (% of voids / total volume) from 10% up to 90% approximately. In some embodiments, the porosity can be less than 10% or higher than 90%. The porosity mentioned above relates to the spaces created by the channels and through holes of the product modular layer design, regardless of (or non conditioned by) the intrinsic porosity of the raw material used on for device production.

[0070] Channels in the structure may take any cross-sectional forms or shapes. Said channels may be squared, circular, triangular, trapezoidal or any other free form shapes resulting from the combination of the previous ones. Examples of possible combinations are represented in the figures. In some embodiments, it is advantageous if the cross-sectional shape is the same for channels formed by the recesses in the surface of the layer modules as the cross-sectional shape of the through-holes of the layer modules.

[0071] One, some, substantially all, or essentially all of the channels created in the structure may have a cross-sectional area of at least about 0.001mm², up to about 100mm². In some embodiments, the cross-sectional area may be less than 0.001 mm², or greater than 100mm².

[0072] Depending on the embodiment, the channels may have a cross-sectional area of at least about 0.002 square millimetres, at least about 0.01 square millimetres, at least about 0.25 square millimetres, at least about 0.5 square millimetres, at least about 1 square millimetre, at least about 2.25 square millimetre, at least about 4 square millimetre, at least about 9 square millimetre, at least about 16 square millimetre, at least about 25 square millimetre, up to about 100 square millimetres, up to about 25 square millimetre, up to about 16 square millimetres, up to about 9 square millimetres, up to about 4 square millimetre, up to about 2.25 square millimetre, up to about 1 square millimetre, up to about 0.5 square millimetre, up to about 0.25 square millimetre, and/or up to about 0.01 square millimetre. In some embodiments, the cross-sectional area may be less than 0.002 square millimetres or greater than 100 square millimetres.

[0073] Depending on the embodiment, the channels may have a cross-sectional diameter (i.e. the average length between internal sides of a pore measured from a two-dimensional cross-section of the pore, the cross-section being perpendicular to the direction in which the pore extends) of up to about 7 mm, up to about 4 mm, up to about 3 mm, up to about 2 mm, up to about 1500 microns, up to about 800 microns, up to about 400 microns, up to about 200 microns, up to about 150 microns, up to about 125 microns, up to about 100 microns, up to about 80 microns, up to about 50 microns, at least about 20 microns, at least about 50 microns, at least about 100 microns, at least about 150 microns, at least about 200 microns, at least about 300 microns, at least about 400 microns, at least about 600 microns, at least about 1 mm, and/or at least about 2 mm.

[0074] In some embodiments, for example in osteointegration embodiments, being able to define the channel dimensions is of particular interest.

[0075] In some embodiments, the cross section can assume a non-uniform diameter. In these cases, the average cross-sectional diameter can be measured, for example, by picking a point in the centre of the channel and measuring (and averaging) the length of a line extending between internal sides of the channel at different angles, say every 5 degrees (i.e. rotating the lines by 5 degrees for on every measurement).

[0076] In some embodiments, the width of the channels may vary within the same structure, as it is not necessary that these have all the same diameter or cross-sectional area. In an embodiment, at least 70% of the channels that are larger than the average channel size of the structure, have a cross-sectional area that is less than 10 times the average channel size of the structure.

[0077] The channels, aligned with the Z-axis (**Erro! A origem da referência não foi encontrada. - Erro! A origem da referência não foi encontrada.**), follow a straight path in some embodiments. However, the Z-axis channels or through-holes of the layer module can have up to 45° with the Z-axis (**Erro! A origem da referência não foi encontrada.A**), an angle advantageous for moulding, or even more in some embodiments. Alternatively or additionally, each subsequent layer module can be slightly shifted (**Erro! A origem da referência não foi encontrada.B**) such that a similar effect is obtained of angled Z-axis channels. This shift can be translational (for example for the layer modules Q1 or Q2 of **Erro! A origem da referência não foi encontrada. - Erro! A origem da referência não foi encontrada.**) or rotational (for example for the layer modules Q3 or Q8 of **Erro! A origem da referência não foi encontrada. or Erro! A origem da referência não foi encontrada.**), or even both.

[0078] In some embodiments, when the layers are offset in any of the described approaches, the channels in both surfaces parallel to the XY plane, may have at least 10%, and up to 90% of the cross section overlapping between adjacent layers. In some embodiments, there will be a compromise – larger offsets between layers means the channels will be more tilted but, at the same time, there will be less continuity in the channels between subsequent layers and, conversely, the inverse.

[0079] The techniques suitable for obtaining the final product shapes can be any industrial technique that allows the joining and/or consolidation of materials, namely: Ultrasonic Welding; Rigid junctions (screws, spiking, rivets, etc...); Snap Fits; Sintering; Thermal fusion; or any other connection techniques suitable for the raw materials in use. It can be noted that minimizing the number of layer joints is relevant in order to minimize the probability of structural faults and layer adhesion issues. These

shortcomings can be mitigated by reducing the number of layer joints or, also, by increasing the contact area being joined between layers.

[0080] The combination of any of the previous described techniques may also be used.

[0081] In some embodiments, before or after performing the assembly operations, the parts may be submitted to a coating, thermal treatment and/or chemical treatment in order to improve functional and/or decorative performance.

[0082] The disclosure has advantages: a maximization of porosity with fully controlled channel sections; a controlled porosity by fully controlled channel sections; a modular solution allowing combinations of designs with different materials or even combinations of materials; easiness of mass production; low series cost due to the use of injection moulding technology; low complexity and low cost tools for the use in injection moulding technology. The use of this technology eliminates the need of using complementary operations of de-flashing, avoiding the possible quality problems like chipping.

[0083] Furthermore, by means of interchangeable moulding inserts, whereby the mould comprises an outer frame and interchangeable moulding inserts, the use of the same outer frame for the production of different modules geometries and versions is possible. This characteristic allows the reduction of the set-up costs.

[0084] Also, unique designs are feasible with improved design freedom, as designs previously not feasible in one step productions are possible to be achieved using this solution, namely designs with non linear paths along the XY plan sections, or macro porous parts with interconnected channels in a totally closed outer contour.

[0085] The combination of different design versions allows porosity variations, as well as the achievement of tilted, even parabolic or spiral axis channels (made with several straight sections) along the Z-axis. There is also the possibility to obtain complex 3D shapes with non-straight, irregular or even randomly irregular inner channels, namely along the Z-axis. In some embodiments, the layer modules can simply be stacked in a random way. In some embodiments, the cross-sectional profile of the layer module z-

channels is sufficiently wide that even if randomly stacked at least partial z-channels will form.

[0086] This production process provides stability in the moulding process in particular for complex geometries and thin walled products. General dimensions and shape of the final products can assume many possibilities, which may be subject to machining or other known material manipulation techniques, like drilling, milling, lathing, pressing.

[0087] The above described embodiments are combinable. The following dependent claims set out particular embodiments of the invention.

C L A I M S

1. Three-dimensional porous moulded-multilayer product comprising a stack assembly of a plurality of a moulded layer module , said module comprising:
 - a. a plurality of through-holes between the layer surfaces of said moulded layer module;
 - b. a plurality of longitudinal recesses on at least one of the layer surfaces of said moulded layer module, along at least two different directions, such that when assembled with a layer surface of another moulded layer module longitudinal channels are formed;wherein said through-holes and recess channels are interconnected.
2. Moulded-multilayer product according to the previous claim, wherein the plurality of modules is assembled with all layer faces of said modules positioned in the same direction.
3. Moulded-multilayer product according to any one of the previous claims, wherein said module comprises alignment features on both layer surfaces of said moulded layer module, in particular protrusions and recesses for receiving protrusions, said features being such that, when a module is assembled with another module, a partial or full overlap of said through-holes is obtained.
4. Moulded-multilayer product according to any one of the previous claims obtainable by powder injection moulding, thermoplastic injection moulding, powder pressing or machining, or combinations thereof.
5. Moulded-multilayer product according to any one of the previous claims comprising plastic, thermoplastic polymer, thermoset resin, metal, or ceramic, or combinations thereof.
6. Moulded-multilayer product according to any one of the previous claims comprising bioresorbable polymer, bioresorbable ceramic, bio-inert polymer, bio-

inert ceramic, bio-inert metallic, or heat-conductive material, or combinations thereof.

7. Moulded-multilayer product according to any one of the previous claims wherein the cross-section of the through-holes and longitudinal channels of the moulded layer module is hexagonal, square, circular, and/or cross-shaped.
8. Moulded-multilayer product according to any one of the previous claims wherein the through-holes of the moulded layer module are laid out in a grid, or concentrically, or both in a grid and concentrically.
9. Moulded-multilayer product according to any one of the previous claims wherein the through-holes of the moulded layer module are perpendicular to the layer surfaces of said moulded layer module or are tilted relative to the layer surfaces of said moulded layer module.
10. Moulded-multilayer product according to any of the previous claims wherein the assembly is obtainable by sintering, welding, ultrasonic welding, rigid junctions, screws, spikes, rivets or snap fits, or combinations thereof.
11. Moulded-multilayer product according to any of the previous claims wherein the assembled plurality of moulded layer modules is offset between adjacent moulded layer modules, in particular such that adjacent moulded layer modules are translationally, rotationally or randomly offset, in order that adjacent moulded layer modules through-holes are partially overlapping.
12. Moulded-multilayer product according to any one of the previous claims for use in medicine or in bone implants.
13. Use of the three-dimensional porous moulded-multilayer product according to any one of the previous claims as a fluid filter, catalytic converter, heat exchanger, or heat sink.

14. Mould for the moulded layer module described in any of the claims 1 - 9 comprising the inverse features for obtaining said moulded layer module features.
15. Method for producing a three-dimensional porous moulded-multilayer product comprising the steps of:
 - a. moulding a plurality of moulded layer modules described in any of the claims 1-9;
 - b. assembling said plurality of moulded layer modules in a stack.
16. Method according to the previous claim wherein the moulding of the moulded layer module comprises powder injection moulding, thermoplastic injection moulding, powder pressing or machining, or combinations thereof.
17. Method according to any of the claims 15 - 16 wherein the assembling of the moulded layer modules comprises applying rigid junctions, screws, spikes, rivets or snap fits, sintering, welding, ultrasonic welding, or combinations thereof.
18. Method according to any of the claims 15 - 17 further comprising, in the moulding step of the moulded layer modules, moulding with a binder, and further comprising, before or during the assembly step, removing said binder, in particular thermally removing said binder during the assembly operation, said assembly operation being by sintering.
19. Method according to the previous claim where said binder is polymeric and the removal of said binder is thermal, catalytic or by solubility.

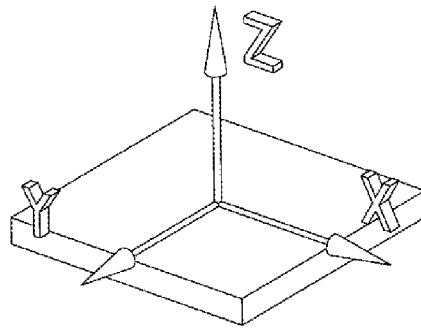


Fig. 1

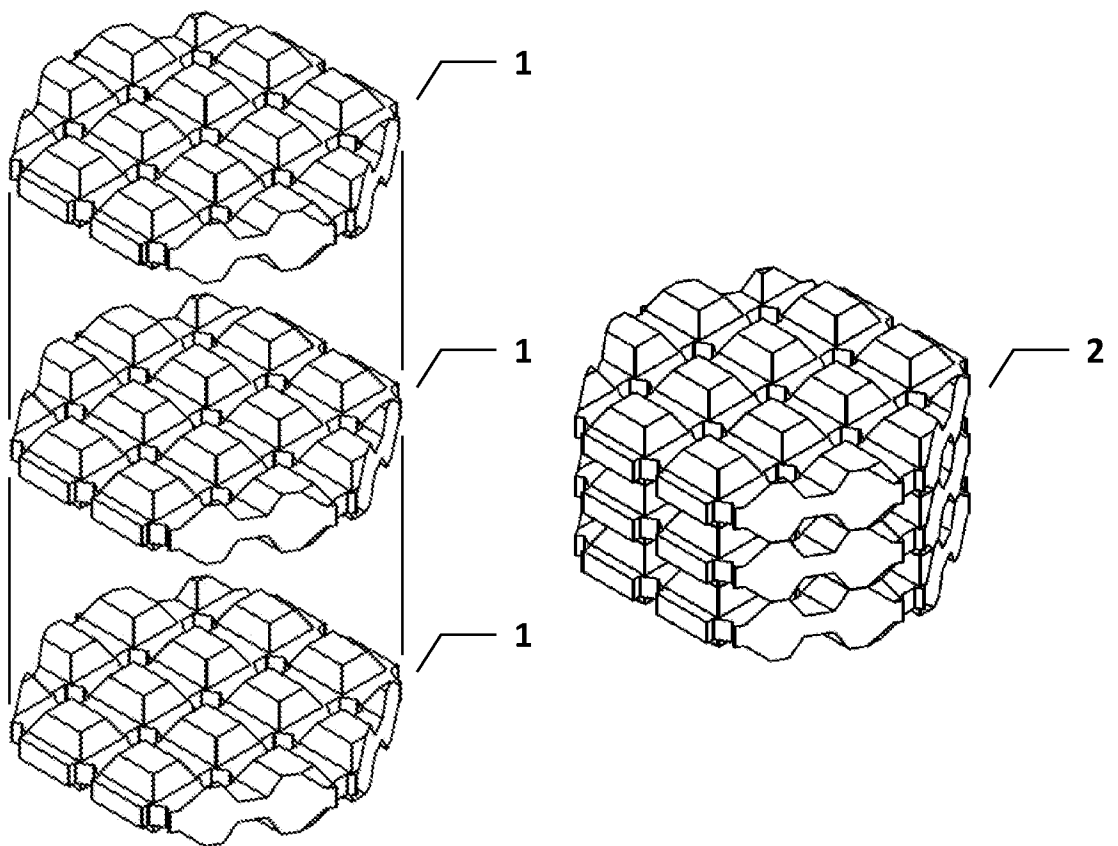


Fig. 2

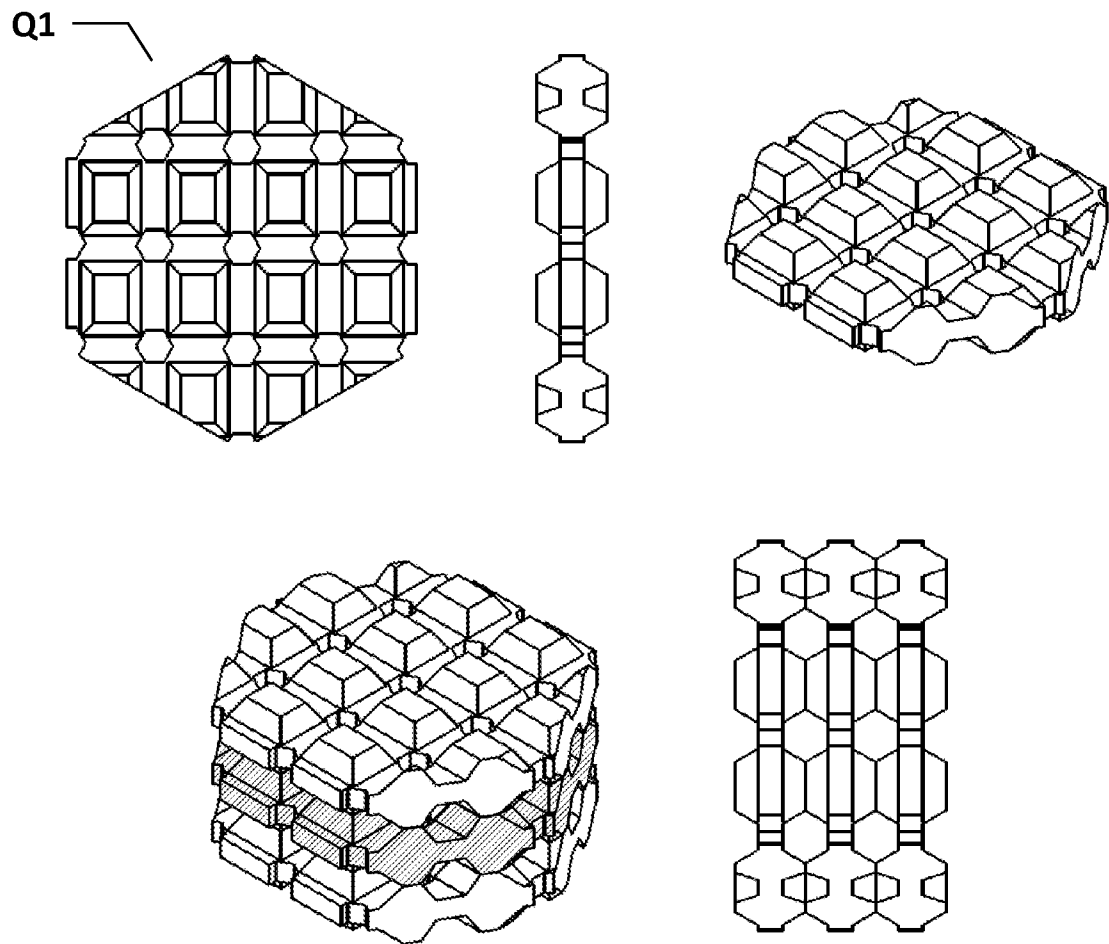


Fig. 3

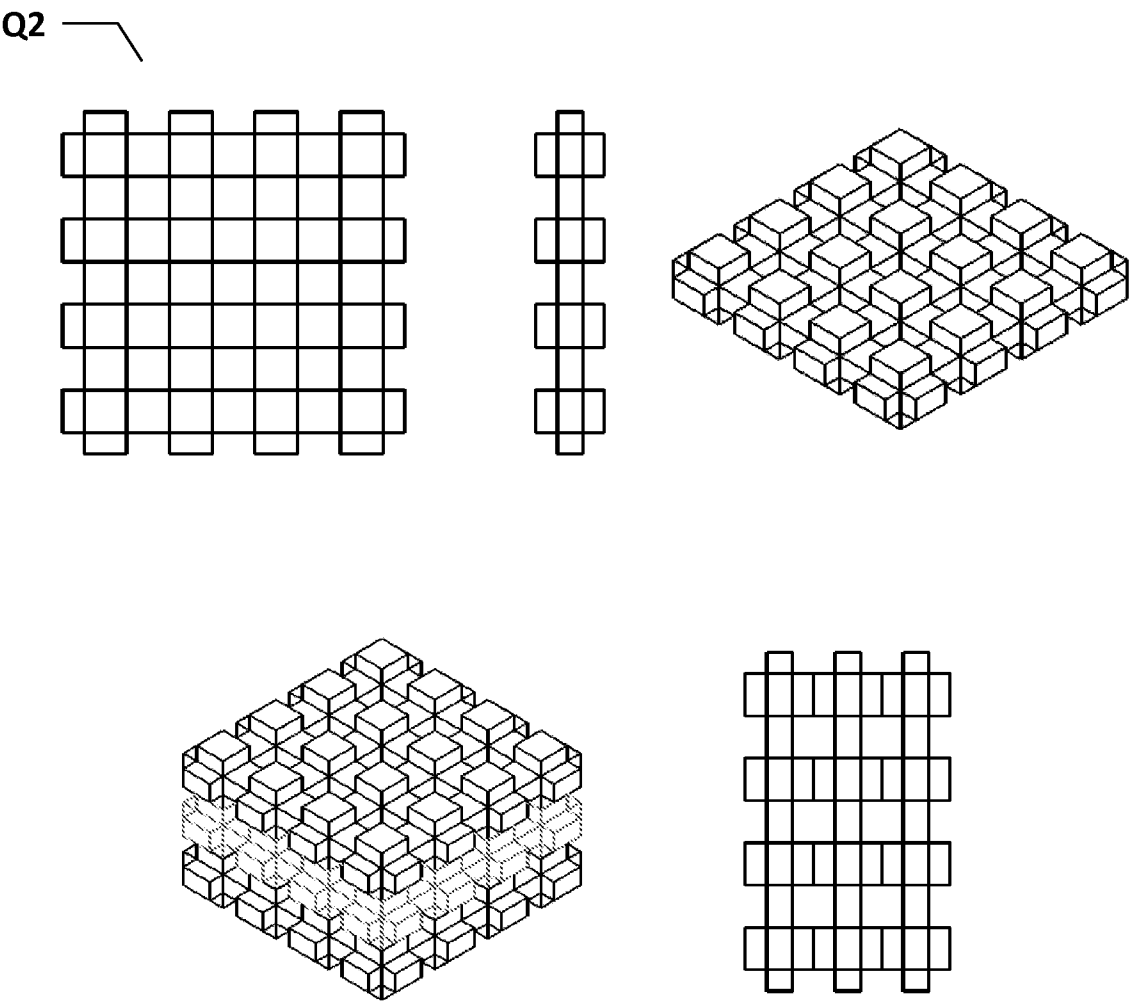


Fig. 4

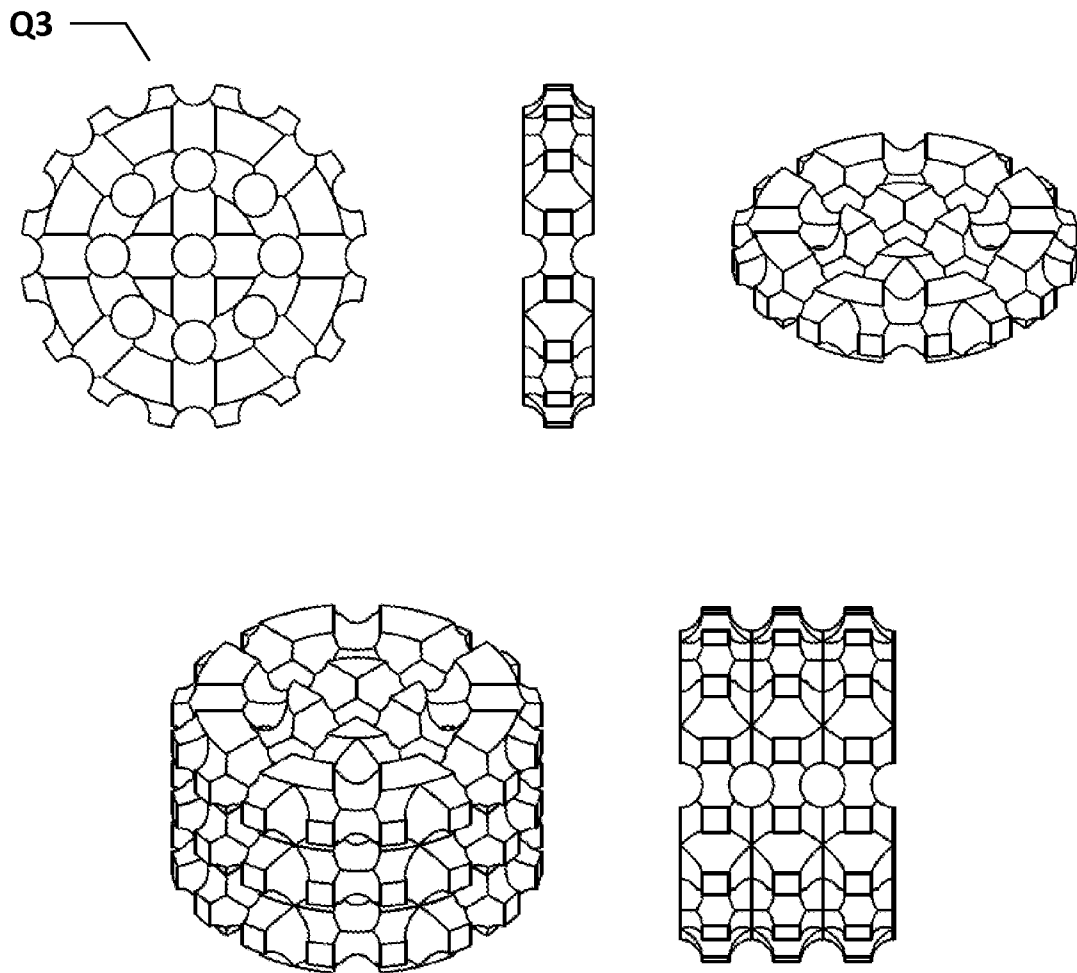


Fig. 5

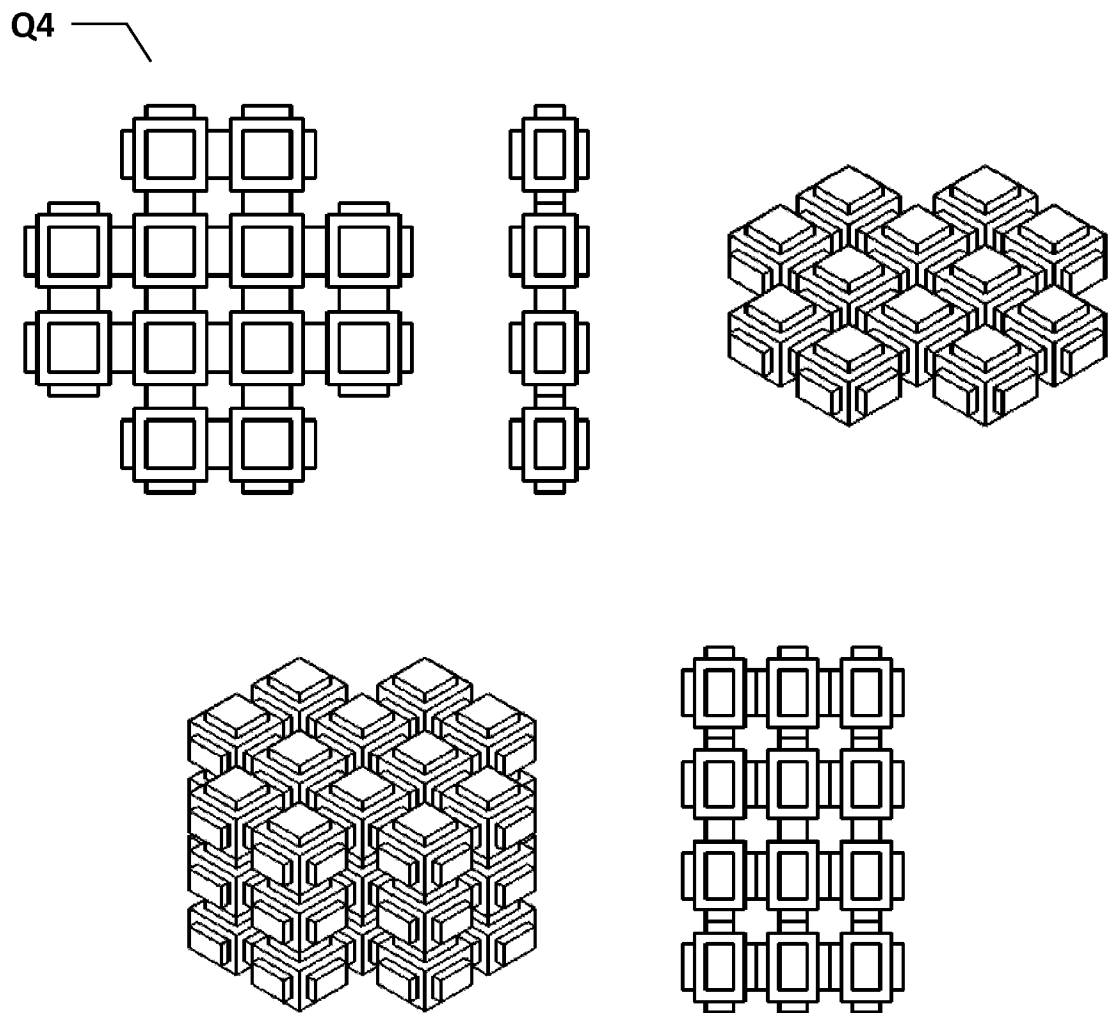


Fig. 6

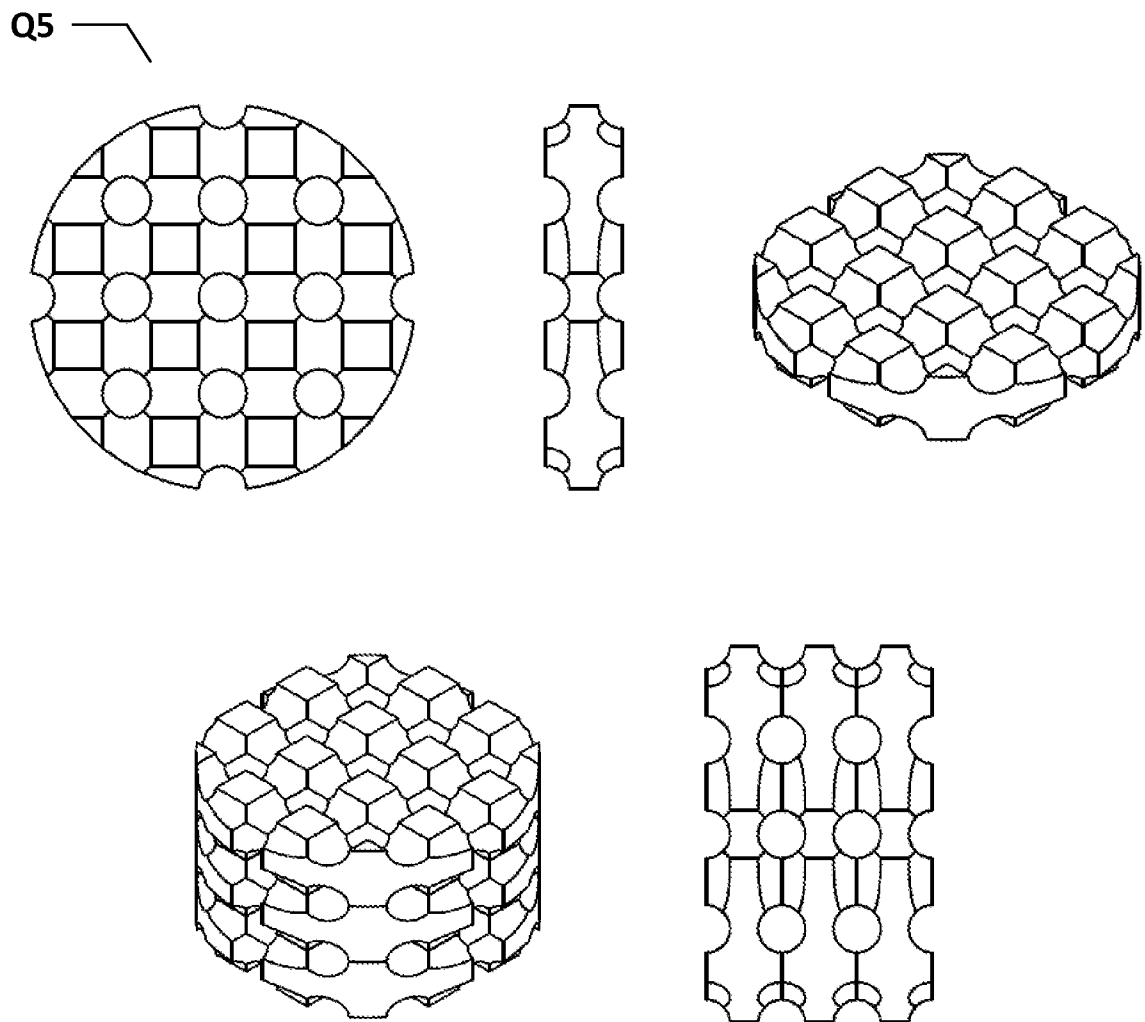


Fig. 7

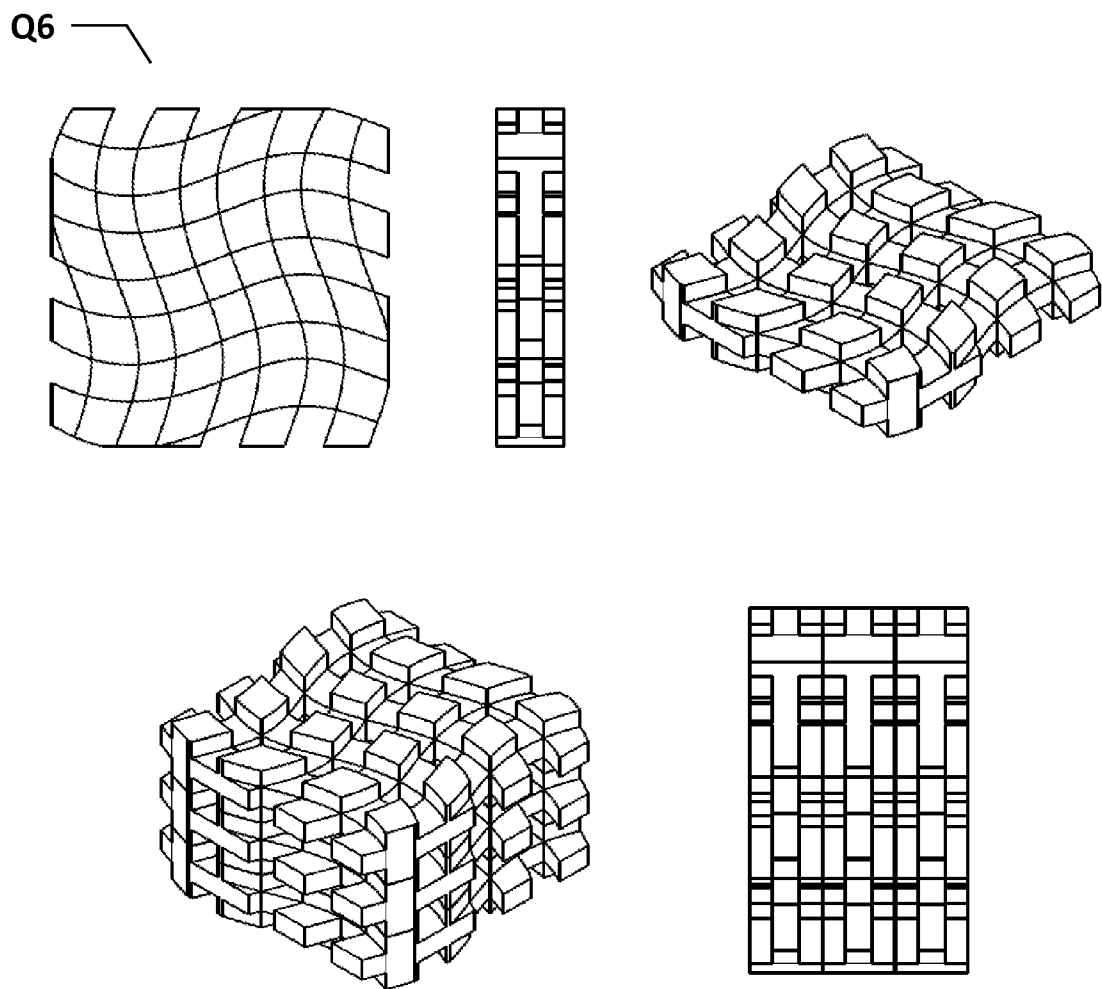


Fig. 8

Q7 

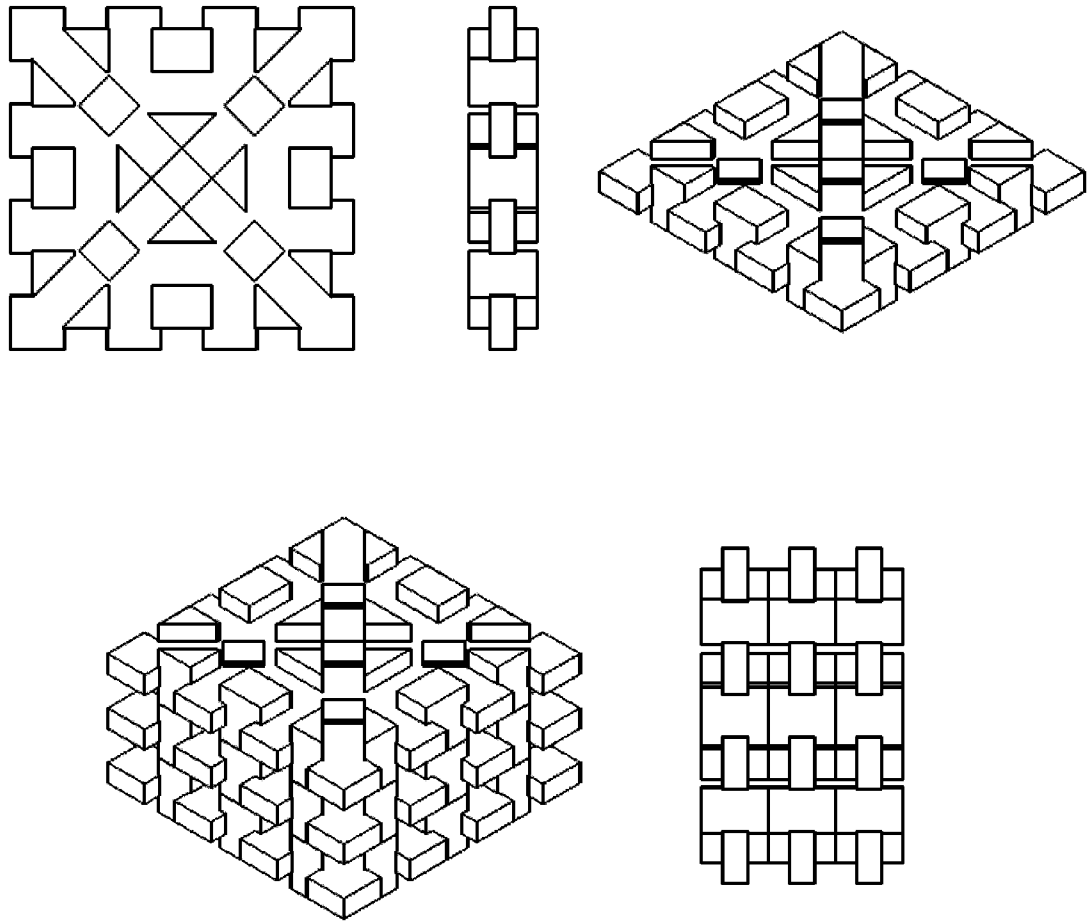


Fig. 9

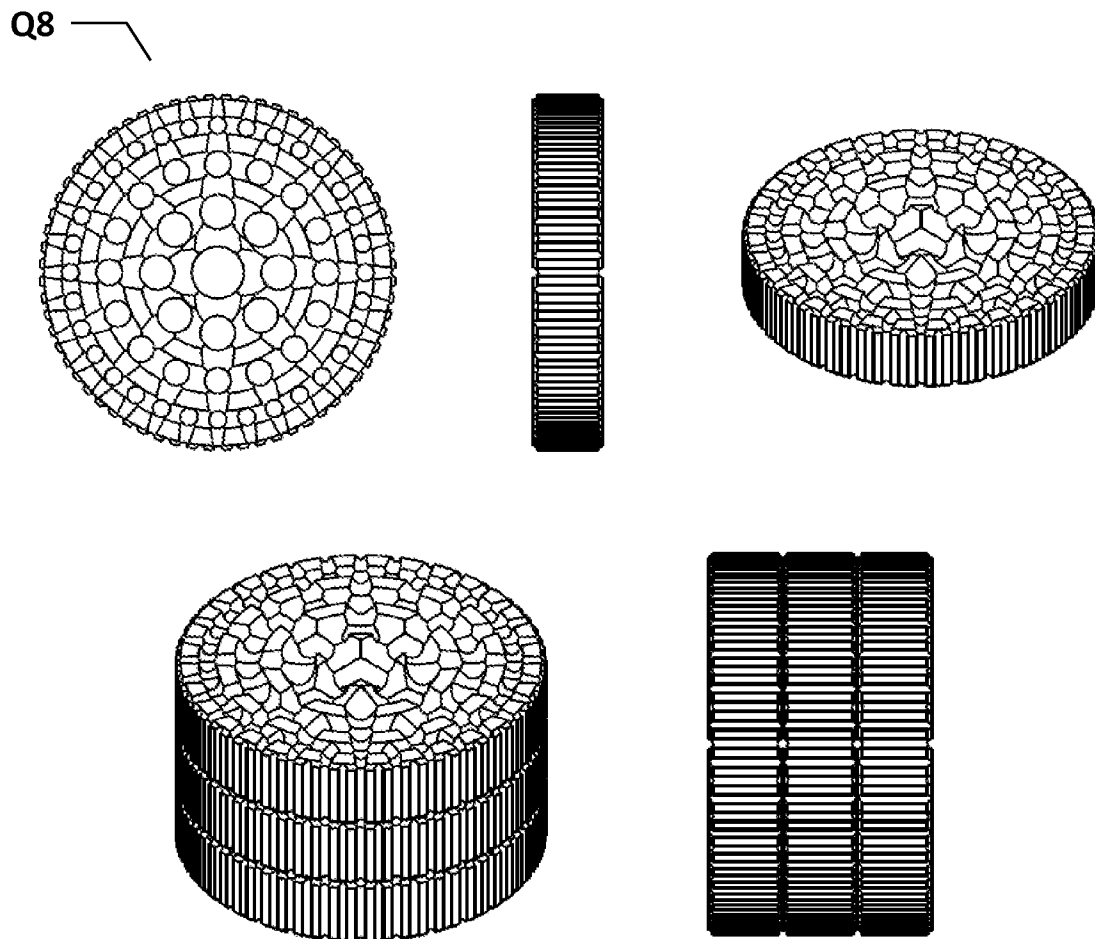


Fig. 10

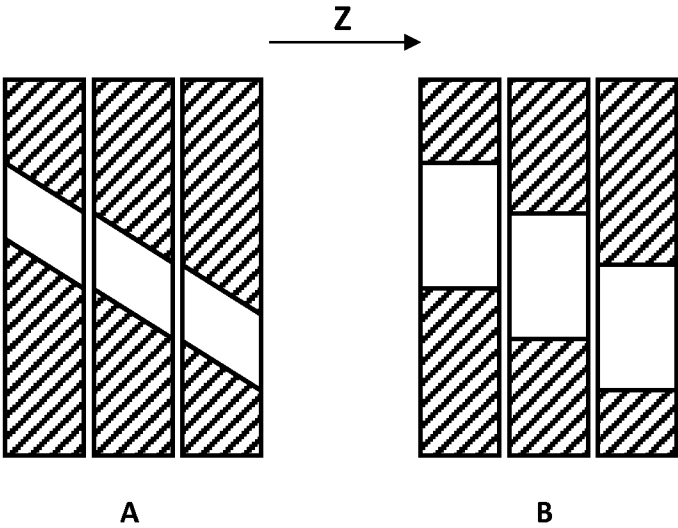


Fig. 11

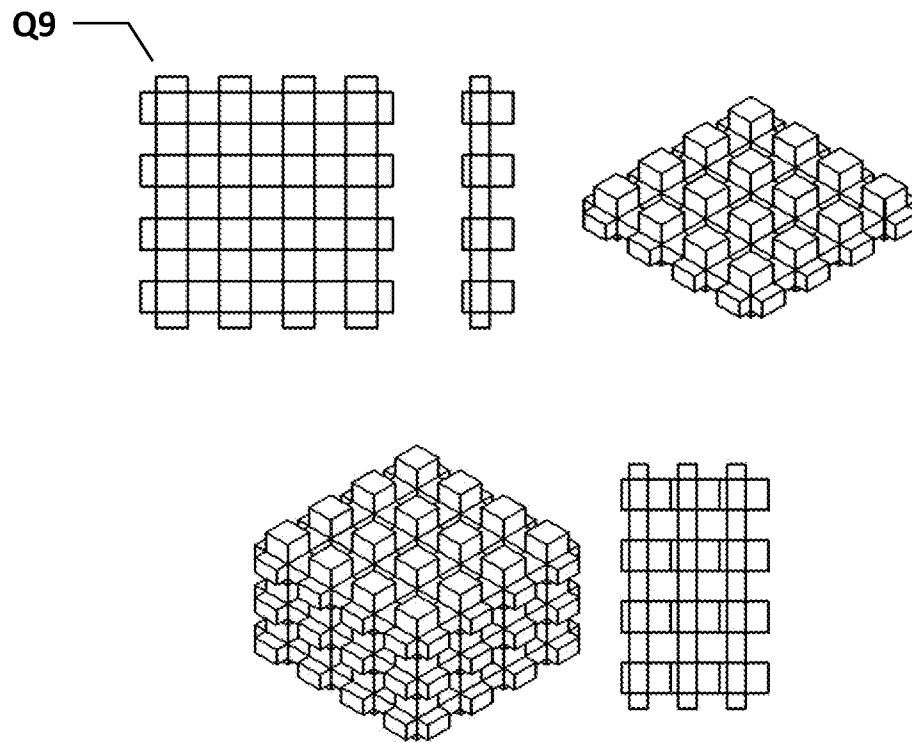


Fig. 12

Q10

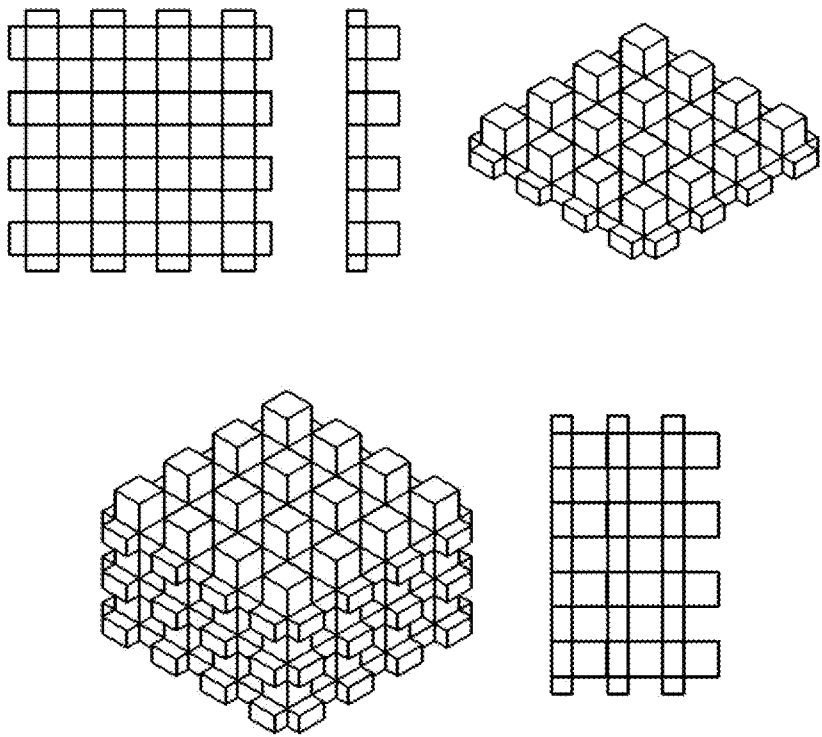


Fig. 13

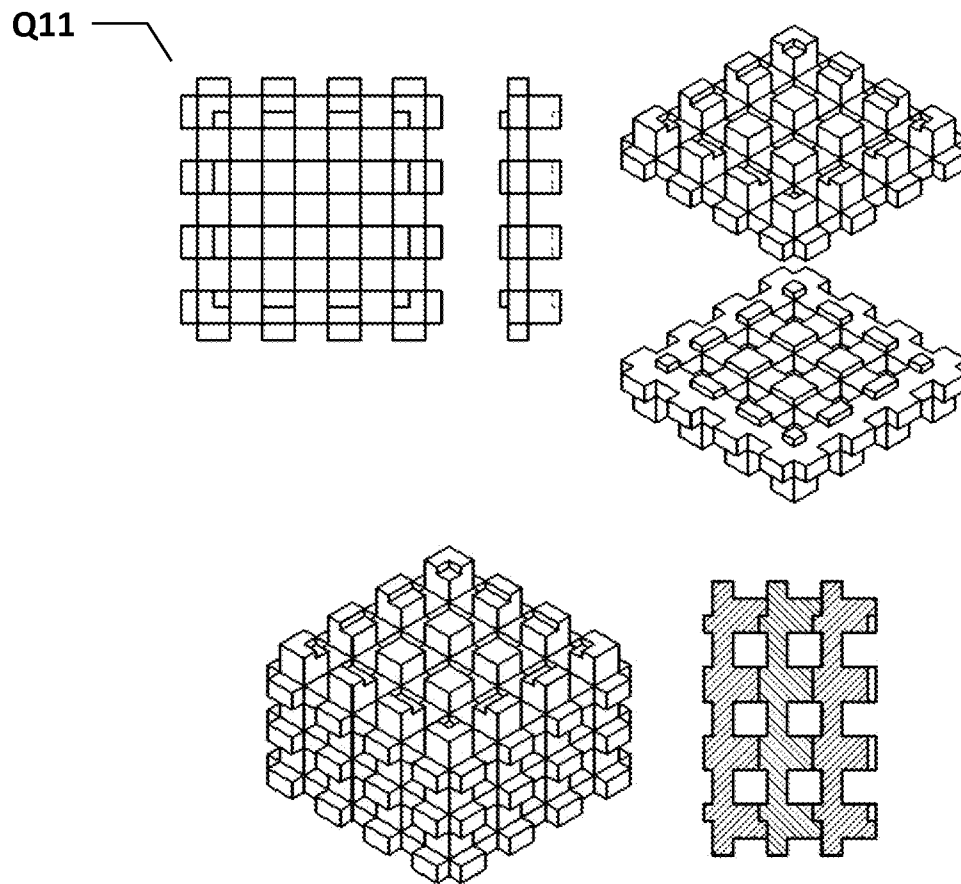


Fig. 14

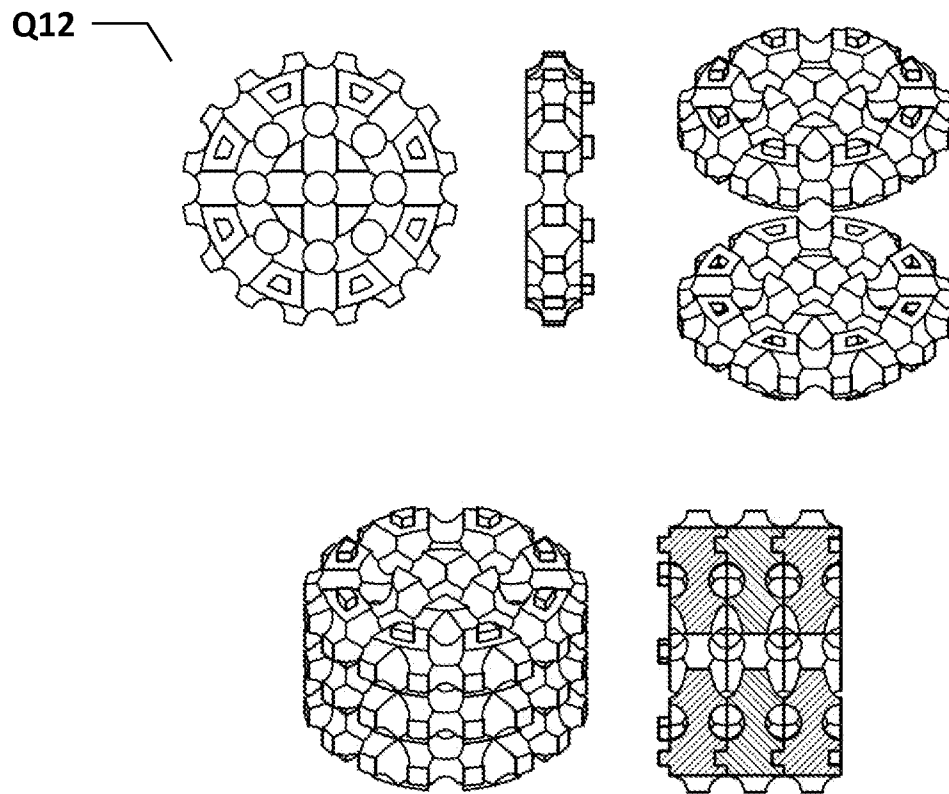


Fig. 15

A. CLASSIFICATION OF SUBJECT MATTER INV. A61F2/28 B29C45/00 F28F13/00 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) A61F F28F B29C		
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	FR 2 580 794 A1 (INST FRANCAIS DU PETROLE [FR]) 24 October 1986 (1986-10-24) page 1, line 1 - line 2 page 12, line 6 - line 14 page 15, line 26 - page 16, line 4 page 21, line 25 - line 28 figures 1-6B	1-19
A	----- US 2006/241776 A1 (BROWN DAVID R [US] ET AL) 26 October 2006 (2006-10-26) paragraph [0044] figures 9A-15 ----- -/-	1-19
☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
* Special categories of cited documents : "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "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 "&" document member of the same patent family		
Date of the actual completion of the international search 17 July 2013	Date of mailing of the international search report 26/07/2013	
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer Bataille, Laurent	

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2009/061127 A1 (ENTEZARIAN MAJID [US] ET AL) 5 March 2009 (2009-03-05) cited in the application paragraph [0037] paragraph [0070] - paragraph [0071] claim 22 figure 7A -----	1-19

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			WO 2009029273 A1 05-03-2009
