



(43) International Publication Date
19 January 2017 (19.01.2017)

(51) International Patent Classification:

F16F 3/02 (2006.01) F16F 9/04 (2006.01)
B29C 67/00 (2017.01)

(21) International Application Number:

PCT/GB2016/052123

(22) International Filing Date:

14 July 2016 (14.07.2016)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

1512470.4 16 July 2015 (16.07.2015) GB

(71) Applicant: UNIVERSITY COLLEGE CARDIFF CONSULTANTS LIMITED [GB/GB]; 7th Floor, 30-36 Newport Road, Cardiff University, Cardiff CF24 0DE (GB).

(72) Inventors: THEOBALD, Peter Simon; 19 Dannog Y Coed, Barry, South Wales CF63 1HF (GB). SOE, Shwe Pyi; 21 Swanage Close, Cardiff, South Wales CF3 0LS (GB).

(74) Agent: WILLIAMS, Rhys; Abel & Imray, 20 Red Lion Street, London WC1R 4PQ (GB).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM,

AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

- with international search report (Art. 21(3))
- before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))

(54) Title: Impact absorbing device and method of producing an impact absorbing device

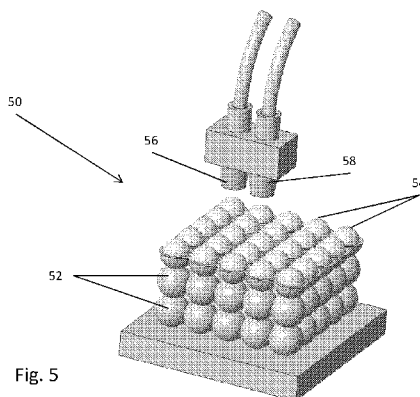


Fig. 5

(57) Abstract: Impact absorbing device and method of producing an impact absorbing device The present invention concerns an impact absorbing device. The impact absorbing device comprises one or more closed cell structures. Each closed cell structure is substantially hollow, and each closed cell structure comprises a plurality of layers of a first material. Each of the plurality of layers of material is fused to an adjacent layer of material. The plurality of layers may be created by a fused deposition modelling technique. The closed cell structures may surround a second, different, material.



Impact absorbing device and method of producing an impact
absorbing device

Field of the Invention

5

The present invention concerns an impact absorbing device. More particularly, but not exclusively, this invention concerns an impact absorbing device and a method of producing an impact absorbing device. The
10 invention also concerns an impact absorbing device produced to conform to a strict set of parameters.

Background of the Invention

15 Impact absorbing devices are often made of cellular materials such as honeycombs, which may be produced using a variety of conventional techniques. Impact absorbing devices may be used for a variety of purposes, for example for personal protection, packaging, and crash
20 protection for vehicles. Techniques of producing impact absorbing devices include production of corrugated cardboard, where an extruded two dimensional honeycomb is sandwiched between two panels.

Other techniques include the use of expandable
25 polystyrene foams which may make up at least part of an impact absorbing device. Foams may be produced as open cell structures or closed cell structures. Open cell structures typically comprise a plurality of struts which deform to absorb impacts, and under deformation air will
30 be pushed out of the open cell structure, with the resistance of the flow of air out of the open cell structure also adding to the impact absorption effect. Closed cell structures include struts and walls, capturing a gas within the wall and strut structure.

Under deformation, cell struts and walls are compressed, as is the gas trapped within the closed cells. The additional compression of the trapped gas may provide a closed cell foam that is capable of absorbing a much greater impact than an open cell foam made of substantially the same material.

Modern three dimensional printing machines, using sintering of powder (laser sintering) or photopolymerisation of resin (stereolithography) have been used to create three dimensional, open cell structures which may be specifically designed to meet a particular set of circumstances, for example the size and shape of the impact absorbing device, and the impact absorption characteristics required. However, these production techniques rely on powder or resin which is not sintered or cured during the production of the impact absorbing device being able to be removed from the device once production is complete. This may typically involve the impact absorbing device being shaken and/or exposed to compressed air or chemicals to remove the unwanted powder or uncured resin. As identified in "The design of impact absorbing structures for additive manufacturing" (Journal of Physics: Conference Series 382 (2012) 012042) "As closed-cell structures cannot be manufactured, the bending of cell walls and compression of trapped air that contribute to energy absorption in closed-cell foams cannot be replicated.. this leaves cell strut bending as the only remaining mechanism for energy absorption in an AM (additive manufacturing) lattice structure."

The present invention seeks to mitigate the above-mentioned problems. Alternatively or additionally, the present invention seeks to provide an improved impact absorbing device and method of producing an impact absorbing device.

Summary of the Invention

The present invention provides, according to a first
5 aspect, an impact absorbing device comprising:

one or more closed cell structures, each closed cell
structure being substantially hollow, wherein each closed
cell structure comprises a plurality of layers of a first
material, wherein each of the plurality of layers of
10 material is fused to an adjacent layer of material, and
each closed cell structure surrounds a second, different,
material.

The second material may be a fluid, for example a
liquid or a gas. The second material may be a solid
15 material. The second material may be chosen to provide
specific impact absorption characteristics.

The first material may be deposited by a first
nozzle, and the second material may be deposited by a
second, different, nozzle.

20 A liquid may be deposited within the closed cell
structure during the manufacturing process by using a
second, temperature controlled, nozzle. The temperature
controlled nozzle may be used to ensure that the second
material is deposited when at a temperature below the
25 melting point of that material, or when at a temperature
below the boiling point of that material. The second
material may be deposited during the layer by layer build
of the closed cell structure. Alternatively, the second
material may be injected into the closed cell structure
30 after the layer by layer build of the closed cell
structure.

Alternatively, the closed cell structure may be
built in a gas chamber flooded with a gas comprising the
second material, such that the gas is inevitably

encapsulated within the closed cell structure.
Alternatively, a gas may be injected into a closed cell structure.

The closed cell structures may surround a second and
5 third material. The second and third materials may be
different to each other, and the first material. For
example a second, solid, material may surround a third,
liquid, material. Combination of a second and third
material in the closed cell structure may allow further
10 tuning of the impact absorption characteristics of the
impact protection device.

Each of the closed cell structures may be the same
shape and size, or vary in shape and size. The closed
cell structures may be any or all of the following
15 shapes: sphere, cube, cuboid, cylinder, hexagonal prism,
cone, pyramid, and triangular prism. The skilled person
will appreciate that these are example shapes only, and
the closed cell structures may be any three dimensional
shape with closed surfaces.

20 The one or more closed cell structures may comprise
a single closed cell structure, the single closed cell
structure comprising a plurality of chambers and channels
between the chambers. The channels may be configured to
allow the flow of fluid from one chamber to an
25 interconnected chamber. The shape and size of the
plurality of chambers and channels may be configured to
provide specific impact absorption characteristics.

The one or more closed cell structures may comprise
a removable plug, such that removing the removable plug
30 from the one or more closed cell structures provides an
opening in the cell structure. Such an arrangement may
allow the impact absorbing device to be collapsed or
reduced in size, by removing the removable plug and
compressing the impact absorbing device. As the impact

absorbing device is compressed, the second material, may be pushed out of the impact protection device, with the resulting reduction in volume of the device. This may be advantageous when providing personal protective

5 equipment, such as cycle helmets. The removable plug may be reinserted to the impact absorption device once compressed to maintain the device in the compressed state. Removing the removable plug again may allow the impact absorption device to return to the uncompressed
10 state, whereby the removable plug is reinserted into the impact absorption device.

The plurality of layers of the first material may comprise layers of materials produced by fused deposition modelling (FDM). Fused deposition modelling comprises a
15 technique of precise filament, layer by layer, fabrication of a three dimensional article. Typically, fused deposition modelling comprises a small, temperature controlled, extruder forcing out a thermoplastic filament material, and depositing the thermoplastic filament
20 material onto a platform in a layer by layer process. Fused deposition modelling has the advantage of being able to process polymers, such as production grade thermoplastics, including ABS, PC, PPSU, and Nylon. Alternative materials may be low melting point alloys,
25 such as zinc alloys, or Gallium alloys. Other alternative materials may be composite materials, such as carbon fibre, glass fibre, powder-filled materials, or ceramic filled materials. Other alternative materials may be shape memory materials and/or foams. The second
30 material may also be deposited using the FDM technique. Therefore, fused deposition modelling provides a method of producing impact absorbing devices which are functional and stable over time. The impact absorption device may comprise a plurality of materials. According

to a second aspect, the invention provides a method of producing an impact absorbing device, the method comprising the steps of:

depositing a first layer of filament material,

5 depositing a second layer of filament material on the first layer of filament material,

depositing one or more layers of a second material, the second material being different to the filament material,

10 depositing further layers of filament material on top of previously laid layers of filament material, such that one or more closed cell structures are created surrounding the second material.

The second material may, for example, be a fluid
15 material located in the closed cell structures. The fluid may be chosen to optimise the impact absorbing characteristics of the impact absorbing device. Alternatively, the second material may, for example, be a solid material.

20 A liquid may be deposited within the closed cell structure during the manufacturing process by using a second, temperature controlled, nozzle. The temperature controlled nozzle may be used to ensure that the second material is deposited when at a temperature below the
25 melting point of that material, or when at a temperature below the boiling point of that material. The second material may be deposited during the layer by layer build of the closed cell structure. Alternatively, the second material may be injected into the closed cell structure
30 after the layer by layer build of the closed cell structure.

Alternatively, the closed cell structure may be built in a gas chamber flooded with a gas comprising the second material, such that the gas is inevitably

encapsulated within the closed cell structure.
Alternatively, a gas may be injected into a closed cell structure.

5 The inventor has realised that applying the fused deposition modelling technique to a method of producing impact absorbing devices allows impact protection devices to be produced, with closed cell structures, and all of the advantages provided by provision of closed cell
10 structures, together with the advantage of being able to tune the impact absorption characteristics of the impact protection device with the choice of the second material, which is surrounded by the closed cell structure.

 The impact absorbing device may be an automotive
15 component. For example, the impact absorbing device may be an impact absorbing panel in a vehicle.

 The impact absorbing device may be an aerospace component. For example, the impact absorbing device may be an impact absorbing panel in an aircraft.

20 The impact absorbing device may be a personal protection device. For example, the impact absorbing device may be a sports protection device, such as a shin pad or shoulder pad, a helmet, or similar protection devices.

25 An advantage of producing an impact absorbing device using fused deposition modelling is that one-off pieces may be produced relatively economically. For example, a personal protection device, for example a shin pad or shoulder pad, may be produced to specifically conform to
30 a particular athlete. Production techniques such as foam extrusion, are less easily adapted for one-off production.

 The method may comprise the step of creating a three dimensional computer model of the impact absorbing

device. The method may comprise the step of depositing layers of filament material using a computer controlled extruder. The computer controlled extruder may be associated with a computer control unit. The method may
5 comprise the step of loading the three dimensional computer model of the impact absorbing device into the computer control unit. In an alternative embodiment, the method may comprise the step of creating the three dimensional model using the computer control unit. The
10 computer control unit may analyse the three dimensional model in order to create a series of instructions for the computer controlled extruder. In alternative embodiments of the invention, the three dimensional model of the impact absorbing device may be converted into a series of
15 extruder instructions by a separate computer, and loaded onto the computer control unit of the extruder as a separate step.

It will of course be appreciated that features described in relation to one aspect of the present
20 invention may be incorporated into other aspects of the present invention. For example, the method of the invention may incorporate any of the features described with reference to the apparatus of the invention and *vice versa*.

25

Description of the Drawings

Embodiments of the present invention will now be described by way of example only with reference to the
30 accompanying schematic drawings of which:

Figure 1 shows an impact absorbing device according to a first embodiment of the invention;

Figure 2 shows a series of method steps according to a second embodiment of the invention;

Figure 3 shows a system for producing impact absorbing devices according to a third embodiment of the invention;

Figure 4 shows an impact absorbing device according to a fourth embodiment of the invention; and

Figure 5 shows a system for producing impact protection devices according to a fifth embodiment of the invention.

Detailed Description

Figure 1 shows a section of an impact absorbing device 10 according to a first embodiment of the invention. The impact absorbing device 10 comprises a plurality of hollow spheres 12 which have been formed using fused deposition modelling. Loads applied to the impact absorbing device 10 will deform the cell walls of the hollow spheres 12 and also compress the gas which is trapped within the spheres 12, thereby at least partially absorbing the energy of the impact.

Figure 2 is a flowchart showing a method of creating an impact absorbing device according to a second embodiment of the invention. The method comprises the initial step 20 of creating a three dimensional computer model of the desired impact absorbing device. This step may, for example, include performing a three dimensional scan or analysis of the object to which the impact absorbing device is to be applied. For a sports protection device, this may comprise taking measurements of the body of an athlete so that the sports protection device fits them with high level of accuracy. This step of creating a three dimensional computer model may also

comprise the step of analysing the impact absorbing properties that the impact absorbing device is required to have. This may determine the size and arrangement of the closed cell structures which make up the impact
5 absorbing device, and/or the materials which are used to make the impact absorbing device.

The next step 22 comprises converting the three dimensional model into a series of instructions to be transmitted to computer controlled filament extruders.
10 This step may be carried out by a conversion engine on a computer separate to the computer controlling the filament extruders, or the computer controlling the filament extruders may also provide this function. If done on a separate computer, the instructions are then
15 transmitted to the computer controlling the filament extruders at step 24, or if the computer used to convert the three dimensional model into a series of instructions is the same as controlling the filament extruders, this step is unnecessary.

20 The computer controlled filament extruders are then controlled, as indicated by step 26, according to the series of instructions such that a plurality of filament layers are extruded, one on top of another, such that a plurality of closed cell structures are created according
25 to the design of the impact absorbing device, with the closed cell structures surrounding a second, different material.

Figure 3 shows an example of a fused deposition modelling manufacturing set up for producing impact
30 absorbing devices according to an embodiment of the invention. A computer controlled extrusion device 34 is arranged to extrude, and deposit in layers, a thermoplastic filament. As described above, a three dimensional computer model of the desired impact

absorbing device is created, in this case by the modelling unit 30. The modelling unit 30 sends the three dimensional model to a control computer unit 32, which translates the three dimensional computer model into a series of commands for the computer controlled extrusion device 34, such that the model may be made up of a series of layers of filament laid on top of each other. The computer controlled extrusion device 34 is located within a frame 36, with mechanical arrangements (not shown to improve clarity) configured to move the computer controlled extrusion device 34, such that the instructions from the control computer unit 32 are carried out, and an impact absorbing device 38 is created. The closed cell structures of the impact absorbing device 38 may be filled with a second material, for example a liquid or gas, by injection through the layers of the extruded thermoplastic material. Alternatively, the closed cell structures may be filled with a second material, for example a solid material, by extruding the second material in conjunction with the extrusion of the first material.

Figure 4 shows cut away view of an impact absorption device 40 comprising a single closed cell, the single closed cell comprising a plurality of chambers 42, wherein each chamber 42 is in fluid communication with one or more other chambers via a plurality of channels 44. When the impact absorption device 40 is compressed, fluid may flow between the chambers 42 via the channels 44. The size and shape of the chambers 42 and the channels 44 may be configured to provide the desired impact absorption characteristics. Such characteristics may include controlling the shape of the impact absorption device as it deforms, for example to direct an impact in a particular way. Alternatively or

additionally, the impact absorbing device may be configured to tune the rate at which energy is dissipated under impact.

Figure 5 shows an impact protection device 50, which
5 comprises a plurality of closed cells 52, each of the closed cells 52 made of a first material. Each of the closed cells 52 is also filled with a second, fluid, material 54. The first material is extruded by a extruder head 56, and the second material is extruded, or
10 deposited, by a second extruder head 58. The first material may be a standard filament material used in fused deposition modelling. The second material may be a non-Newtonian, shear thickening, fluid. Whilst the present invention has been described and illustrated with
15 reference to particular embodiments, it will be appreciated by those of ordinary skill in the art that the invention lends itself to many different variations not specifically illustrated herein. By way of example only, certain possible variations will now be described.

20 The present invention has been described with a single filament material being used to create the impact absorbing device. The fused deposition material technique is equally applicable to the provision of two or more computer controlled extruders, each extruder
25 extruding a different filament material. Therefore, impact absorbing devices comprising two or more different filament materials may be created, further increasing the possibility of creating highly specific impact absorption properties though the use of the different material
30 characteristics.

The closed cell structures of the impact protection device may surround a gas material chosen to have specific characteristics. The gas material may be incorporated within the closed cell structures by

completing the method of filament laying within a gas chamber filled with the desired gas. Alternatively, materials may be deposited within the closed cell structures by the use of temperature controlled nozzles, the temperature controlled to keep the second material below the melting, or boiling point of that material as required.

Example embodiments of the impact absorbing devices have included personal protection devices, automotive, and aerospace applications. However, many other types of device may be created providing the same advantages as detailed above. For example, the method may be used to produce impact absorbing devices for protection against ballistics, where improved impact absorption characteristics may allow a lighter, more wearable, or more discrete, impact absorbing devices to be produced. Additionally, the invention may be applicable in the field of microfluidics. An alternative sport related embodiment of the invention may comprise a sole of a shoe.

Where in the foregoing description, integers or elements are mentioned which have known, obvious or foreseeable equivalents, then such equivalents are herein incorporated as if individually set forth. Reference should be made to the claims for determining the true scope of the present invention, which should be construed so as to encompass any such equivalents. It will also be appreciated by the reader that integers or features of the invention that are described as preferable, advantageous, convenient or the like are optional and do not limit the scope of the independent claims. Moreover, it is to be understood that such optional integers or features, whilst of possible benefit in some embodiments

of the invention, may not be desirable, and may therefore be absent, in other embodiments.

Claims

1. An impact absorbing device comprising:
one or more closed cell structures, each closed cell
5 structure being substantially hollow, and wherein each
closed cell structure comprises a plurality of layers of
a first material, and wherein each of the plurality of
layers of material is fused to an adjacent layer of
material, and each closed cell structure surrounds a
10 second, different, material.
2. An impact protection device as claimed in claim 1,
wherein the second material is a fluid.
- 15 3. An impact protection device as claimed in claim 1 or
2, wherein the second material is a gas.
4. An impact protection device as claimed in claim 1 or
claim 2, wherein the second material is a liquid.
20
5. An impact protection device as claimed in claim 1,
wherein the second material is a solid.
6. An impact absorbing device as claimed in any
25 preceding claim, wherein the impact absorbing device is a
personal protection device.
7. An impact absorbing device as claimed in any
preceding claim, wherein the impact absorbing device is
30 an automotive component.
8. An impact absorbing device as claimed in any
preceding claim, wherein the impact absorbing device is
an aerospace component.

9. An impact absorbing device as claimed in any preceding claim, wherein the one or more closed cell structures is a single cell structure comprising a plurality of chambers connected by a plurality of channels between the chambers.

10. An impact absorbing device as claimed in any preceding claim, comprising a plurality of closed cells with approximately the same shape and size.

11. An impact absorbing device as claimed in any of claims 1 to 9, comprising a plurality of closed cells with different shapes and/or sizes.

12. An impact absorbing device as claimed in any preceding claim, wherein the filament material comprises a production grade thermoplastic.

13. A method of producing an impact absorbing device, the method comprising the steps of:

depositing a first layer of filament material,

depositing a second layer of filament material on the first layer of filament material,

depositing one or more layers of a second material, the second material being different to the filament material,

continuing to deposit further layers of filament material on top of previously laid layers of filament material, such that one or more closed cell structures are created surrounding the second material.

14. A method according to claim 13, further comprising the step of creating a three dimensional model of the impact absorbing device.

5 15. A method according to claim 13 or claim 14, further comprising the step of depositing layers of filament material using a computer controlled extruder.

16. A method according to any of claims 13 to 15,
10 wherein the step of depositing one or more layers of a second material comprises depositing a liquid using a temperature controlled nozzle.

17. A method of producing an impact absorbing device,
15 the method comprising the steps of:

depositing a first layer of filament material within a gas chamber, the gas chamber being filled with a gas which differs from the surrounding air,

20 depositing a second layer of filament material on the first layer of filament material,

continuing to deposit further layers of filament material on top of previously laid layers of filament material, such that one or more closed cell structures are created filled with the gas which differs from the
25 surrounding air.

1/5

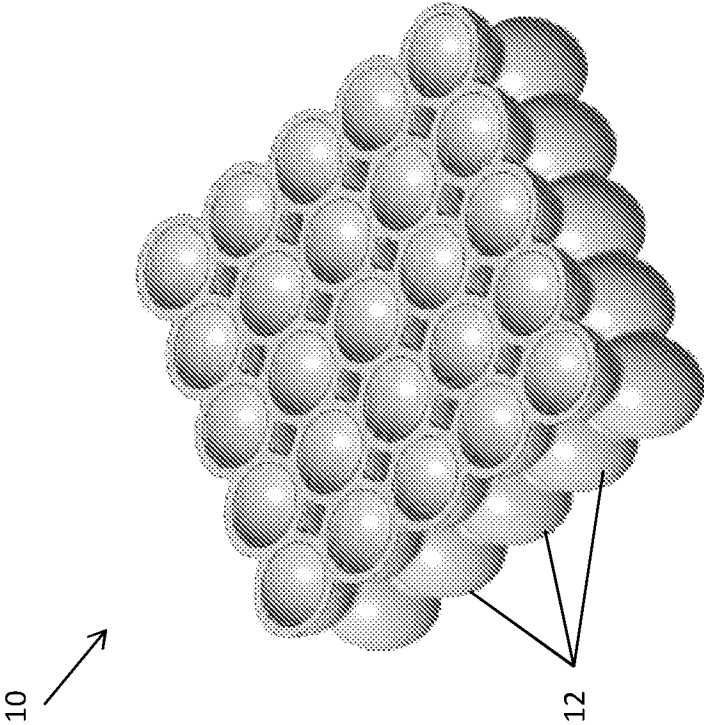


Fig. 1

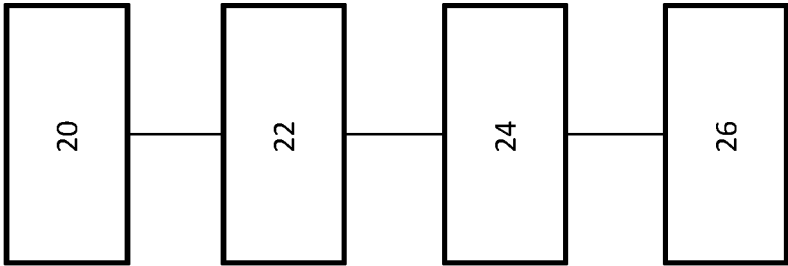


Fig. 2

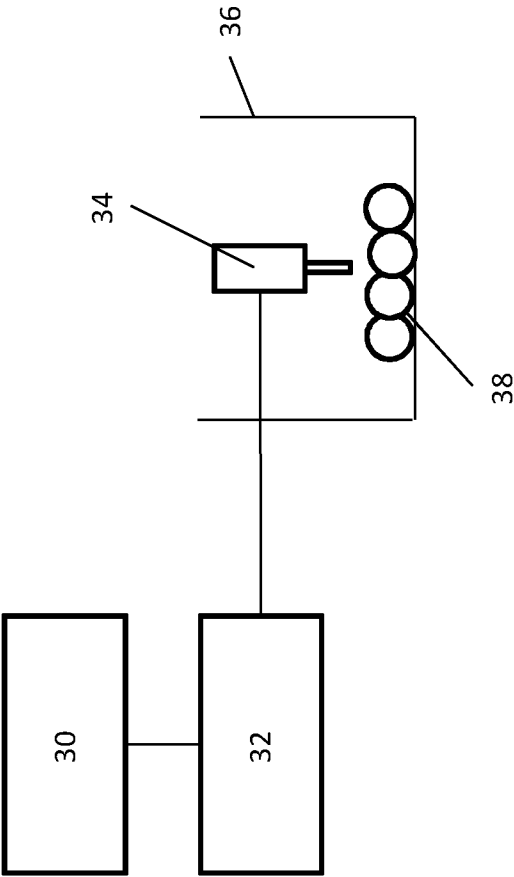


Fig. 3

4/5

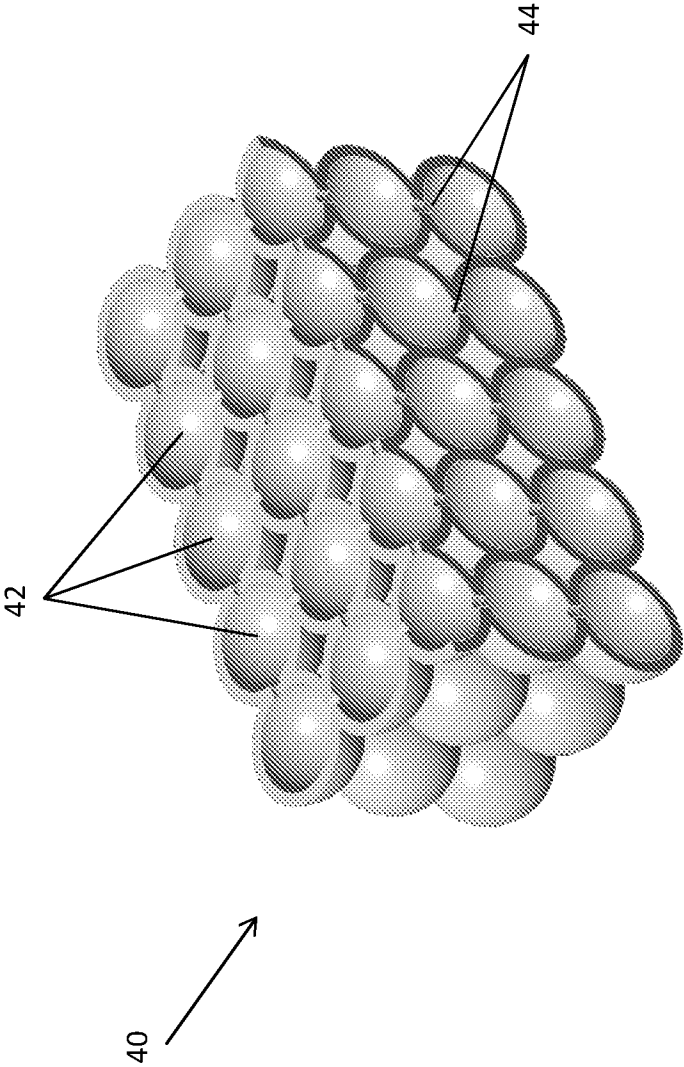


Fig. 4

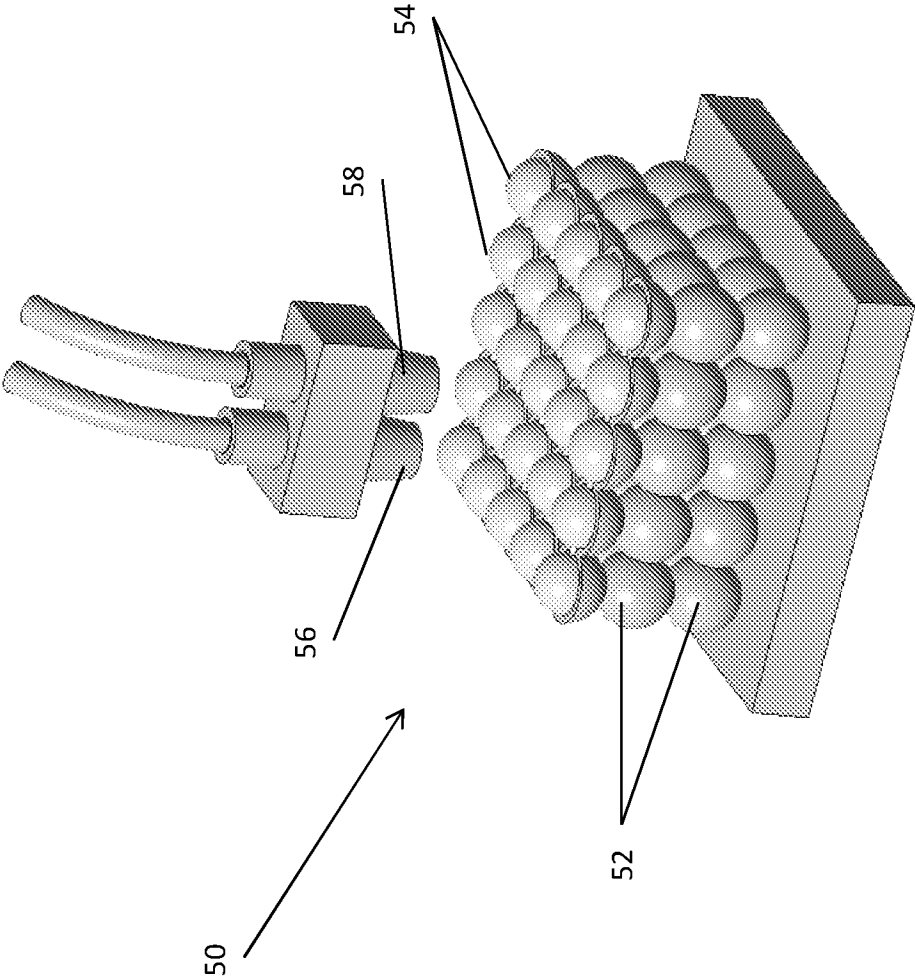


Fig. 5

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2016/052123

A. CLASSIFICATION OF SUBJECT MATTER

INV. F16F3/02 B29C67/00 F16F9/04
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)

F16F 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	WO 99/33641 A1 (MOLECULAR GEODESICS INC [US]; INGBER DONALD E [US]; MEUSE ARTHUR J [US] 8 July 1999 (1999-07-08) figure 3 page 4, line 5 page 6, line 26	1-3,6-8, 10,12 9
A		
X	US 2015/101899 A1 (RUSSO JOSEPH D [US]) 16 April 2015 (2015-04-16) paragraph [0008] claim 21	1-5,11
X	US 2014/356585 A1 (DUOSS ERIC [US] ET AL) 4 December 2014 (2014-12-04) the whole document	1
	----- -/-	



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

11 November 2016

Date of mailing of the international search report

18/11/2016

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

Beaumont, Arnaud

INTERNATIONAL SEARCH REPORT

International application No

PCT/GB2016/052123

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2015/077262 A1 (GUILL TOOL & ENGINEERING [US]) 28 May 2015 (2015-05-28)	13-15
A	abstract	16,17

A	US 2013/224423 A1 (MIKULAK JAMES K [US] ET AL) 29 August 2013 (2013-08-29)	13-17
	abstract	

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/GB2016/052123

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 9933641	A1	08-07-1999	NONE
US 2015101899	A1	16-04-2015	EP 3054802 A1 17-08-2016 US 2015101899 A1 16-04-2015 WO 2015054431 A1 16-04-2015
US 2014356585	A1	04-12-2014	US 2014356585 A1 04-12-2014 WO 2014193984 A1 04-12-2014
WO 2015077262	A1	28-05-2015	EP 3071396 A1 28-09-2016 US 2016297104 A1 13-10-2016 WO 2015077262 A1 28-05-2015
US 2013224423	A1	29-08-2013	US 2012231225 A1 13-09-2012 US 2013224423 A1 29-08-2013