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(54) **Method and device for production of nanofibrous textile, mainly for seeding living organisms**

(57) The invention relates to a method of production of a nanofibrous textile, mainly for seeding living organisms and/or cells, for example for scaffolds in tissue engineering, using electrostatic spinning of polymers in an electrostatic field of high intensity. During the deposition of nanofibers (211) into a layer (2110) by the action of the electrostatic forces, a stream (43) of gas acts against the direction of the movement of nanofibers (211), by which means in the created layer (2110) of nanofibers (211) interfibrous spaces increase and its volume in-

creases as well.

The invention also relates to a device for production of a nanofibrous textile, mainly for seeding living organisms and/or cells, for example for scaffolds in tissue engineering, using electrostatic spinning of polymers in an electrostatic field of high intensity between a spinning electrode (2) and a collecting electrode (4), in which aligned with the collecting electrode (4) is at least one jet (42) for supplying gas against the direction of the movement of the nanofibers (211).

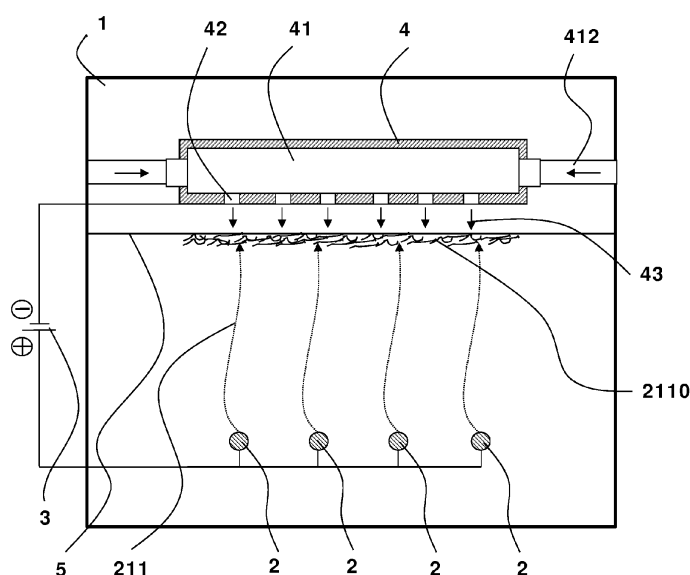


Fig. 1

Description

Technical field

[0001] The invention relates to a method of production of a nanofibrous textile, mainly for seeding living organisms and/or cells, for example for scaffolds in tissue engineering, using electrostatic spinning of polymers in an electrostatic field of high intensity.

[0002] The invention also relates to a device for production of a nanofibrous textile, mainly for seeding living organisms and/or cells, for example for scaffolds in tissue engineering, using electrostatic spinning of polymers in an electrostatic field of high intensity between a spinning electrode and a collecting electrode.

Background art

[0003] Tissue engineering is a branch of biomedicine, which deals primarily with substitution and regeneration of damaged tissues. For these purposes, among others, porous biodegradable matrices (scaffolds) are used. Scaffolds are seeded with a cell culture and implemented into the area of damage. The cells seeded in scaffolds gradually proliferate in its porous structure and form a new tissue. The material from which a scaffold is made is subject to biological degradation in the organism and gradually gives way to newly formed tissue.

[0004] Scaffolds are created from biodegradable polymers using different methods, such as 3D printing or electrostatic spinning, whereby the method of electrostatic spinning seems to be very perspective for seeding with cells. Conventionally produced nanofibrous textiles are formed by a relatively thin layer of nanofibers and have excellent properties for filtration, however, in relation to their total volume they have a small proportion of interfibrous spaces, therefore it is difficult to seed them with cells, or, in other words, they can be placed a smaller amount of cells than would be optimal for tissue engineering applications.

[0005] Seeding living organisms in textile carriers is also used in other fields, for example in fermentation processes or in waste water treatment plants. In these technologies, too, nanofibrous textiles produced by electrostatic spinning of polymers are considered to be very perspective, whereby it appears that apart from the price the major disadvantage is a low proportion of interfibrous spaces in relation to the total volume of a nanofibrous textile.

[0006] The aim of the invention is therefore to propose a method for production of porous nanofibrous matrices or textiles with sufficient portion of interfibrous spaces and to create a device for production of such matrices, whereby for some applications the electrospun polymer must be biodegradable.

Principle of invention

[0007] The goal of the invention is achieved through a method of spinning of biodegradable polymers, whose principle consists in that during depositing nanofibers into a layer by the action of electrostatic forces, nanofibers are acted upon by a stream of gas moving against the direction of the movement of nanofibers, by which means in the formed layer of nanofibers the interfibrous spaces are increased. Thus a space for seeding a greater amount of living organisms and/or cells is created.

[0008] In discontinuous production a plurality of gas streams act against the direction of the movement of nanofibers within the whole deposited surface. Discontinuous production is suitable mainly for production of small-size nanofibrous formations, especially scaffolds.

[0009] In continuous production a plurality of gas streams act against the direction of the movement of nanofibers within the whole width of the deposited surface. A textile produced in this manner is suitable for seeding for example with yeasts to be used in fermentation processes or for seeding with bacteria to be used in waste water treatment plants as well as for other processes, in which it is necessary to seed a large amount of living organisms and/or cells into a nanofibrous layer.

[0010] In terms of costs it is advantageous if air is used as the gas.

[0011] If there is a need to prevent reaction of the polymer of nanofibers or substances contained in the nanofibers, it is favourable if the gas to be supplied is inert gas.

[0012] The principle of the device according to the invention consists in that to a collecting electrode is aligned at least one jet for supplying the gas against the direction of the movement of the nanofibers.

[0013] Arrangements of jets, collecting electrodes and the support are included in the dependent claims referring to the device.

Description of drawings

[0014] Examples of embodiment according to the invention are schematically represented in enclosed drawings, where Fig. 1 shows a device for discontinuous production, Fig. 2 shows a device for continuous production, Fig. 3 shows a longitudinal section of the collecting electrode according to Fig. 3, Fig. 4 is a side view of an embodiment of the collecting electrode for discontinuous production and Fig. 5 is an axonometric view of the collecting electrode according to Fig. 4.

Examples of embodiment

[0015] The method of production of nanofibrous textiles according to the invention will be explained on examples of embodiment of the device represented in the enclosed drawings. For production of nanofibrous textiles of small planar dimensions intended particularly for

scaffolds in tissue engineering is used a device schematically represented in Fig. 1 and in a concrete embodiment shown in Fig. 4 and 5.

[0016] In the spinning chamber 1 of the device according to Fig. 1 there are arranged four spinning electrodes 2, which are formed by a suitable known spinning electrode, for example by a cord, a rod, a row of tips or jets arranged next to each other, and are connected to one pole of a high voltage source 3. The number of spinning electrodes 2 and their type serves merely as an example and depends on technological requirements. Person skilled in the art will select one using his experiences and, as the case may be, also according to the results of testing. Arranged against the spinning electrodes 2 is a collecting electrode 4, which is connected to the other pole of the high voltage source 3 and in the illustrated embodiment is composed of a hollow plate, whose cavity constitutes a pressure chamber 41, which is connected to a known unillustrated source of compressed gas and in whose wall oriented towards the spinning electrodes 2 are created jets 42 for the formation of streams 43 of gas directed against the spinning electrodes 2. Arranged between the spinning electrodes 2 and the collecting electrode 4 is a support 5 made of a gas permeable material, for example of a textile grid, a metal grid or a non-metal grid.

[0017] The gas used for creating streams 43 of gas may be according to the technological requirements air, inert gas or some other gas.

[0018] After application of the electrospun polymer 21 onto surface of the spinning electrodes 2, between the spinning electrodes 2 and the collecting electrode 4, having been connected to the high voltage source 3, an electrostatic field of high intensity is created, which is able to create nanofibers 211 from the surface of the polymer 21 situated on the spinning electrode 2, and to carry them to the collecting electrode 4 and deposit them on the support 5. Before falling on the support 5 the streams 43 of gas coming out of the jets 42 begin to act upon the nanofibers 211. The streams 43 of gas act upon the nanofibers 211 before their falling on the support 5 and slow down their flight, accelerate drying of solvents, thus increase the mechanical stiffness of the nanofibers 211. The streams 43 of gas act against the direction of the attraction force of the electrostatic forces acting between the nanofibers, and between the nanofibers and the collecting electrode 4, and therefore the nanofibers are deposited in a layer with a larger volume and a larger amount of interfibrous spaces. If such a layer 2110 of nanofibers 211 is produced from a biodegradable polymer, it is very sufficient for usage in tissue engineering as a scaffold for seeding with cells.

[0019] In the cases when the support 5 is made from electrically conductive material, it is advantageous if instead of the collecting electrode 4 the support 5 is connected to the other pole of the high voltage source 3. Thus on the original collecting electrode 4 is no voltage and it only serves to supply gas and create streams 43

of gas. An electrostatic field of high intensity is then created between the spinning electrodes 2 and the support 5. With this embodiment corresponds the collecting electrode 4 shown in Fig. 4 and Fig. 5, which comprises a flange 400 for mounting in the spinning chamber 1 of the device for production of nanofibers. To the flange 400 there is mounted a cover plate 411, which is a part of the pressure chamber 41. The pressure chamber 41 is provided with inlets 412 of compressed air, by which it is in a known unillustrated manner connected to a source of the compressed air. The second wall 413 of the pressure chamber 41 is fitted with a plurality of jets 42 for creating streams 43 of gas. At least on part of the circumference of the second wall 413 of the pressure chamber 41 there is created a frame 414 for fastening a metal grid 51, which constitutes a support 5 and is connectable to the high voltage source 3, so that if it is used during spinning, an electrostatic field of high intensity is created between the spinning electrodes 2 and the support 5.

[0020] The above-described examples of embodiment are suitable only for discontinued production of nanofibrous layers with a large amount of interfibrous spaces.

[0021] Continuous production of such nanofibrous layers takes place on the device according to Fig. 2, in which in the spinning chamber 1 there are arranged spinning electrodes 2, which are in the illustrated embodiment composed of cylindrical bodies carrying polymer out of a vessel into the spinning space on their surfaces, for example according to EP1673493. It is possible to use spinning electrodes of any type, whereby, according to experiences, it is advisable to use nozzle-less spinning electrodes, in which spinning takes place from the surface of the polymer created on the surface of the body of the spinning electrode. Against the spinning electrodes 2 there are in the spinning chamber 1 arranged collecting electrodes 4. Between the spinning electrode 2 and to it corresponding collecting electrode 4 there is created an electrostatic field of high intensity, for example by connecting each of the electrodes to a different pole of the high voltage source 3, as is illustrated, or by connecting one of the electrodes to the high voltage source 3 and grounding the other electrode of the corresponding pair. Between the spinning electrodes 2 and the collecting electrodes 4 there is created a path for the passage of the support 5 through the spinning chamber 1, which is in proximity of the collecting electrodes 4. In the illustrated embodiment the support 5 touches the surfaces of the collecting electrodes 4. The length of the spinning electrodes 2, the length of the collecting electrodes 4 and the width of the support 5 correspond to the width of the created nanofibrous layer 2110. The collecting electrodes 4 are in the illustrated embodiment composed of a tube, whose cavity forms a pressure chamber 41, which is closed on one side and on the other side is provided with an inlet 412 of compressed gas, through which it is in a known manner connected to a source of compressed gas. In the body of the spinning electrode 4, along its whole length, there are created jets 42 for creating

streams 43 of gas, as is shown in Fig.3. The jets 42 are arranged in one row along the whole length or in more rows, for example in three rows, as in case of the illustrated embodiment.

[0022] Spinning takes place from the surface of the polymer situated on the surface of the spinning electrodes 2, which is according to the type of electrode renewed continuously or at certain intervals, and the nanofibers are carried by the influence of the electrostatic field towards the collecting electrode 4, from which streams 43 of gas are coming out against them, for example of air, which help to slow down their flight, accelerate vaporization of solvents and act against the direction of the attraction force of electrostatic forces, whereby interactions occur between the nanofibers 211 mutually as well as between the nanofibers 211 and the collecting electrode 4. The nanofibers 211 therefore are deposited on the support 5 in a layer 2110 with a larger volume and a larger amount of interfibrous spaces than would be the case without the streams 43 of gas acting against their movement. The produced nanofibrous textile is suitable especially for seeding living organisms and/or cells.

[0023] A method of production of nanofibrous textiles by electrostatic spinning of polymers in an electrostatic field of high intensity, in which during deposition of nanofibers 211 into a layer 2110 by the action of the electrostatic forces there is acted by a stream 43 of gas against the direction of the movement of nanofibers 211, by which means the interfibrous spaces in the formed layer 2110 of nanofibers 211 increase, as well as the volume increases, can be performed also on other devices than those described above. The principle always consists in supplying streams of gas against the direction of the movement of nanofibers before they touch the support, which is always made from permeable material which gives little resistance to the penetrating gas.

[0024] The direction of spinning may vary, depending on particular known arrangements of spinning devices. Vertical spinning in upward direction has been chosen in the description only because its demonstration is usual and simple.

Claims

1. A method of production of a nanofibrous textile, mainly for seeding living organisms and/or cells, for example for scaffolds in tissue engineering, using electrostatic spinning of polymers in an electrostatic field of high intensity, **characterized in that** during the deposition of nanofibers (211) into a layer (2110) by action of the electrostatic forces, a stream (43) of gas acts against the direction of the movement of nanofibers (211), by which means in the created layer (2110) of nanofibers (211) the interfibrous spaces increase and its volume increases as well.
2. A method according to Claim 1, **characterized in**

that during discontinuous production a plurality of streams (43) of gas act against the direction of the movement of nanofibers (211) within the whole deposited area.

3. A method according to Claim 1, **characterized in that** during continuous production a plurality of streams (43) of gas act against the direction of the movement of nanofibers (211) within the whole width of the deposited layer (2110) of nanofibers (211).
4. A method according to any of Claims 1 to 3, **characterized in that** the gas is air.
5. A method according to any of Claims 1 to 3, **characterized in that** the gas is gas which is inert to the electrospun polymer.
6. A device for production of a nanofibrous textile, mainly for seeding living organisms and/or cells, for example for scaffolds in tissue engineering, using electrostatic spinning of polymers in an electrostatic field of high intensity between a spinning electrode (2) and a collecting electrode (4), **characterized in that** to the collecting electrode (4) is aligned at least one jet (42) for supplying gas against the direction of the movement of nanofibers (211).
7. A device according to Claim 6, **characterized in that** jets (42) are created in the collecting electrode (4).
8. A device according to Claim 6 or 7, **characterized in that** the collecting electrode (4) comprises a pressure chamber (41), in whose wall (413) there is created a system of jets (42) for formation of streams (43) of gas and in which a gas permeable support (5) is arranged against the outlets of the jets (42).
9. A device according to Claim 6 or 7, **characterized in that** the collecting electrode (4) is composed of a tube or a similar elongated body, in which there is created a pressure chamber (41) connectable to a source of compressed air, whereby the jets (42) are arranged along the whole length of the collecting electrode (4) and are oriented against the support (5), arranged in proximity of the collecting electrode (2), and coupled with a device for leading the gas out of the space of the spinning chamber (1).
10. A device according to Claim 8 or 9, **characterized in that** the support (5) is composed of a textile grid, a non-metal grid or a metal grid.
11. A device according to Claim 10, **characterized in that** the metal grid of the support (5) is connected to the opposite pole of the high voltage source (3) than the spinning electrode (2).

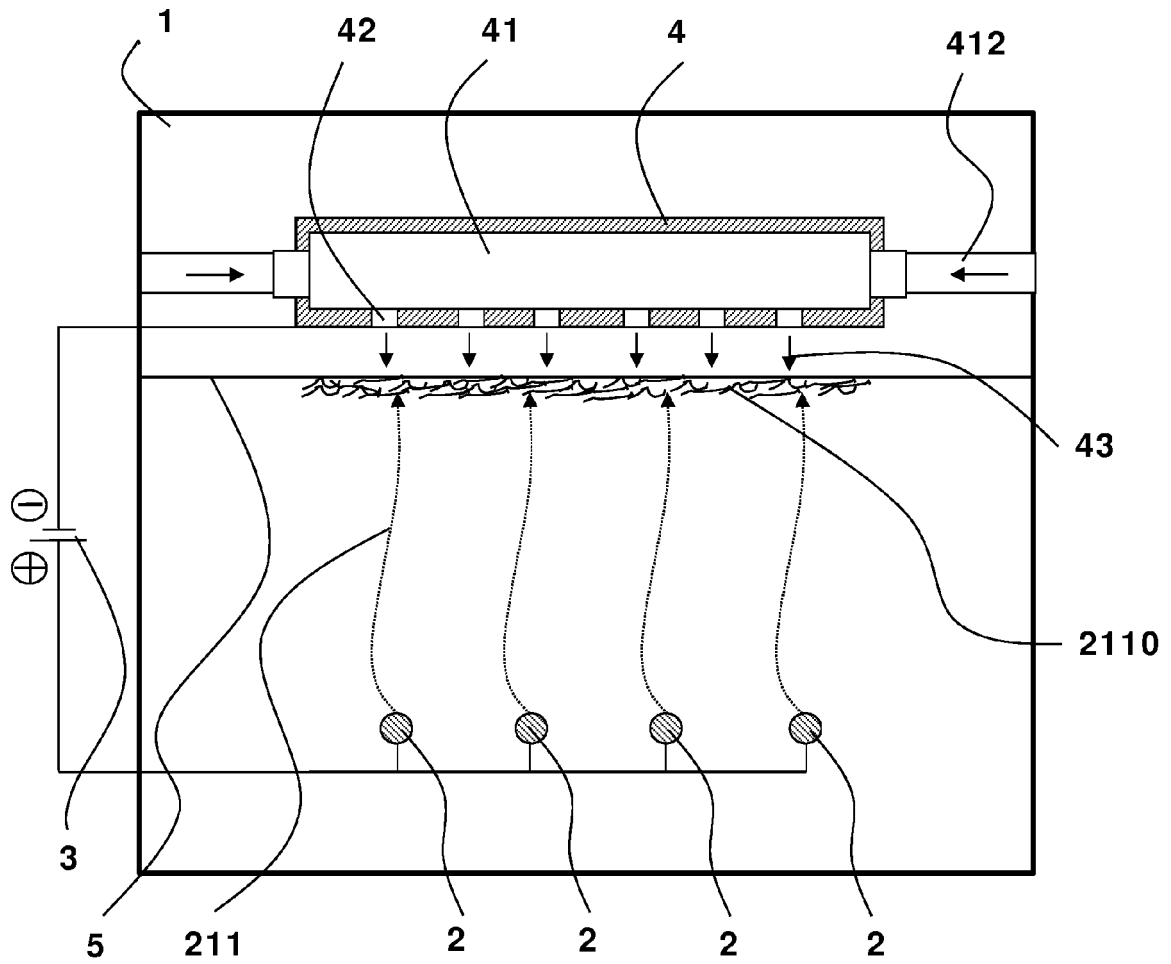


Fig. 1

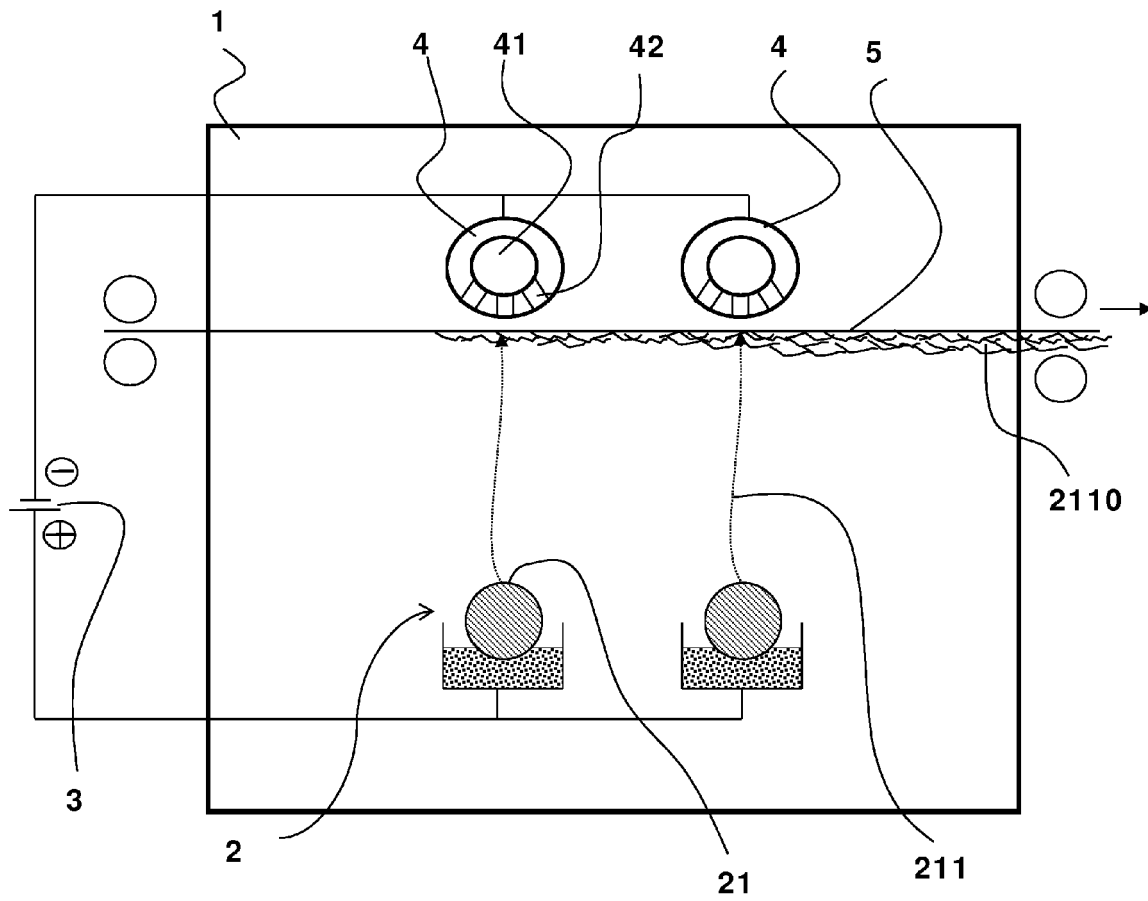


Fig. 2

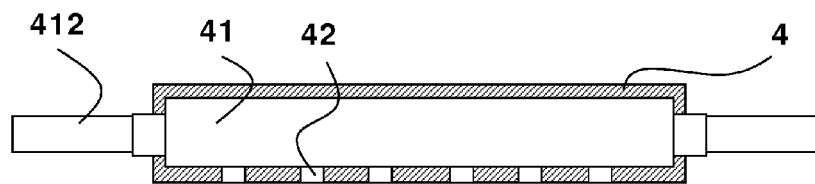


Fig. 3

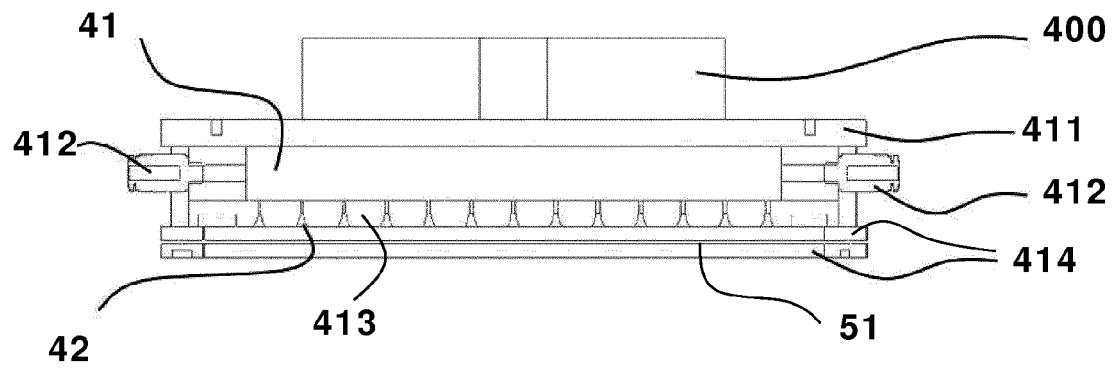


Fig. 4

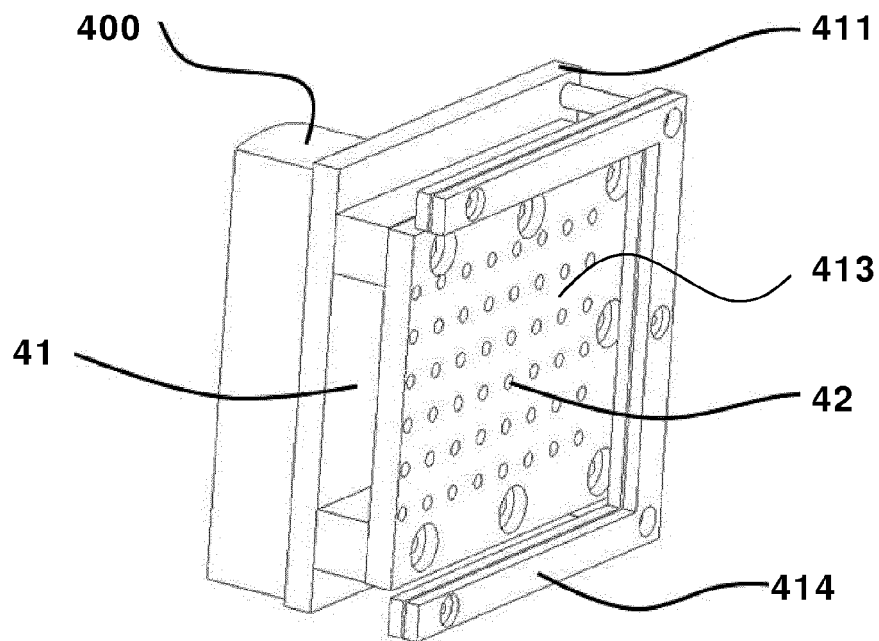


Fig. 5



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Application Number
EP 13 19 3616

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The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 18 February 2014	Examiner Barathe, Rainier
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**ANNEX TO THE EUROPEAN SEARCH REPORT
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