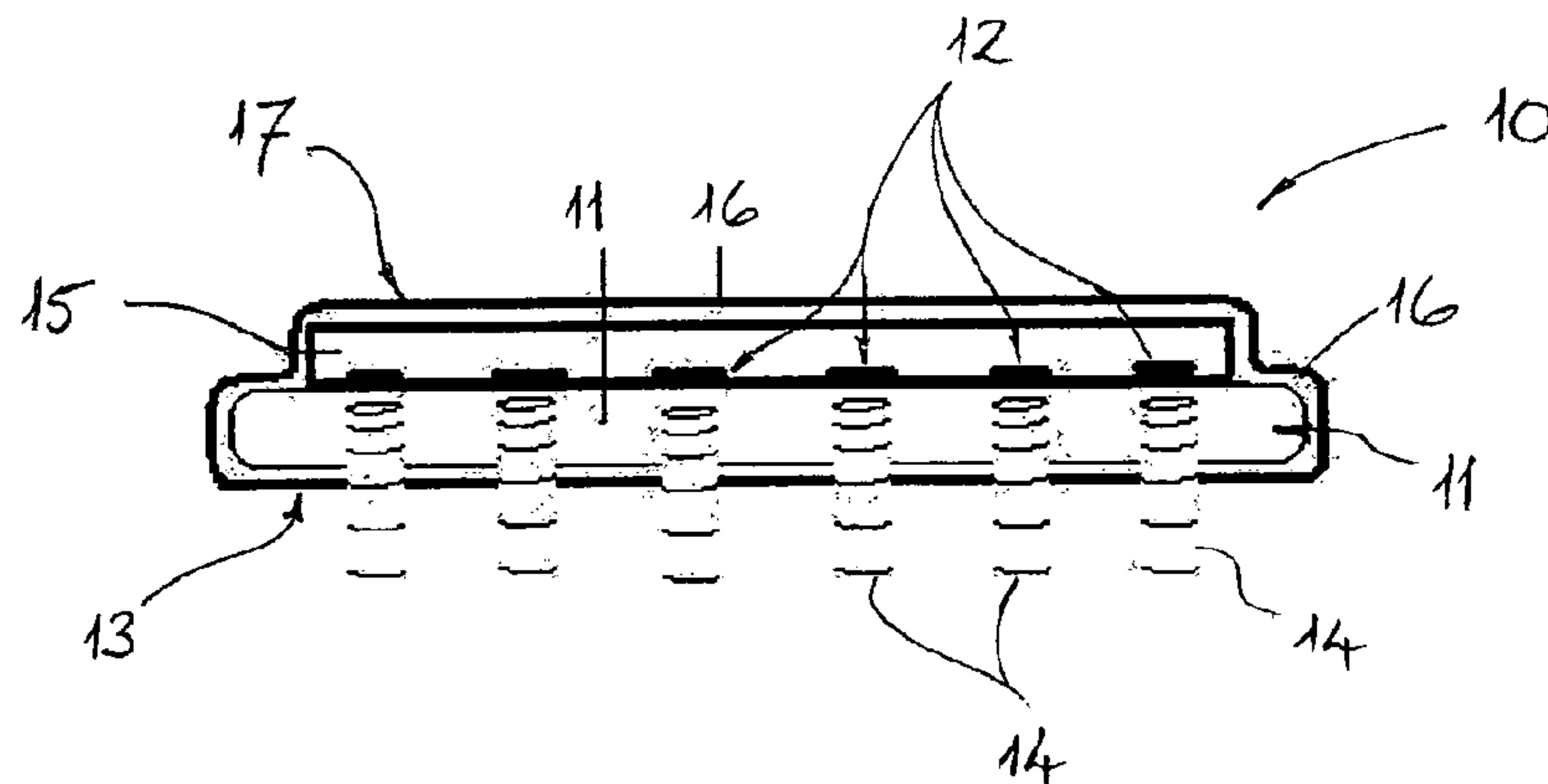




(86) Date de dépôt PCT/PCT Filing Date: 2010/04/01
(87) Date publication PCT/PCT Publication Date: 2011/10/06
(45) Date de délivrance/Issue Date: 2017/04/25
(85) Entrée phase nationale/National Entry: 2012/09/14
(86) N° demande PCT/PCT Application No.: EP 2010/002112
(87) N° publication PCT/PCT Publication No.: 2011/120540

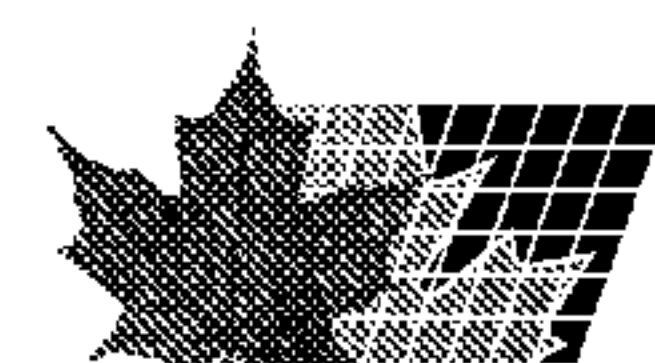
(51) Cl.Int./Int.Cl. *A61F 9/08* (2006.01),
A61N 1/36 (2006.01)
(72) Inventeurs/Inventors:
KLAVER, TOM, DE;
DAPPER, MARCUS, DE;
TIEDTKE, HANS-JUERGEN, DE
(73) Propriétaire/Owner:
PIXIUM VISION SA, FR
(74) Agent: KIRBY EADES GALE BAKER

(54) Titre : IMPLANT RETINIEN ET PROTHESE VISUELLE INCORPORANT UN TEL IMPLANT
(54) Title: RETINAL IMPLANT AND VISUAL PROSTHESIS INCORPORATING SUCH AN IMPLANT



(57) Abrégé/Abstract:

A system for generating artificial vision in a subject, comprising: an image capture means for capturing an image from a surrounding environment; an image processing means for processing the image and converting the image into an image signal; and a retinal implant or stimulation device configured to be implanted within an eye of a patient and positioned on or adjacent the retina. The implant or stimulation device comprises a substrate and a plurality of light sources arranged in an array on the substrate for stimulating nerve cells of the retina, wherein each of the plurality of light sources is configured to emit infrared radiation to stimulate one or more nerve cells in response to a respective stimulation signal derived from the image signal.



Abstract

A system for generating artificial vision in a subject, comprising: an image capture means for capturing an image from a surrounding environment; an image processing
5 means for processing the image and converting the image into an image signal; and a retinal implant or stimulation device configured to be implanted within an eye of a patient and positioned on or adjacent the retina. The implant or stimulation device comprises a substrate and a plurality of light sources arranged in an array on the substrate for stimulating nerve cells of the retina, wherein each of the plurality of
10 light sources is configured to emit infrared radiation to stimulate one or more nerve cells in response to a respective stimulation signal derived from the image signal.

RETINAL IMPLANT AND VISUAL PROSTHESIS INCORPORATING SUCH AN IMPLANT

5

Technical Field

10 The present invention relates to a medical implant device, and more particularly to a retinal or ocular implant for a visual prosthesis for use in artificially generating vision in a patient suffering from partial or total vision loss.

Background Art

15 Since the 1990s various research groups have been working on the development of a visual prosthesis that would allow at least partial restoration of sight to individuals suffering from certain forms of vision loss or blindness, most notably from the effects of retinitis pigmentosa and/or age-related macular degeneration. The majority of the prostheses or systems for generating artificial vision that have been developed to
20 date comprise an ocular implant designed for electrically stimulating the functional nerves of the retina. One example of such a system is described in the International Patent Application Publication No. WO 2007/006376 A2. That system includes a camera for capturing an image, which is then processed and transmitted as electric signals to an electrode array provided on the implant to electrically stimulate the
25 retinal nerve cells. The system employs a wireless power supply via induction, and employs telemetry for data transfer, either as RF signals or as infrared light.

Because the environment within the eye is aqueous, problems arise in association with the penetration of solutes or moisture into the implants and/or electrochemical
30 reactions involving the electrodes. As the electrodes project from the implant for direct physical contact with the nerve tissue of the retina, they are naturally exposed to the aqueous environment. The electrodes, which are typically made of platinum-

coated gold, tend to dissolve in this environment as a result of the application of a direct current to stimulate the nerve tissue. In the interests of a highly localized or specific stimulation, and thus good vision resolution, the electrodes are desirably made as small as possible. But the impact of electrochemical degradation increases with diminishing size and this, in turn, limits size reduction. Furthermore, the locations where the electrodes physically emerge from the sealed implant present potential sites for the ingress of moisture into the electronics or circuitry of the implant. For example, the conductive traces that electrically connect each of the electrodes are extremely fine or thin so that any ingress of moisture may also expose those traces to electrochemical degradation. Apart from electrochemical processes, the de-lamination of the sheath or coating that hermetically seals the implant can also be highly damaging.

In addition to electrode size, another factor which may affect the resolution of the artificially generated vision is electrical interference between electrodes, also known as 'cross-talking'. The electrical current directed into the tissue from each electrode tends to spread through the tissue around that electrode. Thus, at the threshold current necessary to evoke a depolarisation of the nerve cells, there is a limit to the proximity of electrodes to each other. If the electrodes are too close together, the stimulus field from one electrode can overlap and interfere with a region of nerve tissue served by another electrode, with unwanted stimulation as a result. Accordingly, not only should the electrodes have at least a certain size, they should also be spaced at a sufficient distance from each other to prevent 'cross-talking'.

The greater the proximity of the electrodes to the nerve cells to be stimulated, the smaller the currents that are required for stimulation. Although the 'cross-talking' effect can be reduced by using smaller currents, thereby enabling the electrodes to be spaced closer together, the electrodes must then penetrate into the retina tissue to be very close to the nerve cells to be stimulated. A significant drawback of this arrangement is that, if the implant needs to be replaced for some reason, extracting the electrodes will almost certainly cause serious damage to the retinal tissue.

Thus, it is an object of the present invention to provide a medical implant device, and in particular an implant for a visual prosthesis, with which one or more of the above the drawbacks or limitations may be substantially overcome.

5 Summary

Certain exemplary embodiments provide a retinal prosthesis comprising: a substrate, and a plurality of light sources arranged in an array on the substrate, wherein the prosthesis is configured to be implanted within an eye of a subject and positioned on
10 or adjacent the retina, and wherein each of the light sources is configured to emit infrared radiation to stimulate nerve cells of the retina.

Other exemplary embodiments provide a system for generating artificial vision in a subject, comprising: image capture means for capturing an image from a surrounding
15 environment; image processing means for processing the image and converting the image into an image signal; and a retinal implant or stimulation device configured to be implanted within an eye of a patient and positioned on or adjacent the retina, the implant or device comprising a substrate and a plurality of light sources arranged in an array on the substrate for stimulating nerve cells of the retina, wherein each of the
20 plurality of light sources is configured to emit infrared radiation to stimulate one or more nerve cells in response to a respective stimulation signal derived from the image signal.

Yet other exemplary embodiments provide use of a plurality of infrared light sources
25 to irradiate nerve cells of a retina with beams of infrared light from the plurality of infrared light sources, to stimulate nerve cells of the retina, wherein said plurality of infrared light sources are directly adjacent the retina to irradiate and to stimulate the nerve cells.

3a

According to one aspect, therefore, disclosed is an ocular implant or a retinal implant or prosthesis comprising: a substrate or support layer, and a plurality of light sources arranged on the substrate, wherein the substrate bearing the light sources is configured to be implanted within an eye of a patient and positioned in, on or adjacent the retina, and wherein each of the light sources is configured to emit infrared (IR) radiation to stimulate nerve cells of the retina.

According to another aspect, disclosed is a visual prosthesis or a system for generating artificial vision in a subject, comprising:

- 10 image capture means to capture an image from a surrounding environment;
- image processing means to process the image and convert the image into an image signal; and
- a retinal implant or stimulation device configured to be implanted within an eye of a patient and positioned in, on or adjacent the retina, the retinal implant or stimulation device comprising: a support layer or substrate and a plurality of light sources arranged on the substrate to stimulate nerve cells of the retina,
- 15 wherein the plurality of light sources are configured to emit infrared radiation in response to stimulation signals derived from the image signal.

20 It will be understood that the references to “light sources” in this application are references to sources of electromagnetic (EM) radiation within the infrared range of the EM spectrum. As such, the term “light” is understood in its broad physical sense

and is not limited to EM radiation visible to the human eye. Rather, the light sources in this context may be considered to be infrared light sources. The present invention has been developed based on research which has demonstrated that, as an alternative to electrical stimulation, nerve cells may be successfully stimulated by infrared (IR) radiation. In other words, instead of applying an electric current, the nerve cells may be stimulated to evoke a depolarization or an action potential by specific application of infrared radiation. As the application of IR radiation does not require an electrode, the present invention is thus able to eliminate the need for electrodes in a retinal implant entirely and thereby overcome the associated disadvantages described above. Although the precise mechanism by which the IR radiation stimulates the nerve cells is not yet fully understood, it is truly fascinating that retina nerve cells no longer functioning normally in visible light (i.e. that have lost their optical potential in visible light) may nevertheless be optically stimulated by light in the infrared spectrum.

In a preferred form of the invention, each of the light sources is configured to emit radiation in the near-infrared or mid-infrared range. In this connection, each of the light sources is desirably configured to emit radiation having a wavelength in the range of about 0.70 μm to 4.0 μm , more preferably in the range of about 0.75 μm to 3.0 μm and particularly preferably in the range of about 1.5 μm to 2.5 μm . The experimental results have indicated that IR radiation having a wavelength in the range of 1.8 μm to 2.2 μm is especially suitable for stimulation of ganglion cells in the retina. Varying the wavelength of the IR radiation has been found to have a significant impact on the penetration depth of the radiation, and this in turn can affect the amplitude of the action potentials generated depending on the depth in the tissue of the nerves to be stimulated. Thus, depending on the particular tissue of the subject to be treated, some degree of tuning of the stimulation wavelength may be required to produce optimal stimulation results. Desirably, the IR radiation is tuned or selected to penetrate the tissue to a depth in the range of 100 μm to 1 mm, and more preferably in the range of 200 μm to 600 μm . The larger wavelengths have been found to be less desirable because they can lead to excessive absorption

of the IR radiation by water in the tissue, which reduces the penetration depth and general efficiency, as well as creating the potential for local temperature increases, which could be damaging.

5 In a preferred form of the invention, each of the plurality of light sources is adapted to emit the infrared radiation in pulses. The duration of the pulses is preferably in the range of about 1 μ s to 10 ms, and more preferably in the range of 10 μ s to 1 ms. Interestingly, shorter pulse durations have been found to require lower stimulation levels to evoke a given action potential. Furthermore, short pulse durations have the
10 advantage of low radiant exposure, which can be particularly important for ensuring that the cells and tissue being stimulated does not experience any adverse thermal effects, i.e. caused by heating. For the purpose of artificially generating vision in a subject, each of the infrared light sources is preferably activated at a frequency of at least 1 Hz, more preferably at least 10 Hz, further preferably at least 25 Hz, and
15 even more preferably at least 50 Hz. Because the pulse durations are relatively brief in comparison to the operating frequency of the light sources, each light source will be inactive, i.e. in an "off"-phase or not emitting, for the majority of the time. For example, a light source that operates at 50 Hz and emits pulses having a duration of 2 ms will be in an "off"-phase or not emitting for about 90% of the time.

20

In a preferred form of the invention, each of the plurality of light sources comprises a semiconductor laser, and more preferably a laser diode, e.g. a surface-emitting laser diode, such as a vertical-cavity surface-emitting laser (VCSEL) diode. VCSEL diodes are particularly suitable for use in a retinal implant of the invention because
25 they can be fabricated with very small dimensions and can be readily integrated into a compact 2-D (i.e. 2-dimensional) array on a microchip, and because they emit light perpendicular to a plane or surface of the microchip. VCSEL diodes also have proven suitability for generating infrared radiation having a wavelength in the range of 1.3 μ m to 2.0 μ m. Further, laser diodes can generate a beam of infrared light
30 having a small spot-size (e.g. with a diameter of about 100 μ m or less, even 30 μ m), thus providing for very specific stimulation of the nerve cells. In this regard, because

the laser beams only stimulate the cells that they directly irradiate, they do also not generate any of the "cross-talk" typical with electrodes in the prior art. This enables the lasers to stimulate the nerve tissue much more specifically and to be arranged in a much more closely spaced array compared to electrodes, thereby providing the
5 potential for higher resolution.

By combining the plurality of infrared light sources (e.g. laser diodes) in a microchip or integrated circuit, they may be pre-arranged in a 2D array on the chip to emit infrared radiation from a surface of the substrate to be directed towards the nerve
10 cells of the retina. Each of the light sources can be controlled for independent actuation based on respective stimulation signals transmitted to or generated by the implant. That is, the implant may be configured to receive respective stimulation signals transmitted to it, e.g. by optical or telemetric means, or to generate such stimulation signals itself, e.g. based on the image signal from the image processing
15 means.

In a preferred form of the invention, the substrate comprises a web or film which carries the IR light sources and is configured to be implanted epiretinally. In this connection, the substrate may be formed so flexible that it readily adopts the
20 curvature of the epiretinal surface when it is applied to the retina. Alternatively, the substrate may be pre-formed having a curvature adapted to the curvature of the epiretinal surface, e.g. using techniques disclosed in the co-pending International Patent Application No. PCT/EP2008/008225). Thus, in a preferred form of the invention, the substrate may comprise at least two layers of material including a first
25 layer and a second layer. The first and second layers in the substrate preferably consist of polymer material, such that the substrate of the implant or stimulation device preferably comprises a layered polymer web or film. Further, the first layer of material and the second layer of material may be selected to have different coefficients of thermal expansion to generate a desired curvature in the substrate.

In a preferred form, therefore, the invention provides a method of manufacturing an implant or stimulation device according to the invention described above, including the steps of:

5 providing a first layer of material having a first coefficient of thermal expansion;

providing a second layer of material having a second coefficient of thermal expansion preferably different from the first coefficient of thermal expansion;

10 combining the first layer and the second layer to form a substrate, preferably at a temperature different to a normal service temperature or operation temperature of the implant or stimulation device; and

arranging a plurality of infrared light sources in an array on the substrate. The infrared light sources are preferably arranged to emit infrared radiation in a direction substantially perpendicular to a primary surface or plane of the substrate.

15 In a preferred form of the invention, the step of providing the first layer includes the step of applying the first layer of material on a base or support structure. Further, the step of providing the second layer includes the step of applying the second layer of material to the first layer.

20 In one form of the invention, the step of arranging the plurality of IR light sources in an array on the substrate comprises placing and/or arranging the plurality of light sources individually. In an alternative preferred form, however, the step of arranging the plurality of IR light sources in an array on the substrate comprises: combining a prefabricated microchip or integrated circuit, on which the infrared light sources
25 (e.g. laser diodes) have already been fixed in an array, with one or more layers of the substrate. The spacing between the individual diode lasers arranged in the array on the substrate is preferably less than or equal to about 500 μm , more preferably in the range of 100 μm to 400 μm , and even more preferably in the range of 200 μm to 300 μm . The microchip or integrated circuit may itself be provided as a flexible foil
30 or wafer. The prefabricated microchip or integrated circuit may be sandwiched between the first layer and the second layer of the substrate. Alternatively, the

microchip or integrated circuit may be applied and secured to an outer surface of a layer of the substrate. In either case, but particularly the latter, a sealing layer or coating may be applied over the microchip or integrated circuit to hermetically seal it from an aqueous environment within the body. Parylene is especially suitable for
5 coating the laser diodes because it is substantially transparent to infrared light.

In a preferred form of the invention, the material(s) employed in the first and second layers of the substrate is/are polymer material(s), and more particularly, bio-compatible polymer material(s). In this connection, the polymer material(s) is/are
10 preferably selected from the group consisting of polyimide, parylene, and silicone. It will be appreciated that a polymer material selected for the substrate layers may be coated to ensure its bio-compatibility. For example, a parylene coating may be applied to an outer surface of the substrate.

15 During production of the implant or stimulation device, the first and second layers of the substrate are preferably bonded, fused, cured or otherwise combined with one another in a flat condition at a temperature that is elevated compared to a normal operating temperature for the implant or stimulation device. Accordingly, a temperature differential exists (i.e. a change in temperature occurs) between that
20 production phase and the normal operation of the implant. If the first and second material layers of the substrate have different coefficients of thermal expansion, this temperature change induces stresses or forces between the first and second layers of the substrate which act to deform or re-shape the substrate, and thereby endow the implant with a desired form. In particular, the substrate layer having the higher
25 coefficient of thermal expansion will tend to form a concavely curved outer surface. In other words, because the materials of the first and second layers of the substrate are typically polymer materials which are bonded, fused and/or cured to form a layered structure at relatively high temperatures (e.g. in range of 200°C to 400°C) compared to room temperature (e.g. 22°C) or body temperature for a human or
30 animal (e.g. 37°C) at which the implant typically operates, the temperature change between production and operation of the device will be a significant temperature

reduction. Thus, the substrate layer having a higher coefficient of thermal expansion will tend to form a concavely curved outer surface. Where the stimulation device is intended to be employed as a retinal implant, in which the plurality of infrared light sources are to be directed outwardly from and/or through a second layer of the substrate having a convexly curved outer surface complementing a concave surface profile of the retina, the first layer of polymer material in the substrate will preferably have a higher coefficient of thermal expansion than the second layer.

The degree of curvature which is generated in the implant as a result of the different coefficients of thermal expansion of the first and second layers will depend, for example, upon the respective magnitude of the coefficient of thermal expansion (also called "CTE") of each of the first and second layers, as well as the thickness of each of these layers. The elasticity of the particular material(s) forming the layers will naturally also influence the degree of curvature generated. The CTE of the first layer may be in the range of about 20 ppm/°C (i.e. $20 \times 10^{-6}/^{\circ}\text{C}$) to about 40 ppm/°C (i.e. $40 \times 10^{-6}/^{\circ}\text{C}$). The CTE of the second layer, on the other hand, may be in the range of about 1 ppm/°C (i.e. $1 \times 10^{-6}/^{\circ}\text{C}$) to 10 ppm/°C (i.e. $10 \times 10^{-6}/^{\circ}\text{C}$), and more preferably in the range of 1 ppm/°C (i.e. $1 \times 10^{-6}/^{\circ}\text{C}$) to 5 ppm/°C (i.e. $5 \times 10^{-6}/^{\circ}\text{C}$). The elasticity of the first and second layers will typically be approximately equal.

In a preferred form of the invention, the first layer and the second layer extend with a substantially uniform thickness over the area of the substrate. Either of the first and second layers may itself have a layered structure and comprise multiple sub-layers. Preferably, the thickness of each layer and/or each sub-layer of the substrate is in the range of 1 μm to 100 μm , more preferably in the range of 1 μm to 50 μm , and particularly preferably in the range of 1 μm to 10 μm . The thickness of the first and second layers may be equal or may be adjusted as desired, but is usually within a ratio from about 1:1 to 1:5, or vice versa (i.e. 1:1 to 5:1).

When the retina stimulation device is implanted, the array of light sources (e.g. laser diodes) is preferably substantially centred in the region of the macula, where the

retina has the greatest visual acuity and the greatest concentration of nerve cells. Preferably, fixation means are provided for fixing the substrate to the retina to hold the array of infrared light sources (e.g. laser diodes) in the desired position with respect to the macula. The fixation means may comprise biocompatible adhesive, or
5 alternatively tacks, pins, staples or similar fastening elements. The fixation means are desirably applied spaced a distance away from the region of the retina to be stimulated so that any deleterious effect caused by the fixation means on the tissue does not affect the tissue and nerve cells to be stimulated.

10 As noted above, the substrate may include a semiconductor material and/or an integrated circuit or microchip for carry the plurality of light sources, e.g. laser diodes. The substrate preferably also comprises a sheath or coating of at least one polymer material for hermetically sealing sensitive components (e.g. electronics and circuitry) of the substrate from the aqueous environment within the eye. The
15 polymer material may, for example, comprise one or more of a silicone, a parylene, and/or a polyimide. Furthermore, the sheath or coating may comprise multiple layers of such polymer material.

According to an alternative aspect, the present invention provides a medical implant
20 device in the form of a pacemaker. Thus, the pacemaker of the invention comprises a substrate configured to be implanted in contact with heart tissue, and a plurality of infrared light sources arranged in an array on the substrate, wherein each of the light sources is configured to emit infrared radiation to stimulate muscle cells of the heart.

25 Brief Description of the Drawings

The above and further features and advantages of the present invention will become more apparent from the following detailed description of particular embodiments of the invention with reference to the accompanying drawing figures, in which like
30 components are designated with like reference characters, and in which:

Figure 1 is a schematic plan view of an internal part of a visual prosthesis according to an embodiment of the present invention; and

Figure 2 is a schematic side cross-sectional view of a retinal stimulation device
5 in the embodiment of the visual prosthesis shown in Figure 1.

Detailed Description of the Preferred Embodiments of the Invention

The visual prosthesis according to a preferred embodiment of the present invention
10 incorporates both an "internal" part comprising components to be implanted in the body of the subject, and an "external" part comprising components to be carried or worn externally (i.e. non-implanted) by the subject. The basic system architecture of the visual prosthesis according to the invention generally reflects the state-of-the-art design described, for example, in International Patent Application Publication No.
15 WO 2007/006376. As the details of the system architecture of the visual prosthesis are described in WO 2007/006376 at some length, much of that description will not be repeated here for the sake of economy. Rather, the reader should make direct reference to that document.

20 Thus, the visual prosthesis or system for artificially generating vision in a subject in this embodiment of the invention includes a device resembling a pair of glasses or spectacles (not shown) which incorporates image capture means in the form of a camera for capturing an image of the environment surrounding the user. The camera may, for example, incorporate a CCD or CMOS device, as is known in the art. The
25 visual prosthesis further includes an external image processor (not shown) which may be incorporated in a small unit that is preferably designed to be carried by the subject, for example, in a breast pocket or in a belt-mounted pouch. The image processor device is operatively connected with the camera in the spectacles' frame and is designed to process and convert the images generated by the camera into
30 image signals. The image signals are then transmitted telemetrically to the internal or implanted part of the visual prosthesis. That is, the frame of the spectacles may

include a transmitter device for wirelessly transmitting the image signals to a signal processing device for converting the image signals into stimulation signals or stimulation impulses. The signal processing device is typically in the form of a micro-processor or micro-chip which may be implanted extra-ocularly in the user or
5 subject, e.g. enclosed in a housing attached to an outer surface of the sclera.

With reference now to Fig. 1 of the drawings, an internal part 1 of a visual prosthesis according to an embodiment of the invention is illustrated. The internal part 1 of the visual prosthesis shown in Fig. 1 includes a circular housing 2 which is configured
10 to be implanted extra-ocularly in the subject, e.g. outside of, and possibly attached to, the sclera. The housing may be anchored in position using sutures or fastening bands, as it is known in the art. In this embodiment, the housing 2 includes a micro-processor or microchip 3 belonging to the signal processor device mentioned above for converting the image signals into stimulation signals or stimulation impulses.
15 Further, a telemetry coil 4 is schematically shown in Fig. 1 overlying the housing 2. This coil 4 forms a receiver coil for receiving an RF or inductively transmitted data signal for the signal processor 3 and/or power signal for driving the internal part 1 of the visual prosthesis. In this regard, the housing 2 typically also incorporates circuitry for regulating the power supply for this internal part 1 of the prosthesis and
20 a tuning capacitor for the receiver coil 4.

The housing 2 and the receiver coil 4 are physically and electrically connected to a retinal stimulation device 10 to be implanted adjacent the retina via an elongate flexible web 5. The elongate web 5 is formed of a polymer material incorporating
25 electrical traces or wiring 6 so that it forms a kind of ribbon cable. As schematically illustrated in Fig. 1, the traces or wiring 6 provide electrical communication from the signal processor 3 and the coil 4 to the retinal implant or stimulation device 10, to be described in more detail later. Also provided on the ribbon cable is an infrared receiver-transmitter 7, which may comprise one or more photo-diodes, for receiving
30 and/or transmitting data signals as described in WO 2007/006376. This receiver-transmitter 7 may be connected with the signal processor 3 via one of the traces 6

and/or may be separately connected with the retinal stimulation device 10, e.g. via another electrical trace or wiring 8.

Referring now to Fig. 2 of the drawings, the retinal stimulation device 10 according to a preferred embodiment of the invention is schematically illustrated in somewhat more detail. The stimulation device 10 comprises a substrate or support layer 11 formed from a flexible web of polymer material which is connected to, and may also be continuous with, the polymer web of the ribbon cable 5. Furthermore, the stimulation device includes a multitude of infrared light sources in the form of laser diodes 12, and in particular VCSEL diodes, which are arranged and fixed in a grid-like array (e.g. 50x50, 50x100, or 100x100) on the substrate 11. The plurality of laser diodes 12 are arranged with their laser-emitting surfaces facing substantially perpendicular to an outer surface 13 of the substrate 11. As the retinal stimulation device 10 is designed to be positioned with the outer surface 13 either in contact with, or directly adjacent to, the epiretinal surface, each of the infrared light sources (i.e. laser diodes 12) is configured to emit beams 14 of infrared (IR) radiation directly onto the tissue to be stimulated. The polymer material of the substrate 11 through which the beams 14 pass is therefore designed to be substantially transparent to infrared radiation, at least within the range of wavelengths emitted by the diodes 12, which in this case is in range from 1.8 μm to 2.2 μm .

The laser diodes 12 are themselves preferably fixed on a microchip or integrated circuit 15 which is secured or bonded to the substrate 11. That microchip 15 is responsible for the switching, activation and control of the laser diodes 12 based on the stimulation signals derived from the image signal. Both the microchip 15 and the substrate 11 may be coated with a suitable polymer material to provide a hermetic sealing layer 16 which is also biocompatible. As this sealing layer 16 should also be transparent to IR radiation, parylene is especially preferred.

In operation, the image signal is transmitted telemetrically from the image processor in the external part of the visual prosthesis to the internal part 1 of the system, e.g.

via RF transmission to the receiver coil 4 or via optical transmission to the receiver-transmitter 7. After that image signal has been transformed into stimulation signals or impulses in the signal processor microchip 3, those stimulation signals are then conveyed from the signal processor 3 to the control microchip 15 incorporating the
5 array of laser diodes 12. Each of the diodes 12 is then individually or independently actuated to generate a beam 14 of IR radiation in dependence upon the stimulation signals to artificially generate a visual sensation for the subject corresponding to the image captured by the camera.

10 A possible modification or alternative embodiment of the system of this invention includes combining the circuitry for the power supply and signal processor 3 with the circuitry for controlling the infrared light sources, i.e. laser diodes 12. This could be achieved, for example, by incorporating all of this electronic control circuitry on a single microchip, namely the microchip 15 of the retina stimulation device. With
15 sufficient miniaturization, it may then be possible to completely avoid the need for any extra-ocularly implanted housing 2 outside of the sclera. Because the laser diodes 12 can be operated at much lower power consumption than the electrodes used in convention retina stimulation devices, the overall power requirements and associated potential heat generation can be kept to a minimum. A further alternative
20 embodiment of the invention would be to provide that side 17 of the retinal stimulation device 10 facing away from the retina (i.e. the upper side in Fig. 2) with the infrared receiver-transmitter device 7 (i.e. one or more photo-diode) instead of placing this component on the ribbon cable, as illustrated in Fig. 1.

25 It will be appreciated that the above description of the preferred embodiments of the invention with reference to the drawings has been made by way of example only. Accordingly, a person skilled in the art will appreciate that various changes, modifications and/or additions may be made to the parts particularly described and illustrated without departing from the scope of the invention as defined in the
30 appended claims.

CLAIMS:

1. A retinal prosthesis comprising:
a substrate, and
5 a plurality of light sources arranged in an array on the substrate,
wherein the prosthesis is configured to be implanted within an eye of a
subject and positioned on or adjacent the retina, and wherein each of the light
sources is configured to emit infrared radiation to stimulate nerve cells of the
retina.
10
2. The retinal prosthesis according to claim 1, wherein each of the light sources is
configured to emit infrared radiation having a wavelength in the range of
about 0.75 μm to about 3.0 μm .
- 15 3. The retinal prosthesis of claim 2, wherein each of the infrared light sources is
configured to emit infrared radiation having a wavelength in the range of
about 1.5 μm to about 2.5 μm .
4. The retinal prosthesis according to any one of claims 1 to 3, wherein the
20 plurality of light sources are configured to be controlled for independent
actuation based on stimulation signals transmitted to or generated by the
prosthesis.
5. The retinal prosthesis according to claim 2, 3 or 4, wherein the prosthesis is
25 configured to receive telemetrically transmitted stimulation signals.
6. The retinal prosthesis according to any one of claims 1 to 5, wherein each of
the plurality of light sources comprises a laser diode, and wherein the laser
diodes are arranged in an array on a semiconductor material.

7. The retinal prosthesis according to claim 6, wherein each laser diode is a vertical-cavity surface-emitting laser (VCSEL) diode.
8. The retinal prosthesis according to claim 6 or 7, wherein the semiconductor material comprises an integrated circuit or microchip.
9. The retinal prosthesis according to any one of claims 1 to 8, wherein the substrate comprises a flexible web or film, configured to be implanted epiretinally.
10. The retinal prosthesis according to claim 9, wherein the flexible web or film is a polymer film.
11. The retinal prosthesis according to any one of claims 1 to 10, wherein the substrate comprises at least one layer or coating of a material that hermetically seals the plurality of light sources from an aqueous environment within the eye.
12. The retinal prosthesis according to any one of claims 1 to 11, wherein the substrate is formed having a curvature that is adapted to a curvature of the retina.
13. The retinal prosthesis of claim 12, wherein the curvature of the substrate is a result of a temperature influence and/or a coefficient of thermal expansion of the substrate material.
14. The retinal prosthesis according to any one of claims 1 to 13, wherein fixation means are provided for fixing the substrate to the retina.

15. The retinal prosthesis of claim 14, wherein the fixation means comprises tacks or similar fastening elements.
16. A system for generating artificial vision in a subject, comprising:
- 5 image capture means for capturing an image from a surrounding environment;
- image processing means for processing the image and converting the image into an image signal; and
- 10 a retinal implant or stimulation device configured to be implanted within an eye of a patient and positioned on or adjacent the retina, the implant or device comprising a substrate and a plurality of light sources arranged in an array on the substrate for stimulating nerve cells of the retina, wherein each of the plurality of light sources is configured to emit infrared radiation to stimulate one or more nerve cells in response to a respective
- 15 stimulation signal derived from the image signal.
17. The system according to claim 16, further comprising signal processing means for converting the image signal into a plurality of stimulation signals for activating the plurality of light sources.
- 20
18. The system according to claim 17, wherein the system comprises an external part which is to be worn or carried externally on the body of the subject, and an internal part which is to be implanted in the body of the subject, wherein the image capture means and the image processing means form components
- 25 of the external part, and wherein the retinal implant or stimulation device and the signal processing means are components of the internal part.
19. The system according to claim 18, wherein the external part further comprises signal transmission means for transmitting the image signal to the image

processing means, the signal transmission means including an RF or optical telemetry means.

20. The system according to any one of claims 16 to 19, wherein each of the plurality of light sources comprises a laser diode, wherein the laser diodes are integrated on a microchip and arranged to emit IR radiation substantially perpendicular to a surface of the substrate.
21. The system according to claim 20, wherein the laser diodes comprise vertical-cavity surface-emitting laser (VCSEL) diodes.
22. Use of a plurality of infrared light sources to irradiate nerve cells of a retina with beams of infrared light from the plurality of infrared light sources, to stimulate nerve cells of the retina, wherein said plurality of infrared light sources are directly adjacent the retina to irradiate and to stimulate the nerve cells.
23. The use of claim 22, wherein each of the infrared light sources emits infrared radiation having a wavelength in the range of from about 0.75 μm to about 3.0 μm .
24. The use of claim 22, wherein each of the infrared light sources emits infrared radiation having a wavelength in the range of from about 1.5 μm to about 2.5 μm .

1 / 1

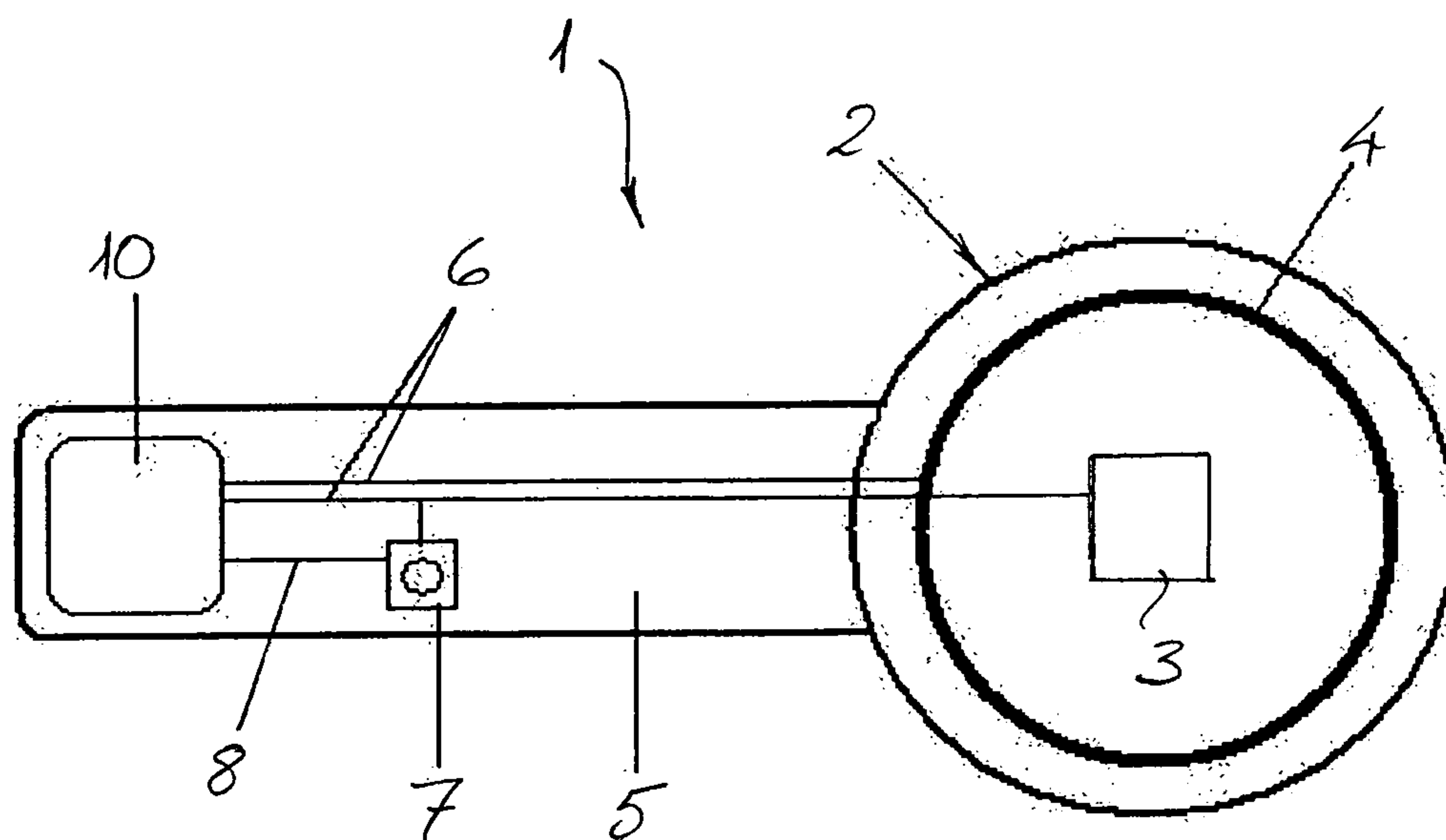


Fig. 1

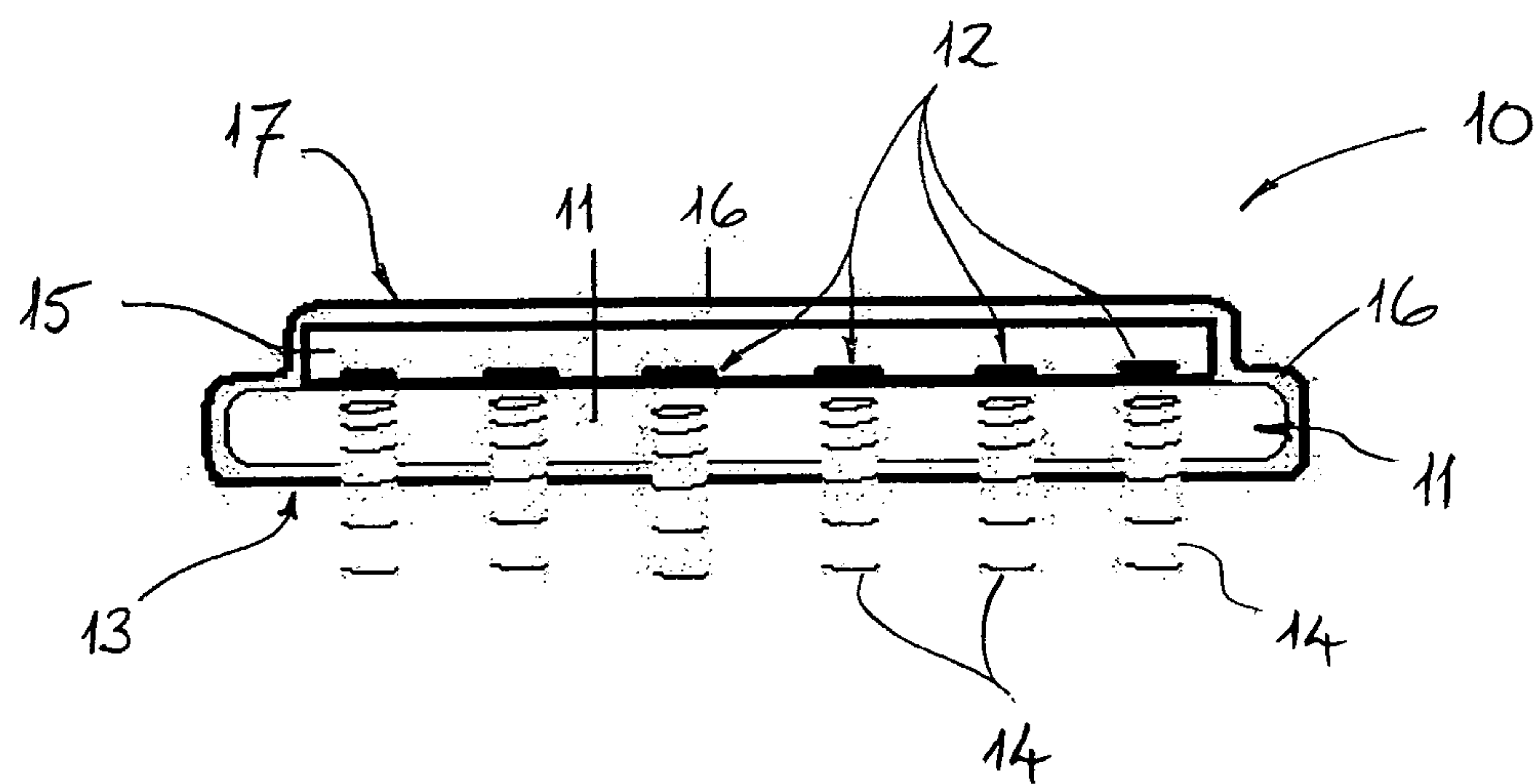


Fig. 2

