(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 494 753 B1

(12) EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention of the grant of the patent:
24.02.2016 Bulletin 2016/08

(21) Application number: **03716904.2**

(22) Date of filing: **28.03.2003**

(51) Int Cl.:
A61N 1/05 *(2006.01)* *A61B 5/00* *(2006.01)*

(86) International application number:
PCT/US2003/009701

(87) International publication number:
WO 2003/082404 (09.10.2003 Gazette 2003/41)

(54) VARIABLE PITCH ELECTRODE ARRAY

ELEKTRODENANORDNUNG MIT VARIABLEM ABSTAND

JEU D'ELECTRODES A PAS VARIABLE

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IT LI LU MC NL PT RO SE SI SK TR

(30) Priority: **28.03.2002 US 112801**

(43) Date of publication of application:
12.01.2005 Bulletin 2005/02

(73) Proprietor: **Second Sight Medical Products, Inc.**
Sylmar, CA 91342 (US)

(72) Inventors:
- **GREENBERG, Robert**
  Los Angeles, CA 90068 (US)
- **WILLIAMSON, Richard**
  Saugus, CA 91350 (US)
- **HUMAYAN, Mark**
  Glendale, CA 91206 (US)

(74) Representative: **Carter, Stephen John et al**
Mewburn Ellis LLP
City Tower
40 Basinghall Street
London EC2V 5DE (GB)

(56) References cited:
WO-A-00/56393
WO-A-99/56818
US-A- 4 628 933
US-A- 4 721 551
US-A- 4 837 049
US-A- 5 215 088
US-A- 5 643 330
US-A- 5 810 725
US-A- 5 935 155
US-A- 6 038 480
US-A- 6 091 979
US-A- 6 165 192
US-B1- 6 400 989

- **DAVID H LIANG * ET AL: "The Nerve-Electrode Interface of the Cochlear Implant: Current Spread" IEEE TRANSACTIONS ON BIOMEDICAL ENGINEERING, IEEE SERVICE CENTER, PISCATAWAY, NJ, US, vol. 46, no. 1, 1 January 1999 (1999-01-01), XP011006645 ISSN: 0018-9294**
- **JESINGER R A ET AL: "FLEXIBLE ELECTRODE ARRAY FOR RETINAL STIMULATION" PROCEEDINGS OF THE ANNUAL INTERNATIONAL CONFERENCE OF THE ENGINEERING IN MEDICINE AND BIOLOGY SOCIETY. PARIS, OCT. 29 - NOV. 1, 1992; [PROCEEDINGS OF THE ANNUAL INTERNATIONAL CONFERENCE OF THE ENGINEERING IN MEDICINE AND BIOLOGY SOCIETY], NEW YORK, I, vol. 14, 29 October 1992 (1992-10-29), page 2393, XP000346990**

Printed by Jouve, 75001 PARIS (FR)

Description

Field of the Invention

[0001] The present invention is generally directed to electrode arrays, and more particularly to implantable electrode arrays for medical devices.

Background of the Invention

[0002] Arrays of electrodes for neural stimulation are commonly used for a variety of purposes. Some examples include: US Patent 3,699,970 to Brindley describes an array of cortical electrodes for visual stimulation. Each electrode is attached to a separate inductive coil for signal and power. US Patent 4,573,481 to Bullara describes a helical electrode to be wrapped around an individual nerve fiber. US Patents 4,837,049 to Byers describes spike electrodes for neural stimulation. Each spike electrode pierces neural tissue for better electrical contact. US Patent 5,215,088 to Norman describes an array of spike electrodes for cortical stimulation. US Patent 5,109,844 to de Juan describes a flat electrode array placed against the retina for visual stimulation. US Patent 5,935,155 to Humayun describes a retinal prosthesis for use with the flat retinal array described in de Juan.

[0003] It is well known that the resolution of light perception on the retina is highest at the fovea, and significantly lower at the periphery of the retina. Resolution reduces gradually across the surface of the retina moving from the fovea to the periphery.

[0004] Applicant has discovered, through experimental use of a retinal prosthesis, that a very small amount of power is needed to stimulate the perception of light near the fovea; while a much larger amount of power is needed to stimulate the perception of light further from the fovea. The resolution of a retinal electrode array is limited by the size and spacing of the individual retinal electrodes. The size of a retinal electrode is limited the amount of power that must be transferred from the electrode to neural tissue, to create the perception of light. As electrode size decreases, or power increases, charge density on the electrode increases. At high charge densities, electrodes tend to corrode, or dissolve in a saline environment. Charge density is the primary limit on how small electrodes can be made and how closely that can be placed.

[0005] US 4 837 049, US 5 643 330, WO 99/56818, US 6 091 979 and David H Liang et al: "The Nerve-Electrode Interface of the Cochlear Implant: Current Spread" published in IEEE TRANSACTIONS ON BIOMEDICAL ENGINEERING, vol. 46, no. 1, January 1999, all describe further examples of electrode arrays for medical applications.

Summary of the Invention

[0006] The present invention is an implantable electrode array as set forth in claim 1, having electrodes with variable pitch and preferably also variable size. Electrode arrays of the prior art provide electrodes with a common spacing and size. However, this is not how the human body is arranged. As an example, the retina has closely spaced retinal light receptors near the fovea. The light receptors are spaced farther apart, farther away from the fovea, near the periphery of the retina. Further, the amount of electrical current required to stimulate the perception of light increases with distance from the fovea. Hence, larger electrodes are required to transfer the necessary current farther away from the fovea. By placing small, closely spaced low power electrode near the fovea, and larger widely spaced electrode at the periphery, resolution is maximized.

[0007] The novel features of the invention are set forth with particularity in the appended claims. The invention will be best understood from the following description when read in conjunction with the accompanying drawings.

Brief Description of the Drawings

[0008]

FIG. 1 is a view of the preferred retinal electrode array.

FIG. 2 is a view of the preferred retinal prosthesis.

FIG. 3 is a view of an alternate electrode array used in a cortical stimulator.

Detailed Description of the Preferred Embodiments

[0009] The following description is of the best mode presently contemplated for carrying out the invention. This description is not to be taken in a limiting sense, but is made merely for the purpose of describing the general principles of the invention. The scope of the invention should be determined with reference to the claims.

[0010] The present invention provides an array of variable pitch, variable size electrodes. **FIG. 1** shows the invention applied to a retinal stimulator for artificial sight. Electrodes on the preferred retinal electrode array 10 begin very small and close together with a center electrode 12 at the fovea. A first circle of electrodes 14 approximately 10 microns in width are placed 5 microns apart. The size and pitch of the electrodes increases proportionally moving away from the fovea. It is not necessary that the fovea be at the center of the electrode array. The preferred electrode array extends further from the fovea in the direction opposite from the optic nerve (not shown), with the largest electrode 16 at the furthest point from the optic nerve. The largest electrode is 1 millimeter in width and 4 millimeters from the nearest electrode. The preferred array body is curved to match the curvature of the retina.

[0011] It should be noted that **Fig. 1** is not drawn to scale as a scale drawing would be impossible, given PTO accepted dimensions. Further, the preferred electrode array would have far more electrodes than those shown. Several different types of electrode are possible in a retinal electrode array such as spikes (as shown in Fig. 3) mushrooms or other elongated or recessed shapes. The present invention is independent of the type of electrode used. The variation of electrode size is due to limitations in the charge density supported by current electrode designs. Future electrode designs may improve charge density capability obviating the need to vary electrode size. In such a case, it would still be advantageous to vary electrode pitch.

[0012] **FIG 2** shows the preferred retinal prosthesis for use with the variable pitch electrode array of the present invention. The variable pitch electrode array 10 is placed against the outer surface of a retina 22 (epiretinally). A cable 24 pierces a sclera 26 and attaches to an electronic control unit 28. The electronic control unit is attached to the sclera and moves with the sclera. A return electrode 30 is placed outside the sclera and distant from the retina 22. Electricity travels through the body between the stimulating electrode array 10 and return electrode 30, to complete an electrical circuit.

[0013] The retinal prosthesis also includes a coil 32 around the front of the sclera and coupled to the electronic control unit 28. The coil 32 receives an inductive signal from an external unit (not shown). The signal includes the video information provided to the stimulating electrode array 10.

[0014] The present invention is not limited to the retina, but is applicable to may parts of the human body as show in the alternate embodiment of **FIG 3.**

[0015] **FIG. 3** shows an alternate embodiment of the invention applied to a cortical brain stimulator. In a cortical brain stimulator, the electrode must pierce the cerebral cortex. Hence spike electrodes are used. Spike electrodes on the cortical electrode array 40 begin very small and close together with a center electrode 42 at the center of the visual "area" of the cerebral cortex. A first circle of electrodes 44 approximately 5 microns in width are placed 2.5 microns apart. The size and pitch of the electrodes increase proportionally moving away from the center of the visual portion of the cortex. It is not necessary that the center of the visual portion of the cortex be at the center of the electrode array. The furthest electrode 46 is also the largest. Charge density is less of an issue in cortical stimulation than in retinal stimulation. Hence an array that varies electrode pitch without varying electrode size could be quite effective.

[0016] Accordingly, what has been shown is an improved electrode array for neural stimulation with electrodes of variable pitch and variable size. While the invention has been described by means of specific embodiments and applications thereof, it is understood that numerous modifications and variations could be made thereto by those skilled in the art without departing from the scope of the invention, as defined by the appended claims. For example, while it is preferable to vary both pitch and size, varying only pitch will have advantageous results. It is therefore to be understood that within the scope of the claims, the invention may be practiced otherwise than as specifically described herein.

Claims

1. An implantable electrode array (10, 40) comprising:

an array body;
a plurality of electrodes (12, 14, 16, 42, 44, 46) spaced across said array body at varying pitch, **characterised in that**,
said varying pitch is small toward a central portion of said array body and increases along a radial direction moving away from the central portion toward an outer edge of said array body; and
said varying pitch increases proportionally with distance along the radial direction moving away from said central portion.

2. The implantable electrode array (10, 40) according to claim 1, wherein said electrodes (12, 14, 16, 42, 44, 46) are of varying size.

3. The implantable electrode array (10, 40) according to claim 2, wherein said varying size of said electrodes is small toward said central portion of said array body, and increases toward an outer edge of said array body.

4. The implantable electrode array (10, 40) according to claim 3, wherein said varying size of said electrodes increases proportionally to a distance from said central portion.

5. The implantable electrode array (10, 40) according to any one of claims 1 to 4, wherein said electrodes are elongated electrodes.

6. The implantable electrode array (10, 40) according to claim 5, wherein said elongated electrodes are mushroom shaped electrodes.

7. The implantable electrode array (10, 40) according to claim 5, wherein said elongated electrodes are spike electrodes (42, 44, 46).

8. An implantable retinal electrode array (10) comprising an implantable electrode array according to any one of claims 1 to 4.

9. The implantable retinal electrode array (10) according to claim 8, wherein a central portion of said array is configured to be located toward the fovea and an outer edge of the array is configured to be located toward the outer edge of the retina.

10. An implantable cortical electrode array (40) comprising an implantable electrode array according to any one of claims 1 to 4, wherein said plurality of electrodes are spike electrodes (42, 44, 46).

Patentansprüche

1. Implantierbare Elektrodenanordnung (10, 40), die Folgendes umfasst:

einen Anordnungskörper;
eine Vielzahl von Elektroden (12, 14, 16, 42, 44, 46), die in variierendem Teilungsabstand auf dem Anordnungskörper angeordnet sind,
dadurch gekennzeichnet, dass
der variierende Teilungsabstand in Richtung eines zentralen Teils des Anordnungskörpers klein ist und entlang einer radialen Richtung, sich von dem zentralen Teil in Richtung einer Außenkante des Anordnungskörpers wegbewegend, zunimmt; und
der variierende Teilungsabstand entlang der radialen Richtung, sich von dem zentralen Teil wegbewegend, proportional mit dem Abstand zunimmt.

2. Implantierbare Elektrodenanordnung (10, 40) nach Anspruch 1, worin die Elektroden (12, 14, 16, 42, 44, 46) eine unterschiedliche Größe aufweisen.

3. Implantierbare Elektrodenanordnung (10, 40) nach Anspruch 2, worin die unterschiedliche Größe der Elektroden in Richtung des zentralen Teils des Anordnungskörpers klein ist und in Richtung einer Außenkante des Anordnungskörpers zunimmt.

4. Implantierbare Elektrodenanordnung (10, 40) nach Anspruch 3, worin die unterschiedliche Größe der Elektroden proportional zu einem Abstand von dem zentralen Teil zunimmt.

5. Implantierbare Elektrodenanordnung (10, 40) nach einem der Ansprüche 1 bis 4, worin die Elektroden längliche Elektroden sind.

6. Implantierbare Elektrodenanordnung (10, 40) nach Anspruch 5, worin die länglichen Elektroden pilzförmige Elektroden sind.

7. Implantierbare Elektrodenanordnung (10, 40) nach Anspruch 5, worin die länglichen Elektroden Spike-Elektroden (42, 44, 46) sind.

8. Implantierbare Netzhaut-Elektrodenanordnung (10), die eine implantierbare Elektrodenanordnung nach einem der Ansprüche 1 bis 4 umfasst.

9. Implantierbare Netzhaut-Elektrodenanordnung (10) nach Anspruch 8, worin ein zentraler Teil der Anordnung konfiguriert ist, in Richtung der Sehgrube positioniert zu sein, und eine Außenkante der Anordnung konfiguriert ist, in Richtung des Rands der Netzhaut positioniert zu sein.

10. Implantierbare Cortex-Elektrodenanordnung (40), die eine implantierbare Elektrodenanordnung nach einem der Ansprüche 1 bis 4 umfasst, worin die Vielzahl von Elektroden Spike-Elektroden (42, 44, 46) ist.

Revendications

1. Réseau d'électrodes implantables (10, 40), comprenant :

un corps de réseau ;
une pluralité d'électrodes (12, 14, 16, 42, 44, 46) espacée au travers dudit corps de réseau selon un pas variable,
caractérisé en ce que
ledit pas variable est petit vers une partie centrale dudit corps de réseau, et augmente le long d'une direction radiale s'éloignant de la partie centrale vers un bord extérieur dudit corps de réseau ; et
ledit pas variable augmente proportionnellement avec la distance le long de la direction radiale en s'éloignant de ladite partie centrale.

2. Réseau d'électrodes implantables (10, 40) selon la revendication 1, dans lequel lesdites électrodes (12, 14, 16, 42, 44, 46) sont d'une taille variable.

3. Réseau d'électrodes implantables (10, 40) selon la revendication 2, dans lequel ladite taille variable desdites électrodes est petite vers ladite partie centrale dudit corps de réseau, et augmente vers un bord extérieur dudit corps de réseau.

4. Réseau d'électrodes implantables (10, 40) selon la revendication 3, dans lequel ladite taille variable desdites électrodes augmente proportionnellement à une distance depuis ladite partie centrale.

5. Réseau d'électrodes implantables (10, 40) selon l'une quelconque des revendications 1 à 4, dans lequel lesdites électrodes sont des électrodes allongées.

6. Réseau d'électrodes implantables (10, 40) selon la revendication 5, dans lequel lesdites électrodes allongées sont des électrodes en forme de champignon.

7. Réseau d'électrodes implantables (10, 40) selon la revendication 5, dans lequel lesdites électrodes allongées sont des électrodes en forme de pointe (42, 44, 46).

8. Réseau d'électrodes rétiniennes implantables (10) comprenant un réseau d'électrodes implantables selon l'une quelconque des revendications 1 à 4.

9. Réseau d'électrodes rétiniennes implantables (10) selon la revendication 8, dans lequel une partie centrale dudit réseau est configurée pour être positionnée vers la fovéa, et un bord extérieur du réseau est configuré pour être positionné vers le bord extérieur de la rétine.

10. Réseau d'électrodes corticales implantables (40) comprenant un réseau d'électrodes implantables selon l'une quelconque des revendications 1 à 4, dans lequel ladite pluralité d'électrodes sont des électrodes en forme de pointe (42, 44, 46).

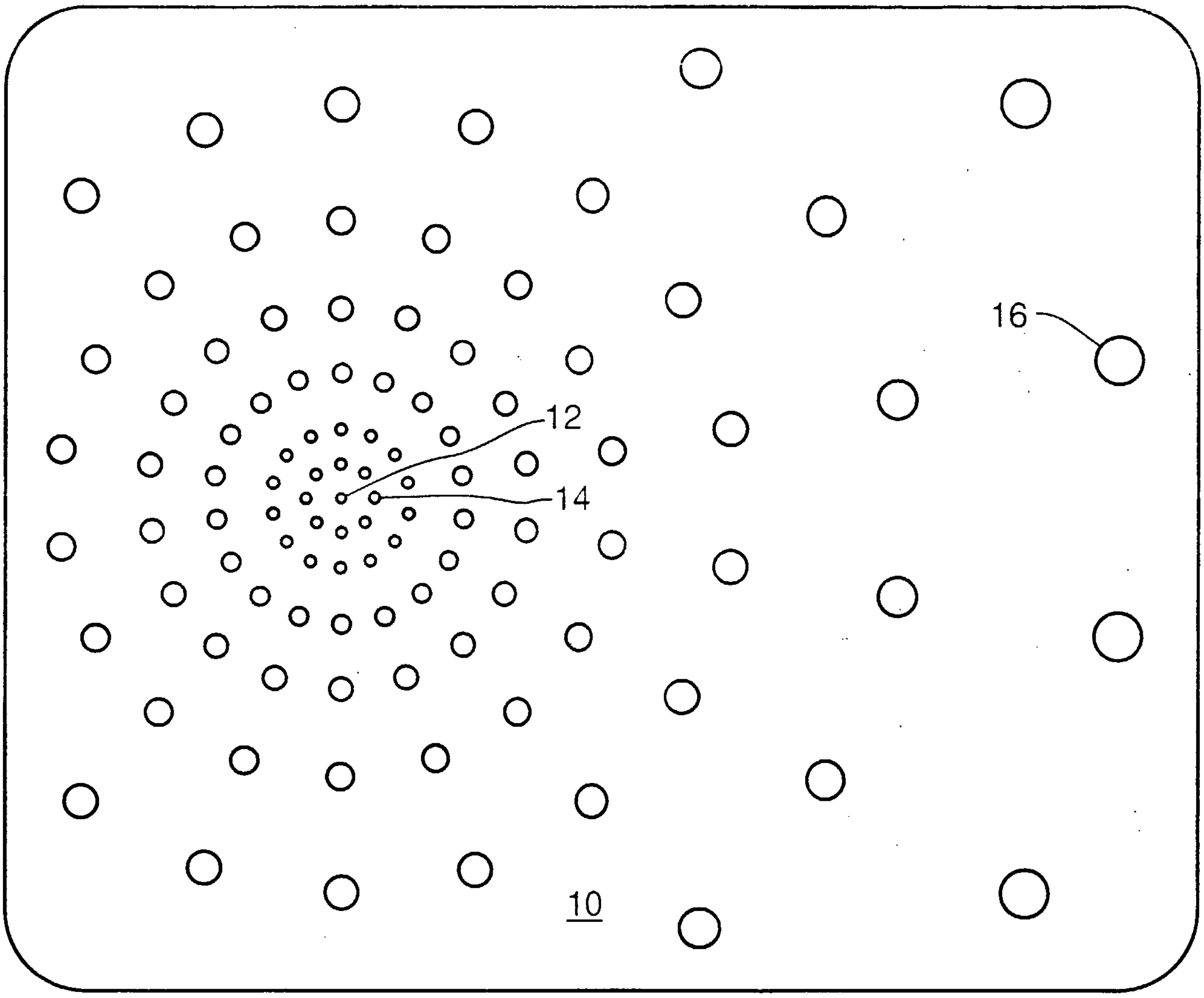

Fig. 1

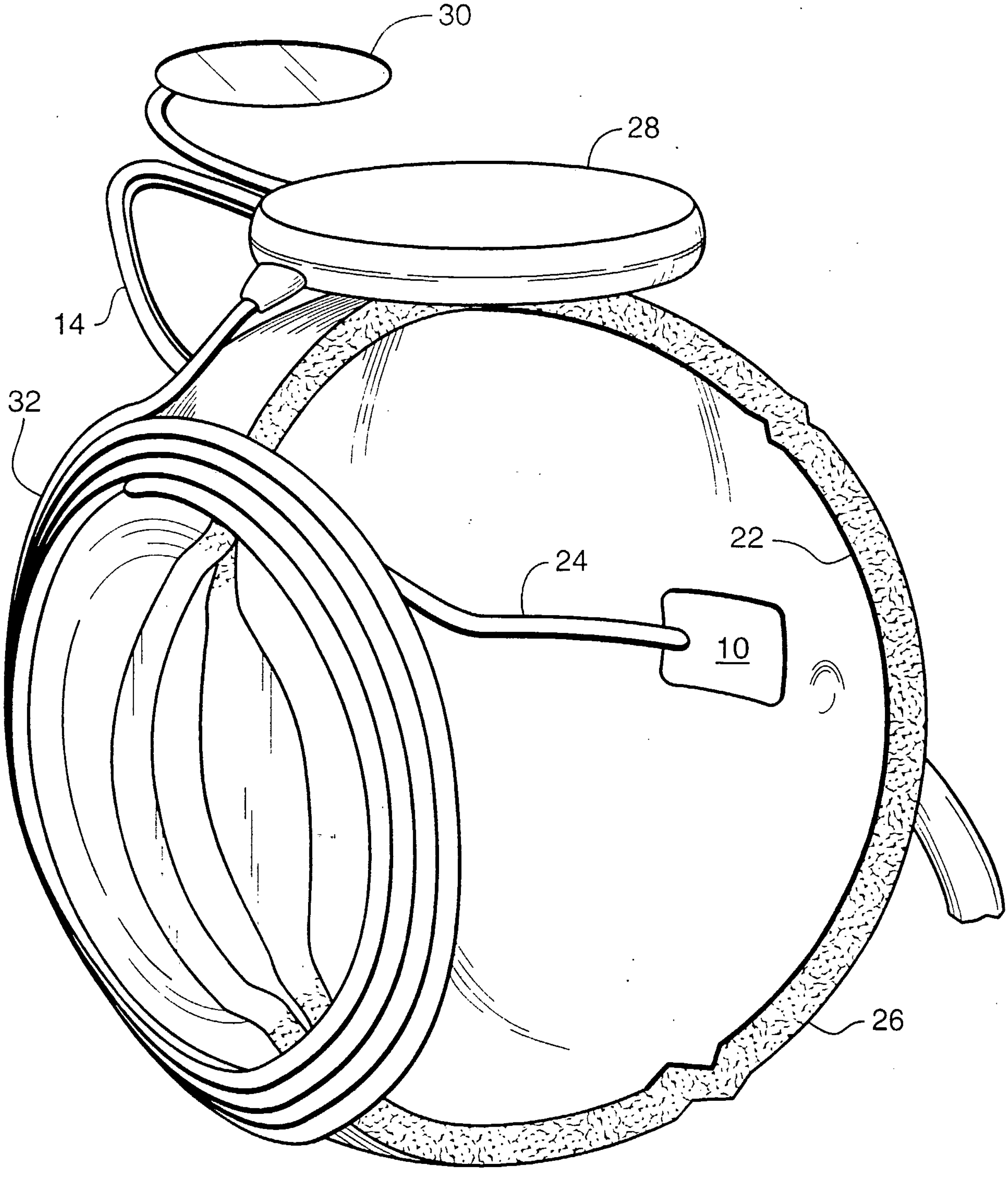

Fig. 2

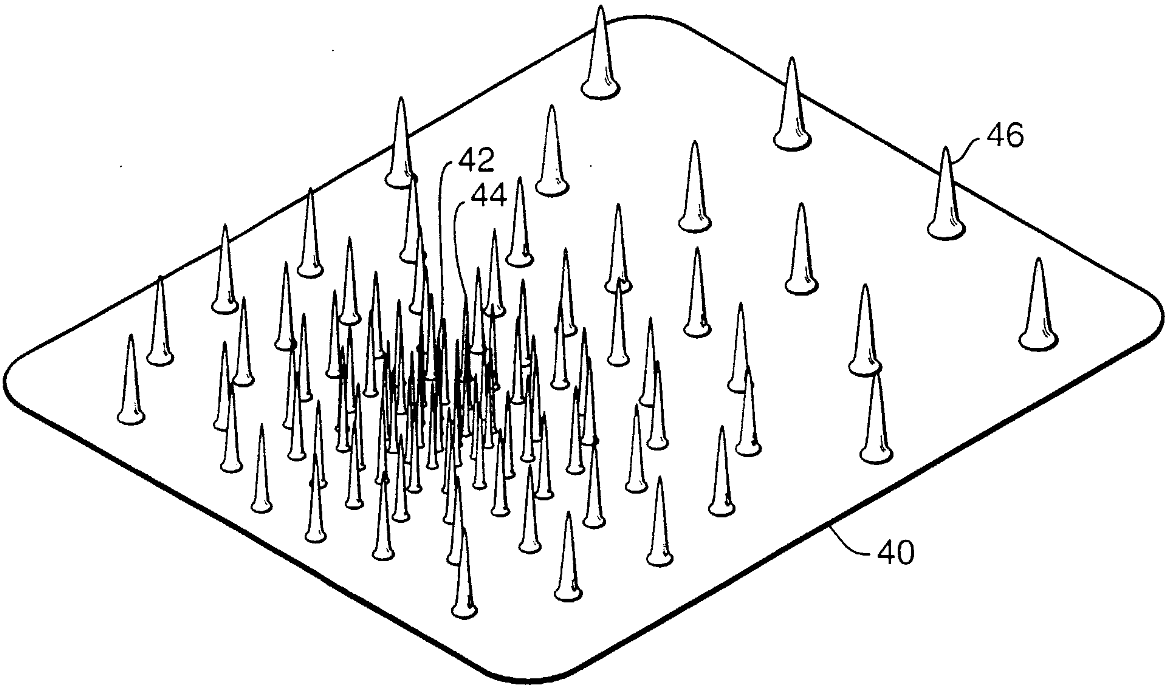

Fig. 3

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- US 3699970 A, Brindley **[0002]**
- US 4573481 A, Bullara **[0002]**
- US 4837049 A, Byers **[0002] [0005]**
- US 5215088 A, Norman **[0002]**
- US 5109844 A, de Juan **[0002]**
- US 5935155 A, Humayun **[0002]**
- US 5643330 A **[0005]**
- WO 9956818 A **[0005]**
- US 6091979 A **[0005]**

Non-patent literature cited in the description

- **DAVID H LIANG et al.** The Nerve-Electrode Interface of the Cochlear Implant: Current Spread. *IEEE TRANSACTIONS ON BIOMEDICAL ENGINEERING,* January 1999, vol. 46 (1 **[0005]**

专利名称(译)	可变间距电极阵列		
公开(公告)号	EP1494753B1	公开(公告)日	2016-02-24
申请号	EP2003716904	申请日	2003-03-28
[标]申请(专利权)人(译)	第二视力		
申请(专利权)人(译)	第二视力，LLC		
当前申请(专利权)人(译)	第二视力医疗产品，INC.		
[标]发明人	GREENBERG ROBERT WILLIAMSON RICHARD HUMAYAN MARK		
发明人	GREENBERG, ROBERT WILLIAMSON, RICHARD HUMAYAN, MARK		
IPC分类号	A61N1/05 A61B5/00		
CPC分类号	A61N1/0543 A61B2562/046 A61N1/05 A61N1/0531		
代理机构(译)	CARTER，STEPHEN JOHN		
优先权	10/112801 2002-03-28 US		
其他公开文献	EP1494753A1 EP1494753A4		
外部链接	Espacenet		

摘要(译)

本发明是一种可植入电极阵列，其具有可变间距和可变尺寸的电极。现有技术的电极阵列提供具有共同间隔和尺寸的电极。然而，这不是人体的排列方式。例如，视网膜在中央凹附近具有紧密间隔的视网膜受体。这些受体间隔得更远，远离中央凹。此外，刺激光感知所需的电流量随着距中央凹的距离而增加。因此，需要更大的电极来将必要的电流转移到远离中央凹的位置。

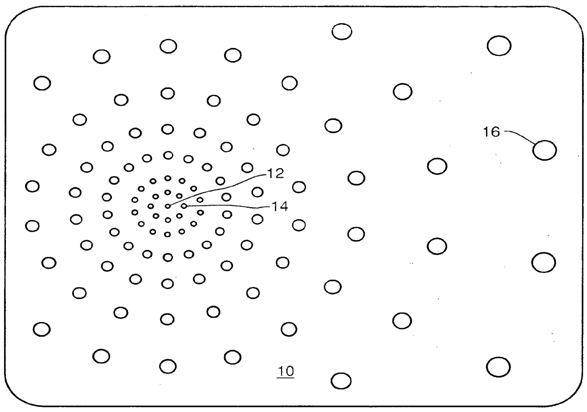

Fig. 1