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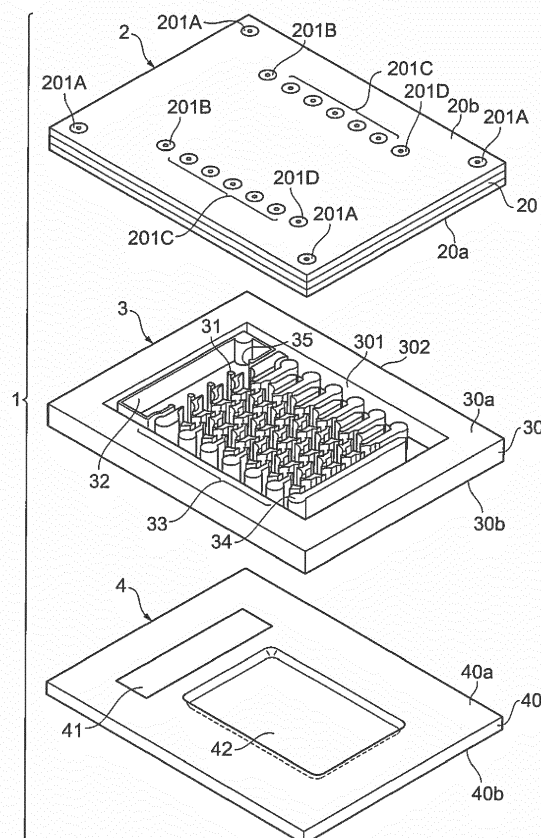
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(54) **PHOTOMULTIPLIER TUBE**

(57) The photomultiplier tube 1 is provided with an upper frame 2 and a lower frame 4 which are arranged so as to oppose each other, with the respective opposing surfaces 20a, 40a made with an insulating material, a side wall part 3 which constitutes a casing together with the frames 2, 4, a plurality of stages of electron multiplying parts 33 which are arrayed so as to be spaced away sequentially from a first end side to a second end side on the opposing surface 40a of the lower frame 4, a photocathode 41 which is installed on the first end side so as to be spaced away from the electron multiplying parts 33, converting incident light from outside to photoelectrons, an anode part 34 which is installed on the second end side so as to be spaced away from the electron multiplying parts 33 to take out electrons multiplied by the electron multiplying parts 33 as a signal, and a wall-like electrode 32 which is arranged so as to enclose the photocathode 41 when viewed from a direction directly opposite to an opposing surface 401 and having a notched part 35 at a site opposing the electron multiplying parts 33 on the second end side.

Fig.2



Description

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention relates to a photomultiplier tube for detecting incident light from outside.

Related Background Art

[0002] Conventionally, compact photomultiplier tubes by utilization of fine processing technology have been developed. For example, there is known a thin-type photomultiplier tube where a photocathode, dynodes, an anode, etc., are arranged on a substrate constituting a casing (refer to Patent Document 1 given below). The above-described structure makes it possible to realize fine processing of a device in a two-stage manufacturing process.

Patent Document 1: U.S. Patent No. 5,568,013

SUMMARY OF THE INVENTION

[0003] However, in the above-described conventional photomultiplier tube, there is a case where some of the photoelectrons emitted from the photocathode are not made incident onto electron multiplying parts but onto a side pipe, a substrate, etc., constituting the casing depending on a potential of the casing. Therefore, the photoelectrons are made incident away from the electron multiplying part, which is then the cause for a decrease in detection sensitivity.

[0004] Under these circumstances, the present invention has been made in view of the above problem, an object of which is to provide a photomultiplier tube capable of enhancing the detection sensitivity by causing photoelectrons emitted from a photocathode to be made efficiently incident onto electron multiplying parts.

[0005] In order to solve the above problem, the photomultiplier tube of the present invention is provided with a first substrate and a second substrate which are arranged so as to oppose each other, with the respective opposing surfaces made with an insulating material, a side wall part which constitutes a casing together with the first and the second substrates, a plurality of stages of electron multiplying parts which are arrayed so as to be spaced away sequentially from a first end side to a second end side on the opposing surface of the first substrate, a photocathode which is installed on the first end side so as to be spaced away from the electron multiplying parts, converting incident light from outside to photoelectrons to emit the photoelectrons, an anode part which is installed on the second end side so as to be spaced away from the electron multiplying parts to take out electrons multiplied by the electron multiplying parts as a signal, and a wall-like electrode which is arranged so as to enclose the photocathode when viewed from a direction

directly opposite to the opposing surface and having a notched part at a site opposing the electron multiplying parts on the second end side.

[0006] According to the above-described photomultiplier tube, incident light is made incident onto the photocathode, by which the light is converted to photoelectrons, these photoelectrons are made incident onto a plurality of stages of electron multiplying parts on the opposing surface of the first substrate and multiplied accordingly, and thus multiplied electrons are taken out from the anode part as an electric signal. Here, the photocathode is enclosed with the wall-like electrode when viewed from a direction directly opposite to the opposing surface of the substrate, and the notched part is formed on the second end side of the wall-like electrode. Therefore, photoelectrons from the photocathode are efficiently guided into the electron multiplying parts and, as a result, it is possible to enhance the detection sensitivity of incident light onto the photocathode.

[0007] It is preferable that the photocathode is electrically connected to the wall-like electrode. In this instance, since there is formed an electric field preferable in guiding photoelectrons from the photocathode into the electron multiplying parts, the photoelectrons can be efficiently guided into the electron multiplying parts to further enhance the detection sensitivity of incident light.

[0008] It is also preferable that the notched part is formed at a site corresponding to a region of electron multiplying channels of the electron multiplying parts. The above constitution makes it possible to guide more efficiently the photoelectrons into an electron multiplying region at the electron multiplying parts and further enhance the detection sensitivity of incident light.

[0009] Further, it is preferable that focusing electrodes for focusing photoelectrons emitted from the photocathode and guiding them into the electron multiplying parts are installed inside the notched part. In this instance, the photoelectrons can be guided more efficiently into the electron multiplying parts to further enhance the detection sensitivity of incident light.

[0010] It is also preferable that the wall-like electrode is provided with a connecting part for electrically connecting to the photocathode. Further, it is also preferable that there are provided conductive layers installed on the upper surface of the connecting part and at a part of the opposing surface, the connecting part is formed in a flat-plate shape which is thinner than a plate-like part enclosing the photocathode of the wall-like electrode, and the photocathode is installed on the opposing surface and on the conductive layers. In this instance, the wall-like electrode can be reliably electrically connected to the photocathode.

[0011] Still further, it is preferable that the conductive layer installed on the upper surface of the connecting part is electrically connected to the conductive layer installed at a part of the opposing surface by using a wire member made with a conductive material. In this instance, even where there is a bump between the con-

necting part and the photocathode, the wall-like electrode can be reliably electrically connected to the photocathode.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012]

Fig. 1 is a perspective view of a photomultiplier tube which is related to one preferred embodiment of the present invention.

Fig. 2 is an exploded perspective view of the photomultiplier tube shown in Fig. 1.

Fig. 3 is a plan view which shows a side wall frame of Fig. 1.

Fig. 4 (a) is a bottom view of an upper frame of Fig. 1 when viewed from the back surface side, and Fig. 4 (b) is a plan view of the side wall frame of Fig. 1.

Fig. 5 is a perspective view showing a state which connects the upper frame to the side wall frame as shown in Fig. 4.

Fig. 6 is an exploded perspective view which shows a photomultiplier tube related to a modified example of the present invention.

Fig. 7 is an exploded perspective view of a photomultiplier tube related to another modified example of the present invention.

Fig. 8 is an exploded perspective view of a photomultiplier tube related to still another modified example of the present invention.

Fig. 9 is an exploded perspective view of a photomultiplier tube related to a further modified example of the present invention.

Fig. 10 is a plan view of a side wall frame in which a wall-like electrode is removed from the side wall frame of Fig. 3.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0013] Hereinafter, a detailed description will be given for preferred embodiments of the photomultiplier tube related to the present invention by referring to drawings. In addition, in describing the drawings, the same or corresponding parts will be given the same reference numerals to omit overlapping description.

[0014] Fig. 1 is a perspective view of a photomultiplier tube 1 related to one preferred embodiment of the present invention. Fig. 2 is an exploded perspective view of the photomultiplier tube 1 shown in Fig. 1. Fig. 3 is a plan view of the side wall frame 3 of Fig. 1.

[0015] The photomultiplier tube 1 shown in Fig. 1 is a photomultiplier tube having a transmission-type photocathode and provided with a casing constituted with an upper frame (a second substrate) 2, a side wall frame (a side wall part) 3, and a lower frame (a first substrate) 4 which opposes the upper frame 2, with the side wall frame 3 kept therebetween. The photomultiplier tube 1 is an electron tube such that when light is made incident from

a direction at which a light incident direction onto the photocathode intersects with a direction at which electrons are multiplied at electron multiplying parts, that is, a direction indicated by the arrow A in Fig. 1, photoelectrons emitted from the photocathode are made incident onto the electron multiplying parts, thereby secondary electrons are subjected to cascade amplification in a direction indicated by the arrow B to take out a signal from the anode part.

[0016] It is noted that in the following description, the upstream side of an electron multiplying channel (the side of the photocathode) along a direction at which electrons are multiplied is given as "a first end side," while the downstream side (the side of the anode part) is given as "a second end side." Further, a detailed description will be given for individual constituents of the photomultiplier tube 1.

[0017] As shown in Fig. 2, the upper frame 2 is constituted with a wiring substrate 20 made mainly with rectangular flat-plate like insulating ceramics as a base material. As the above-described wiring substrate, there is used a multilayer wiring substrate such as LTCC (low temperature co-fired ceramics) in which microscopic wiring can be designed and also wiring patterns on front-back both sides can be freely designed. The wiring substrate 20 is provided on a main surface 20b thereof with a plurality of conductive terminals 2D1A to 2D1D electrically connected to the side wall frame 3, a photocathode 41, focusing electrodes 31, a wall-like electrode 32, electron multiplying parts 33, and the anode part 34 which are described later, to supply power from outside and take out a signal. The conductive terminal 2D1A is installed for supplying power to the side wall frame 3, the conductive terminal 2D1B for supplying power to the photocathode 41, the focusing electrodes 31 and the wall-like electrode 32, the conductive terminal 2D1C for supplying power to the electron multiplying parts 33, and the conductive terminal 2D1D for supplying power to the anode part 34 and taking out a signal respectively. These conductive terminals 2D1A to 2D1D are mutually connected to conductive layers and the conductive terminals (details will be described later) on an insulating opposing surface 20a which opposes the main surface 20b inside the wiring substrate 20, by which these conductive layers and the conductive terminals are connected to the side wall frame 3, the photocathode 41, the focusing electrodes 31, the wall-like electrode 32, the electron multiplying parts 33 and the anode part 34. Further, the upper frame 2 is not limited to a multilayer wiring substrate having the conductive terminals 2D1 but may include a plate-like member made with an insulating material such as a glass substrate on which conductive terminals for supplying power from outside and taking out a signal are installed so as to penetrate.

[0018] The side wall frame 3 is constituted with a rectangular flat-plate like silicon substrate 30 as a base material. A penetration part 301 enclosed by a frame-like side wall part 302 is formed from a main surface 30a of

the silicon substrate 30 toward an opposing surface 30b thereto. The penetration part 301 is provided with a rectangular opening and an outer periphery of which is formed so as to run along the outer periphery of the silicon substrate 30.

[0019] Inside the penetration part 301, the wall-like electrode 32, the focusing electrodes 31, the electron multiplying parts 33 and the anode part 34 are arranged from the first end side to the second end side. The wall-like electrode 32, the focusing electrodes 31, the electron multiplying parts 33 and the anode part 34 are formed by processing the silicon substrate 30 according to RIE (Reactive Ion Etching) processing, etc., and mainly made with silicon.

[0020] The wall-like electrode 32 is a frame-like electrode which is formed so as to enclose a photocathode 41 to be described later when viewed from a direction completely opposite to an opposing surface 40a of the glass substrate 40 to be described later (a direction approximately perpendicular to the opposing surface 40a and a direction opposite to a direction indicated by the arrow A of Fig. 1). Further, the focusing electrode 31 is an electrode for focusing photoelectrons emitted from the photocathode 41 and guiding them to the electron multiplying parts 33 and installed between the photocathode 41 and the electron multiplying parts 33.

[0021] The electron multiplying parts 33 are constituted with N stages (N denotes an integer of two or more) of dynodes (electron multiplying parts) set different in potential along a direction at which electrons are multiplied from the photocathode 41 to the anode part 34 and provided with a plurality of electron multiplying channels (electron multiplying channels) so as to be astride individual stages. Further, the anode part 34 is arranged at a position holding the electron multiplying parts 33 together with the photocathode 41.

[0022] The wall-like electrode 32, the focusing electrodes 31, the electron multiplying parts 33 and the anode part 34 are individually fixed to the lower frame 4 by anode bonding, diffusion joining and joining, etc., using a sealing material such as a low-melting-point metal (for example, indium), by which they are arranged on the lower frame 4 two-dimensionally.

[0023] The lower frame 4 is constituted with the rectangular flat-plate like glass substrate 40 as a base material. The glass substrate 40 forms an opposing surface 40a which opposes the opposing surface 20a of the wiring substrate 20, by use of glass which is an insulating material. The photocathode 41 which is a transmission-type photocathode is formed at a site opposing a penetration part 301 of the side wall frame 3 on the opposing surface 40a (a site other than a joining region with a side wall part 302) and at the end part opposite to the side of the anode part 34. Further, a rectangular recessed part 42 which prevents multiplied electrons from being made incident onto the opposing surface 40a is formed at a site where the electron multiplying parts 33 and the anode part 34 on the opposing surface 40a are loaded.

[0024] A further detailed description will be given for an internal structure of the photomultiplier tube 1 by referring to Fig. 3. The electron multiplying parts 33 inside the penetration part 301 are constituted with a plurality of stages of dynodes arrayed so as to be spaced away sequentially from the first end side to the second end side on the opposing surface 40a (in a direction indicated by the arrow B which is a direction at which electrons are multiplied). The plurality of stages of dynodes are provided in parallel with a plurality of electron multiplying channels C constituted with the N number of electron multiplying holes installed so as to continue along a direction indicated by the arrow B from a 1st stage dynode 33a on the first end side to a final stage (the Nth stage) dynode 33b on the second end side.

[0025] Further, the photocathode 41 is installed so as to be spaced away from the 1st stage dynode 33a on the first end side to the first end side on the opposing surface 40a behind the focusing electrode 31. The photocathode 41 is formed on the opposing surface 40a of the glass substrate 40 as a rectangular transmission-type photocathode. When incident light transmitted from outside through the glass substrate 40, which is the lower frame 4, arrives at the photocathode 41, photoelectrons corresponding to the incident light are emitted, and the photoelectrons are guided into the 1st stage dynode 33a by the wall-like electrode 32 and the focusing electrodes 31.

[0026] Further, the anode part 34 is installed so as to be spaced away from the final stage dynode 33b on the second end side to the second end side on the opposing surface 40a. The anode part 34 is an electrode for taking outside electrons multiplied inside the electron multiplying channels C of the electron multiplying parts 33 in a direction indicated by the arrow B as an electric signal.

[0027] Still further, the wall-like electrode 32 is a rectangular frame-like electrode constituted with a plurality of plate-like parts 32a extending substantially in a perpendicular direction only by as thick as the side wall part 302 inside the penetration part 301 so as to run along the inner wall of the side wall part 302 from the opposing surface 40a to the upper frame 2 and installed upright on the opposing surface 40a in a state that encloses a region of forming the photocathode 41 on the opposing surface 40a. An approximately rectangular notched part 35 which has been notched is formed at a site which is the second end side wall part of the wall-like electrode 32 and opposes a region where the electron multiplying channel C is formed at the 1st stage dynode 33a. Then, a columnar focusing electrode 31 is formed so as to extend substantially in a perpendicular direction from a thin plate-like member 35a installed so as to connect both end parts of the notched part 35 on the opposing surface 40a to the side of the upper frame 2. It is noted that in the present embodiment, the wall-like electrode 32, the thin plate-like member 35a and the focusing electrodes 31 are formed in an integrated manner. However, they may be formed individually.

[0028] Next, a description will be given for a wiring

structure of the photomultiplier tube 1 by referring to Fig. 4 and Fig. 5. In Fig. 4, (a) is a bottom view when the upper frame 2 is viewed from the side of a back surface 20a, and (b) is a plan view of the side wall frame 3. Fig. 5 is a perspective view which shows a state connecting the upper frame 2 with the side wall frame 3.

[0029] As shown in Fig. 4(a), the back surface 20a of the upper frame 2 is provided with a plurality of conductive layers 202 electrically connected to the respective conductive terminals 201B, 201C, 201D inside the upper frame 2, and a conductive terminal 203 electrically connected to the conductive terminal 201A inside the upper frame 2. Further, as shown in Fig. 4(b), power supplying parts 36, 37 for connecting to the conductive layers 202 are installed upright respectively at the end parts of the electron multiplying parts 33 and the anode part 34, and a power supplying part 38 for connecting to the conductive layers 202 is installed upright at a corner of the wall-like electrode 32. Still further, the focusing electrodes 31 are integrated with wall-like electrode 32 on the lower frame 4 side, together with the thin plate-like member 35a, thereby electrically connected to the wall-like electrode 32. In addition, a rectangular flat-plate like connecting part 39 which is thinner than the plate-like part 32a of the wall-like electrode 32 is formed in an integrated manner at the wall-like electrode 32 on the opposing surface 40a side of the lower frame 4. A conductive layer 39a made with a conductive material such as aluminum is formed so as to continue to a part of the opposing surface 40a from the upper surface of the connecting part 39. Further, since there is a bump between the connecting part 39 and the opposing surface 40a, the continuity is discontinued at the bump portion which may result in the possibility that the conductive layer 39a on the connecting part 39 may not be electrically connected to the conductive layer 39a on the opposing surface 40a. Therefore, the conductive layer 39a on the connecting part 39 and the conductive layer 39a on the opposing surface 40a are wire-bonded by using a wire (a wire member) 39b made with a conductive material such as gold (Au), by which the conductive layer 39a is made equal in potential as a whole. Then, the photocathode 41 formed on the opposing surface 40a enclosed with the wall-like electrode 32 is formed also on the conductive layer 39a and the wire 39b, by which the wall-like electrode 32 is reliably electrically connected to the photocathode 41. It is noted that when the photocathode is formed also on an inner wall surface of the wall-like electrode 32, that is, on the surface of the plate-like part 32a on the side of the photocathode 41, it functions as a reflection-type photocathode as well. In this instance, for example, light which is transmitted without being converted to electrons by the photocathode 41 is subjected to photoelectric conversion, thus making it possible to detect the light more efficiently.

[0030] The above constituted upper frame 2 and the side wall frame 3 are joined, by which the conductive terminal 203 is electrically connected to the side wall part

302 of the side wall frame 3. Also, the power supplying part 36 of the electron multiplying part 33, the power supplying part 37 of the anode part 34 and the power supplying part 38 of the wall-like electrode 32 are respectively connected to the corresponding conductive layers 202 independently via conductive members made with gold (Au), etc. The above-described connecting structure makes it possible to electrically connect the side wall part 302, the electron multiplying part 33 and the anode part 34 respectively to the conductive terminals 201A, 201C, 201D. Also, the wall-like electrode 32 is electrically connected to the conductive terminal 201B together with the focusing electrodes 31 and the photocathode 41 (Fig. 5).

[0031] According to the photomultiplier tube 1 which has been so far described, incident light is transmitted through the lower frame 4 and made incident onto the photocathode 41, thereby converted to photoelectrons, and the photoelectrons are made incident onto the plurality of stages of electron multiplying parts 33 on the opposing surface 40a of the lower frame 4 and multiplied accordingly, and the multiplied electrons are taken out from the anode part 34 as an electric signal. Here, the photocathode 41 is enclosed by the wall-like electrode 32, when viewed from a direction directly opposite to the opposing surface 40a, and the notched part 35 is formed on the second end side of the wall-like electrode 32. Therefore, the photoelectrons from the photocathode 41 are prevented from being made incident onto the casing such as the side wall frame 3 and the photoelectrons are guided efficiently into the electron multiplying part 33. As a result, it is possible to enhance the detection sensitivity of incident light onto the photocathode 41.

[0032] Here, effects of the present embodiment will be described in detail by referring to Fig. 3 and Fig. 10. Fig. 10 is a plan view of the side wall frame 903 in which the wall-like electrode 32 is removed from the side wall frame 3 shown in Fig. 3. Where a side wall frame 903 is used, photoelectrons generated from the photocathode 41 by incident light are mostly made incident onto the 1st stage dynode 33a, but a portion is guided in directions to the side wall part 302 (directions indicated by the arrows E_1 , E_2 in Fig. 10) and may not contribute to the detection of a signal. This will be made more apparent in a state that the potential of the side wall part 302 is not stable. In addition, of the photoelectrons generated from the photocathode 41, those from a region closer to the side wall part 302 are influenced to a greater extent by the side wall part 302. That is, within the photocathode 41, a region less influenced by the side wall part 302 is a substantially effective region, and therefore, a substantially effective area of the photocathode 41 is decreased. In order to cope with the above problem, there is an idea that a potential equal to that of the photocathode 41 is given to the side wall part 302. However, in this instance, there is a greater difference in potential among the side wall part 302, the electron multiplying part 33 and the anode part 34, which may result in a failure of withstand voltage. This problem is apparent in particular at the an-

ode part 34 and then more apparent at a further subsequent stage of the electron multiplying parts 33. In order to prevent such a withstand voltage failure, it is necessary to secure a sufficient space. As a result, there is an increase in area of a material used in manufacturing one chip, which may result in an increase in cost. Further, there is a case that light may be emitted at the second end side inside the penetration part 301, etc., by collision of multiplied secondary electrons against an insulating body. When the light advances as indicated by the arrow E_3 and arrives at the photocathode 41, photoelectrons which are not related to incident light are emitted and there is a concern that noise will be generated in a detection signal to decrease an SN ratio.

[0033] On the other hand, in the present embodiment, photoelectrons generated from the photocathode 41 can be efficiently made incident onto the 1st stage dynode 33a (a direction indicated by the arrow E_4 in Fig. 3), irrespective of a potential of the side wall part 302, due to the presence of the wall-like electrode 32 which is set to be stable in potential. Further, even when the light generated on the second end side, etc., inside the penetration part 301 advances in a direction toward the photocathode 41 (a direction indicated by the arrow E_5 in Fig. 3), the light can be blocked by the wall-like electrode 32 and prevented from being made incident onto the photocathode 41. Thereby, it is possible to maintain the detection sensitivity when a potential of the side wall part 302 is set to be free and also enhance an SN ratio by improving noise characteristics. For example, the side wall part 302 is set to be a ground potential as a desired potential, thus making it possible to enhance electric noise characteristics of the photomultiplier tube 1. In particular, a noise-reduction effect can be maximized by being set to the ground potential and a possible risk of electrification of humans can be also decreased. Further, since a region enclosed by the wall-like electrode 32 is a substantially effective region of the photocathode, an appropriate light incident region can be easily specified when the photomultiplier tube 1 is viewed from outside.

[0034] Further, the photocathode 41 is electrically connected to the wall-like electrode 32 and set to be equal in potential. Therefore, there is formed an electric field where photoelectrons from the photocathode 41 are favorably guided into the electron multiplying part 33 without being made incident onto the wall-like electrode 32, by which the detection sensitivity is further enhanced.

[0035] Still further, the notched part 35 of the wall-like electrode 32 is formed at a site opposing a region of the electron multiplying channels C of the electron multiplying parts 33, by which photoelectrons guided into the electron multiplying parts 33 can be efficiently multiplied to further enhance the detection sensitivity of incident light.

[0036] It is noted that the present invention shall not be limited to the embodiments so far described. For example, as shown in a photomultiplier tube 1 A in Fig. 6, which is a modified example of the present invention, a

photocathode 41 A may be installed on the back surface (an opposing surface 50a) side of an upper frame 2A. In this instance, as the upper frame 2A, that in which power supplying terminals are buried into a translucent insulating substrate such as a glass substrate can be used. As a lower frame 4A, various insulating substrates can be used other than a glass substrate. Then, a wall-like electrode 32 is arranged so as to enclose the photocathode 41 A when viewed from a direction directly opposite to the opposing surface 50a of the upper frame 2A (a direction approximately perpendicular to the opposing surface 50a).

[0037] Further, as shown in a photomultiplier tube 1B in Fig. 7, which is a modified example of the present invention, the photocathode may be a reflection-type photocathode. For example, a translucent insulating substrate is used as an upper frame 2B and an inclined surface which is inclined to the second end side with respect to an opposing surface 40a is formed inside a wall-like electrode 32B of a side wall frame 3B. A photocathode 41B is formed from the inclined surface to the opposing surface 40a. A configuration of the inclined surface may include a flat surface or a curved surface as long as it is such a configuration that photoelectrons generated from the photocathode 41B by incident light which has been transmitted through the upper frame 2B move toward electron multiplying parts 33.

[0038] Further, various modified modes can be adopted in a wiring structure of the present embodiment. For example, as shown in Fig. 8, such a structure may be provided that conductive terminals 401 are formed so as to penetrate through the lower frame 4C, and power is supplied via the conductive terminals 401 to the photocathode 41, the wall-like electrode 32, the focusing electrodes 31, the electron multiplying parts 33 and the anode part 34. This structure makes it possible to supply power independently to the conductive layers 202 (Fig. 4(a)) formed on the upper frame 2 and each of the electrodes.

[0039] Still further, as shown in Fig. 9, the lower frame 4C having the conductive terminals 401 may be combined with the upper frame 2C from which the conductive terminals 201 A to 201 D are removed. In this instance, an insulating substrate having a plurality of conductive layers 202 on the back surface side is used as the upper frame 2C. The wiring structure described by referring to Fig. 4 is used in the above combination, thus making it possible to supply power from the conductive terminals 401 of the lower frame 4C to the conductive layers 202 of the upper frame 2C via the wall-like electrode 32, the electron multiplying parts 33 and the anode part 34.

[0040] In addition, in any of the embodiments and the modified examples, it is not always necessary that the wall-like electrode 32 encloses the photocathode 41 as a whole, but may be arranged so as not to enclose an edge part if it encloses a substantially effective region that can guide emitted photoelectrons into the electron multiplying parts 33.

PREFERRED EMBODIMENTS OF THE INVENTION
COMPRISE THE FOLLOW FEATURES:

[0041]

1. A photomultiplier tube comprising:

a first substrate and a second substrate which are arranged so as to oppose each other, with the respective opposing surfaces made with an insulating material;

a side wall part which constitutes a casing together with the first and the second substrates; a plurality of stages of electron multiplying parts which are arrayed so as to be spaced away sequentially from a first end side to a second end side on the opposing surface of the first substrate;

a photocathode which is installed on the first end side so as to be spaced away from the electron multiplying parts, converting incident light from outside to photoelectrons to emit the photoelectrons;

an anode part which is installed on the second end side so as to be spaced away from the electron multiplying parts to take out electrons multiplied by the electron multiplying parts as a signal; and

a wall-like electrode which is arranged so as to enclose the photocathode when viewed from a direction directly opposite to the opposing surface, having a notched part at a site opposing the electron multiplying parts on the second end side, and electrically connected to the photocathode.

2. The photomultiplier tube according to embodiment 1, wherein

the notched part is formed at a site corresponding to a region of electron multiplying channels of the electron multiplying parts.

3. The photomultiplier tube according to embodiment 1, wherein

focusing electrodes for guiding the photoelectrons emitted from the photocathode into the electron multiplying parts are installed inside the notched part.

4. The photomultiplier tube according to embodiment 1, wherein

a connecting part for electrically connecting to the photocathode is installed at the wall-like electrode.

5. The photomultiplier tube according to embodiment 4 which is further provided with conductive layers installed on the upper surface of the connecting part and at a part of the opposing surface, wherein the connecting part is formed in a flat-plate shape which is thinner than a plate-like part enclosing the photocathode of the wall-like electrode, and the photocathode is installed on the opposing sur-

face and on the conductive layers.

6. The photomultiplier tube according to embodiment 5, wherein

the conductive layer on the upper surface of the connecting part is electrically connected to the conductive layer installed at a part of the opposing surface by using a wire member made with a conductive material.

Claims

1. A photomultiplier tube comprising:

a first substrate and a second substrate which are arranged so as to oppose each other, with the respective opposing surfaces made with an insulating material;

a side wall part which constitutes a casing together with the first and the second substrates; a plurality of stages of electron multiplying parts which are arrayed so as to be spaced away sequentially from a first end side to a second end side on the opposing surface of the first substrate;

a photocathode which is installed on the first end side so as to be spaced away from the electron multiplying parts, converting incident light from outside to photoelectrons to emit the photoelectrons;

an anode part which is installed on the second end side so as to be spaced away from the electron multiplying parts to take out electrons multiplied by the electron multiplying parts as a signal; and

a wall-like electrode which is arranged so as to enclose a region of forming the photocathode along the edge of the region when viewed from a direction directly opposite to the opposing surface, having a notched part at a site opposing the electron multiplying parts on the second end side, and electrically connected to the photocathode,

wherein focusing electrodes for guiding the photoelectrons emitted from the photocathode into the electron multiplying parts are installed inside the notched part.

2. The photomultiplier tube according to claim 1, wherein the notched part is formed at a site corresponding to a region of electron multiplying channels of the electron multiplying parts.

3. The photomultiplier tube according to claim 1, wherein a connecting part for electrically connecting to the photocathode is installed at the wall-like electrode.

4. The photomultiplier tube according to claim 3 which

is further provided with conductive layers installed on the upper surface of the connecting part and at a part of the opposing surface, wherein the connecting part is formed in a flat-plate shape which is thinner than a plate-like part enclosing the photocathode of the wall-like electrode, and the photocathode is installed on the opposing surface and on the conductive layers.

5. The photomultiplier tube according to claim 4, wherein the conductive layer on the upper surface of the connecting part is electrically connected to the conductive layer installed at a part of the opposing surface by using a wire member made with a conductive material. 5 10 15
6. The photomultiplier tube according to any one of claims 1 to 5, wherein a conductive layer is installed on the opposing surface so as to be opposed to the photocathode. 20
7. The photomultiplier tube according to claim 6, wherein the wall-like electrode is electrically connected to the conductive layer. 25
8. The photomultiplier tube according to any one of claims 1 to 7, wherein the wall-like electrode is made with silicon.
9. The photomultiplier tube according to claim 6 or 7, wherein a power supplying part for connecting to the conductive layer is installed upright at a corner of the wall-like electrode. 30
10. The photomultiplier tube according to any one of claims 1 to 9, wherein the focusing electrodes are formed so as to extend substantially in a direction perpendicular to the opposing surface from a thin plate-like member installed so as to connect both end parts of the notched part. 35 40
11. The photomultiplier tube according to any one of claims 1 to 10, wherein a flat-plate like connecting part is formed at the wall-like electrode for electrically connecting to the photocathode via a conductive layer. 45

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Fig.1

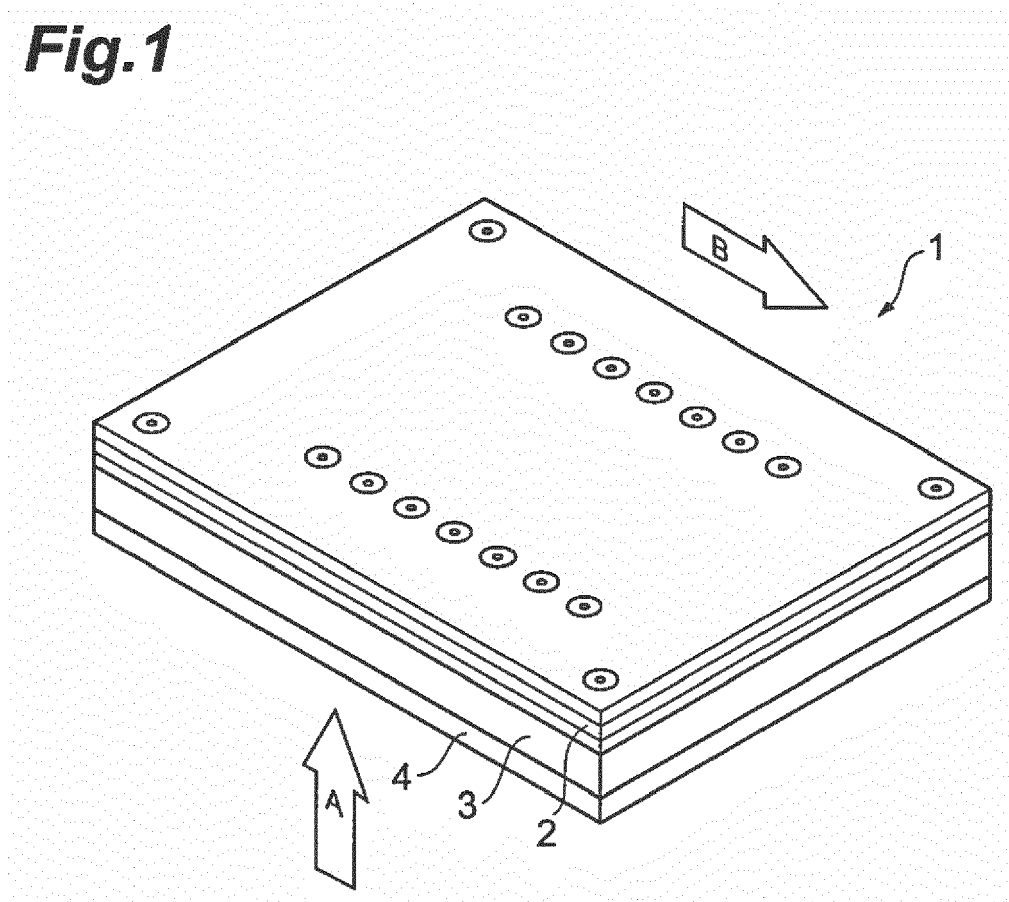


Fig.2

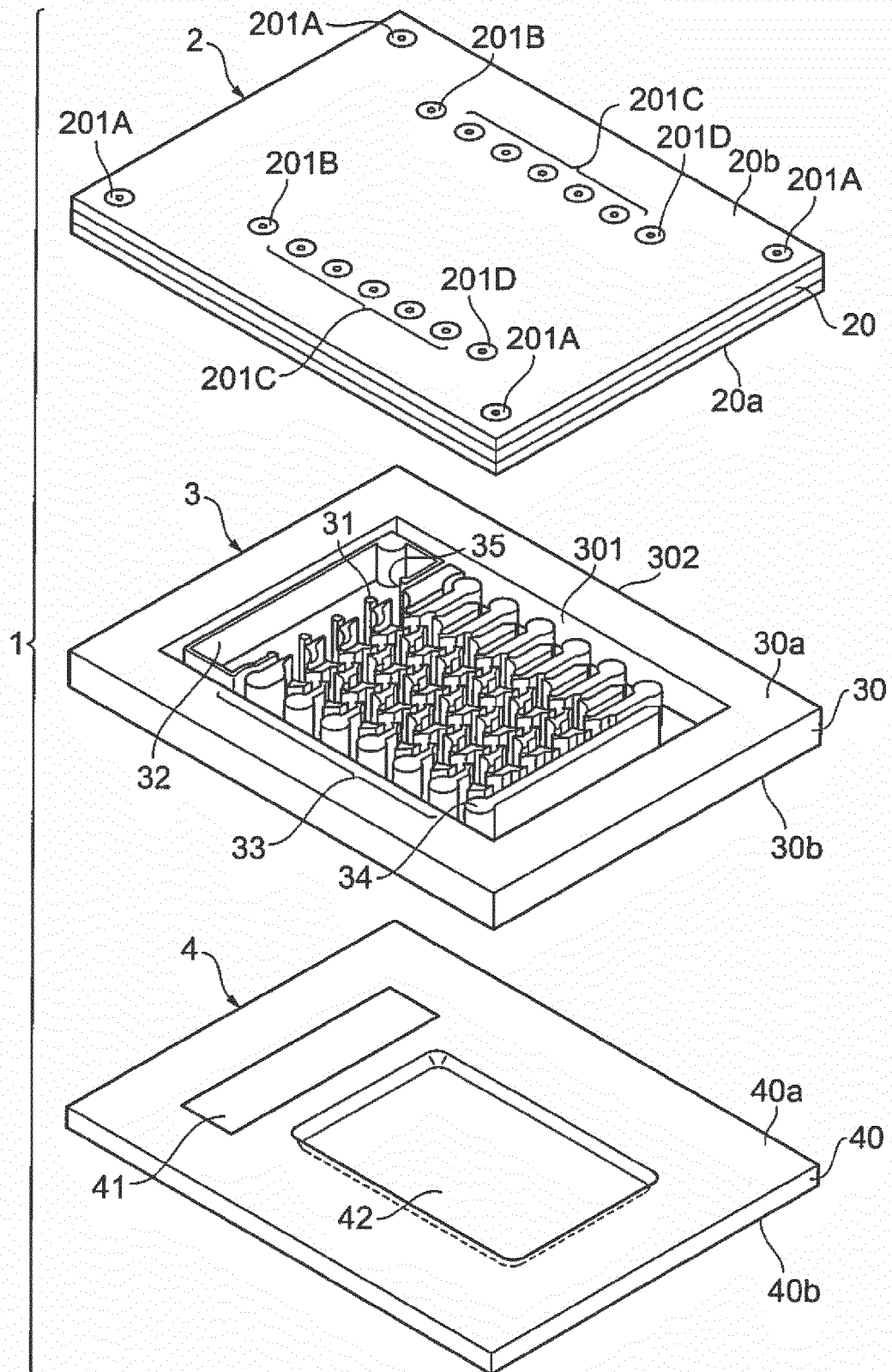


Fig.3

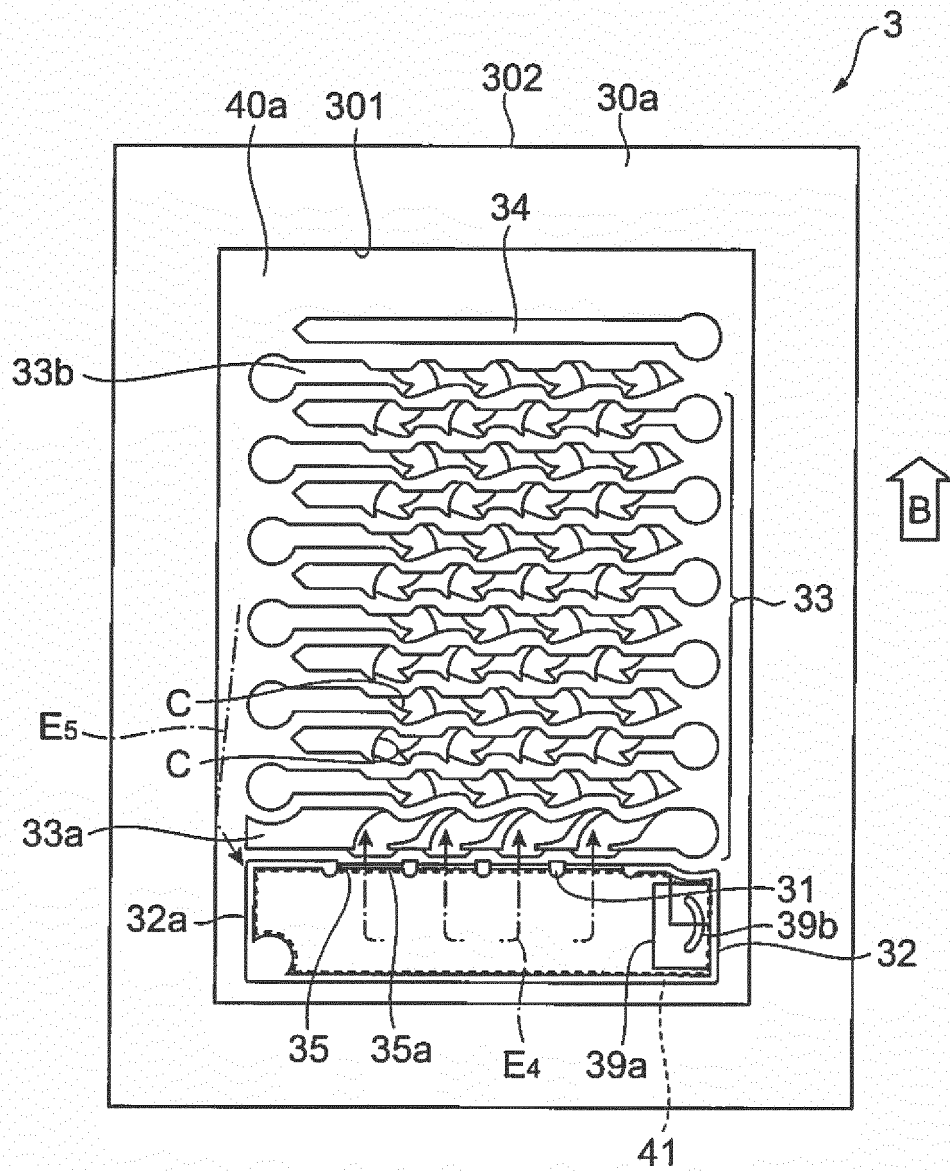


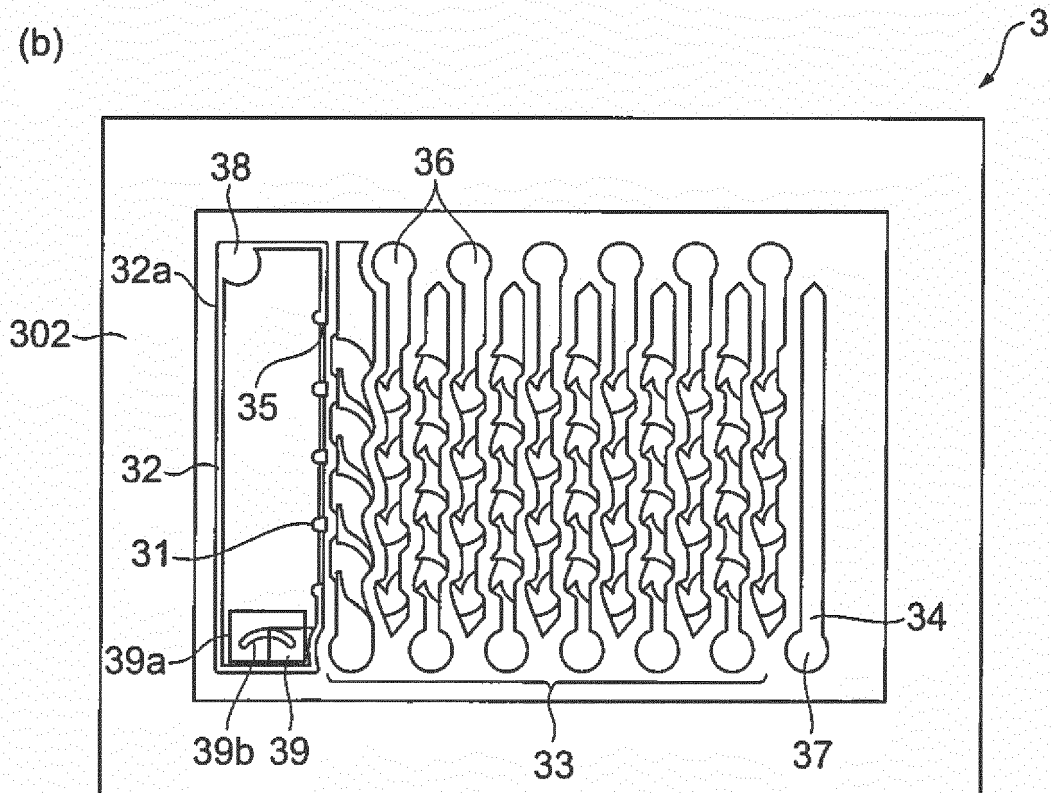
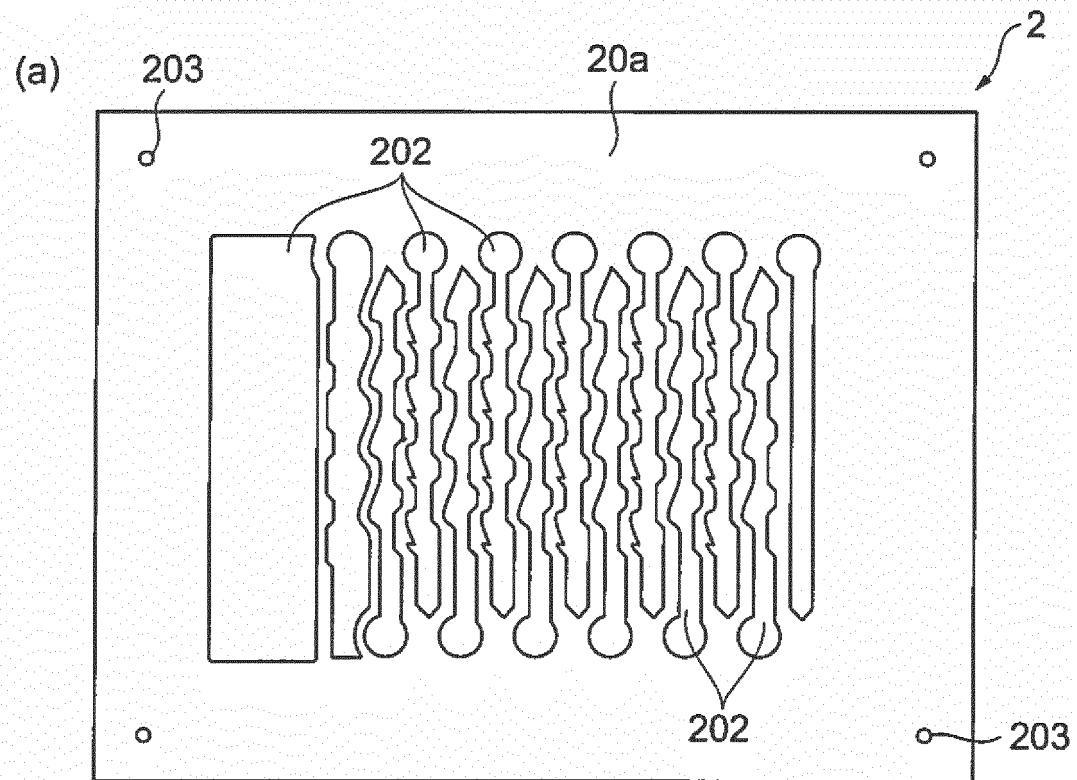
Fig.4

Fig.5

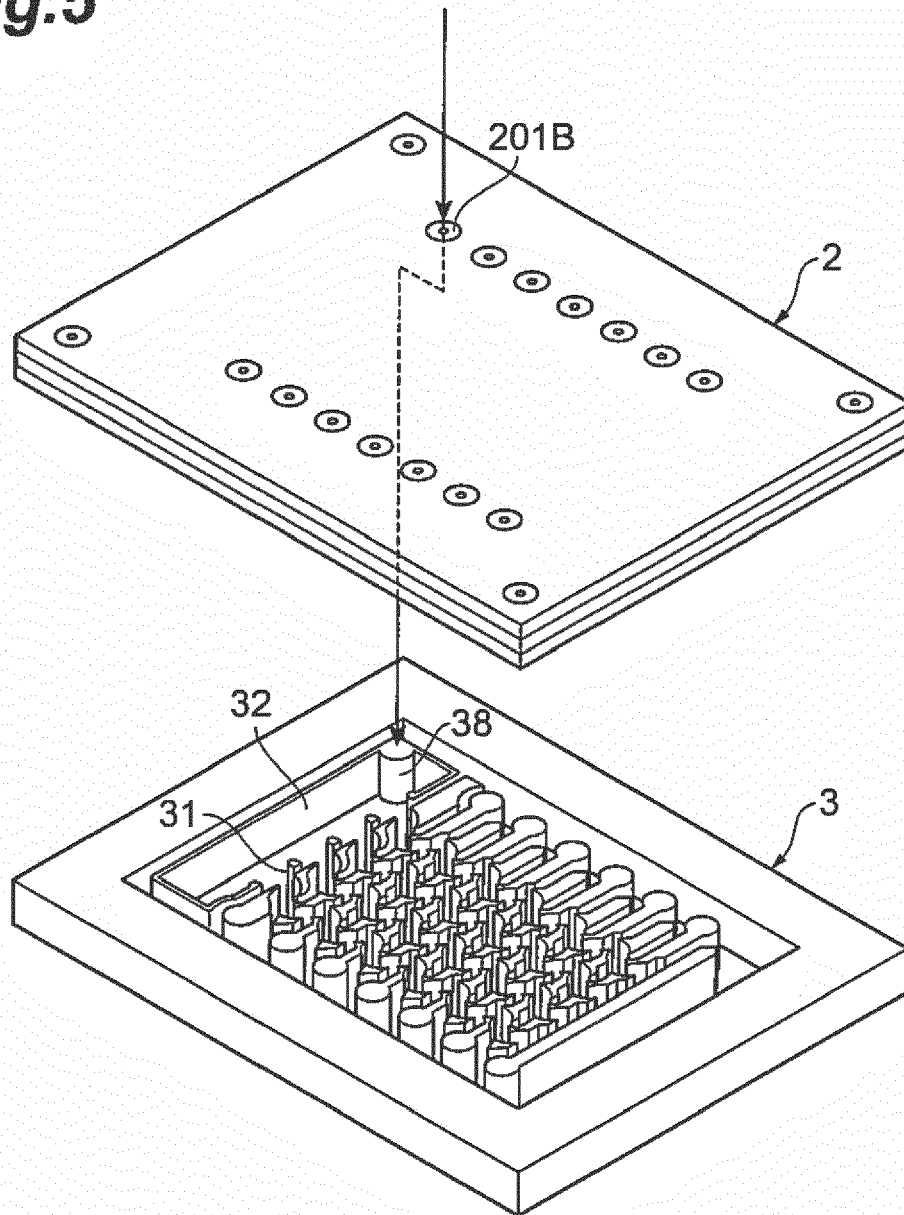


Fig.6

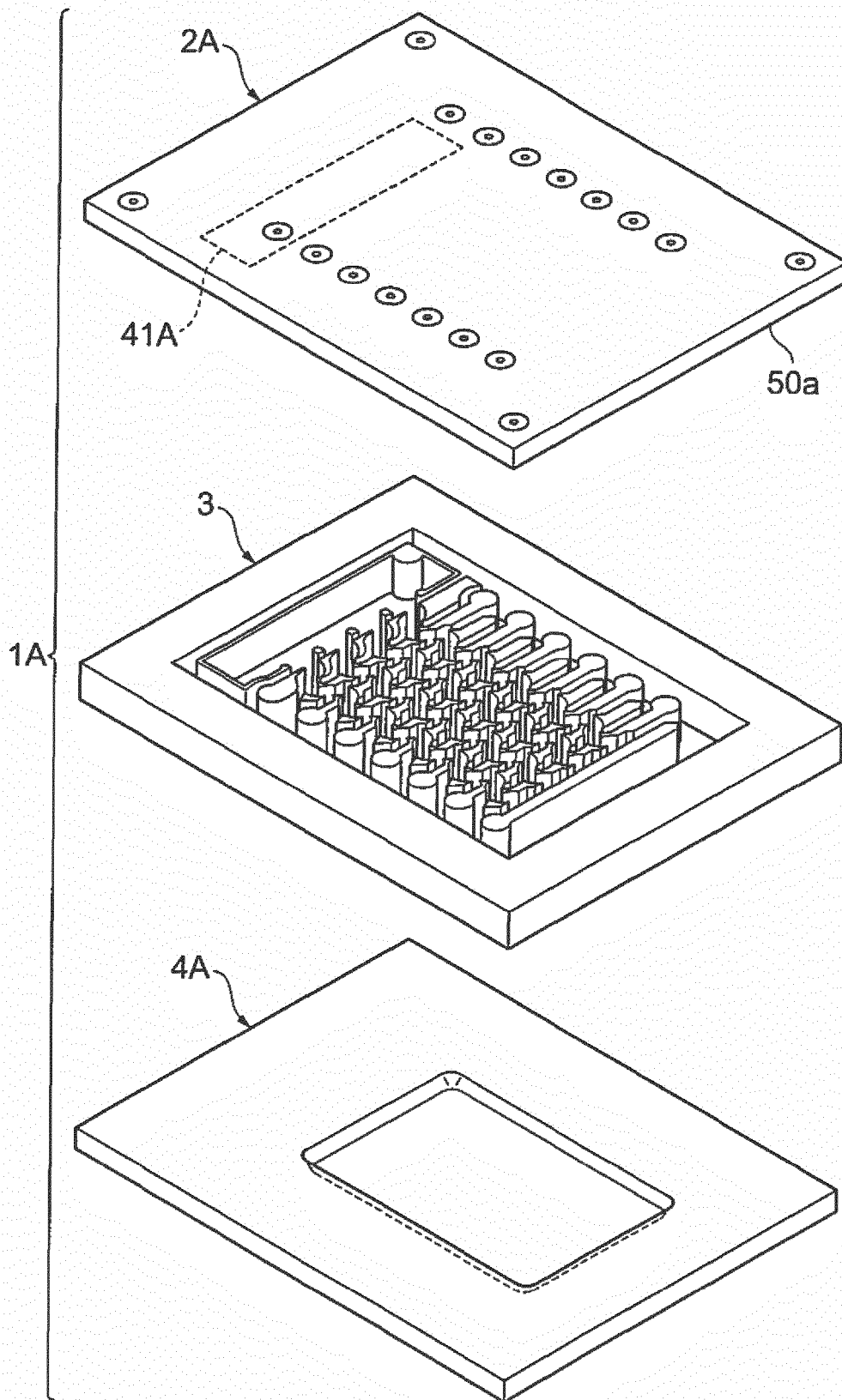


Fig.7

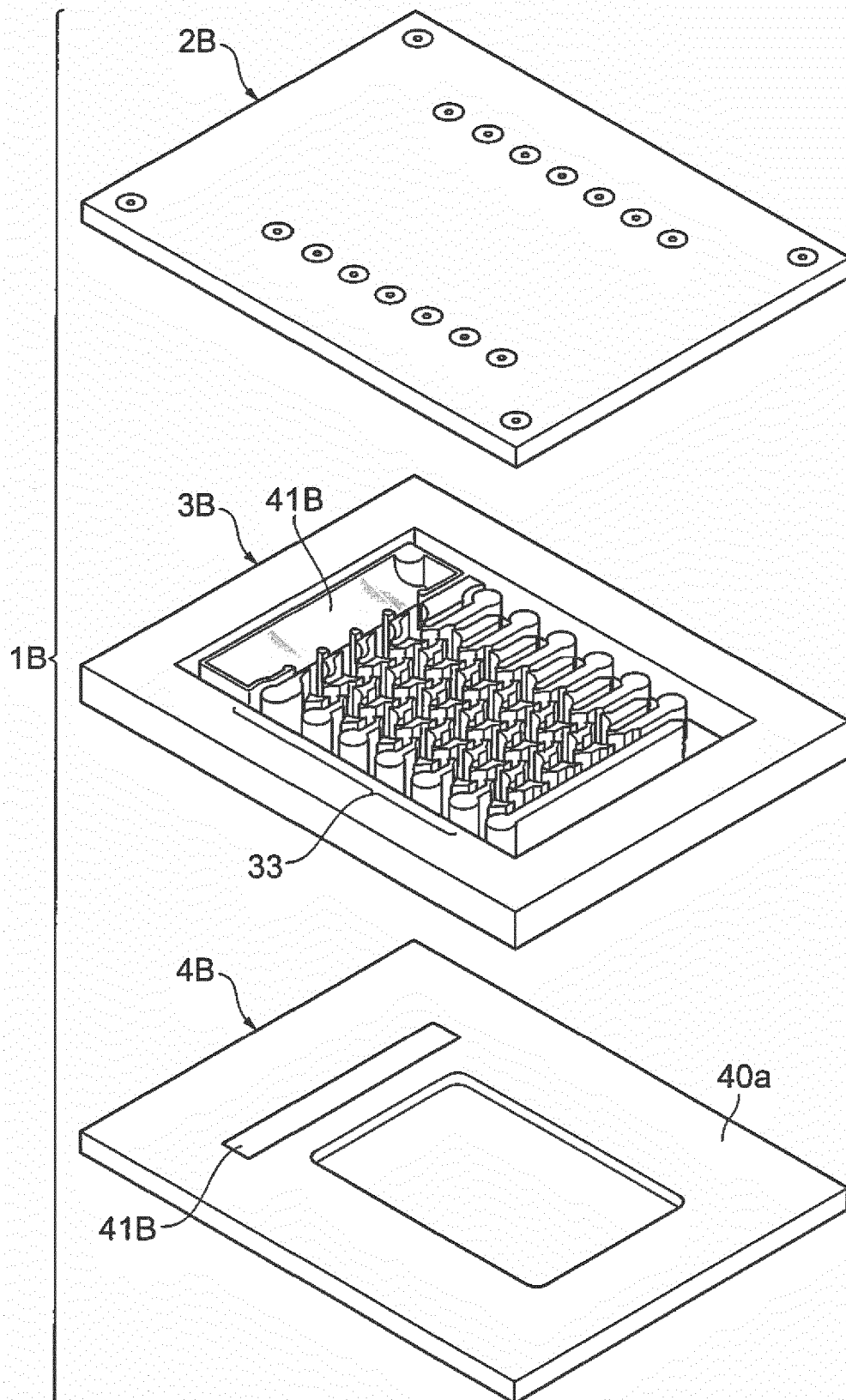


Fig.8

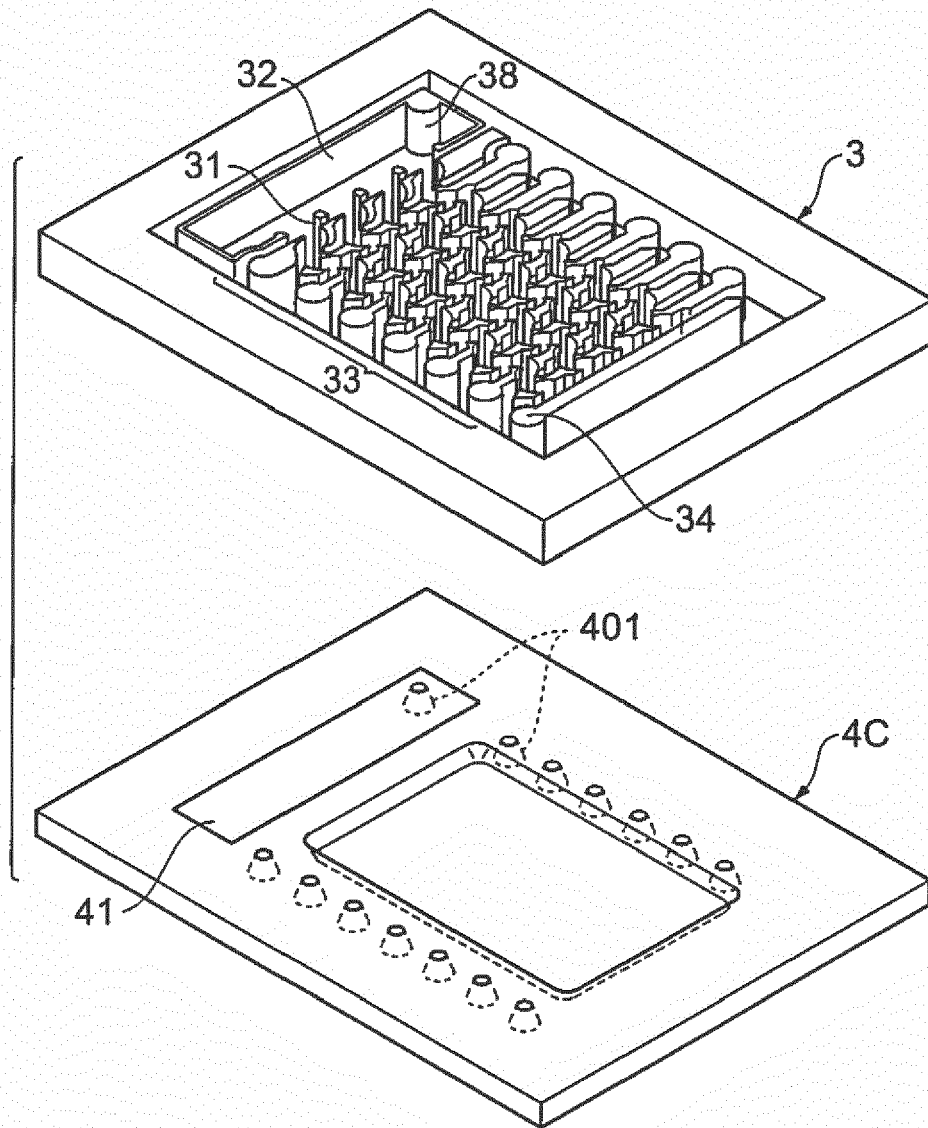


Fig.9

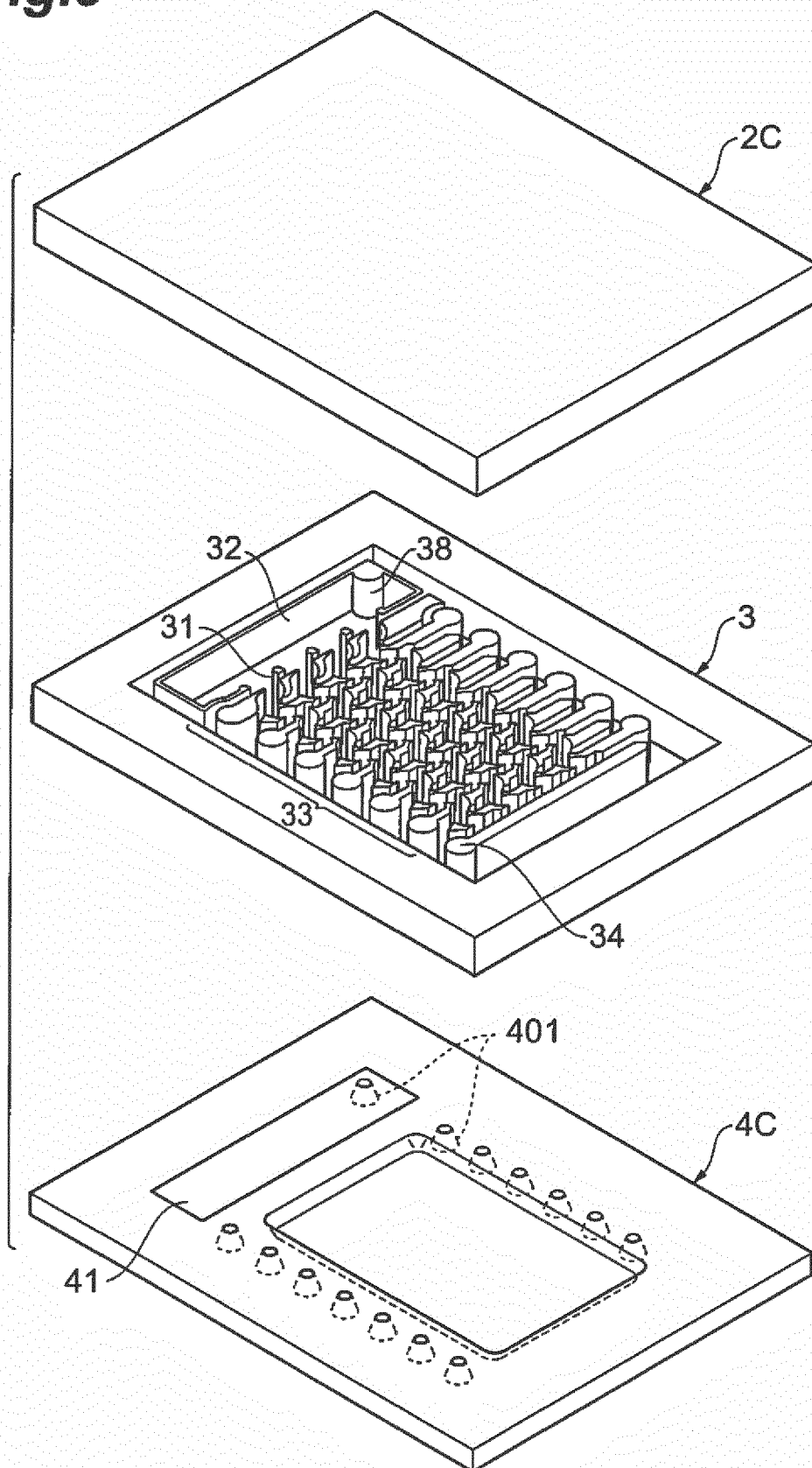
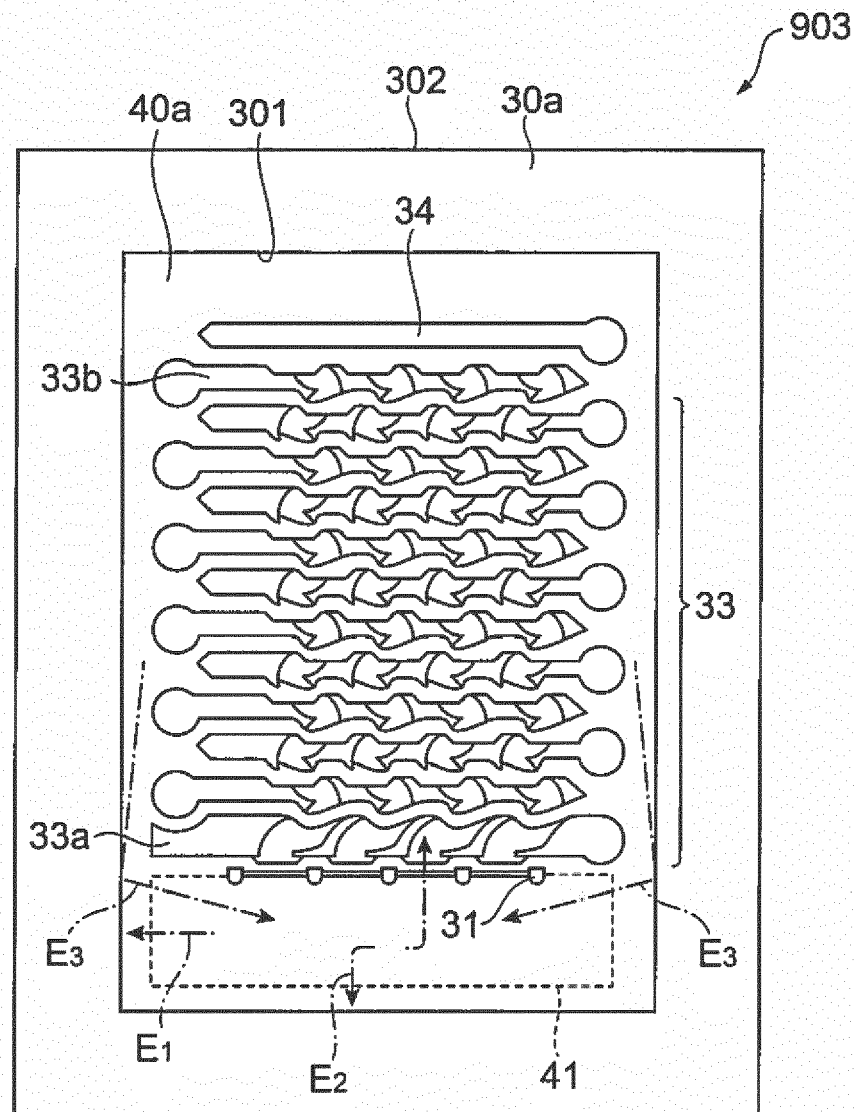


Fig. 10





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EP 17 15 1985

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			H01J
The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 3 May 2017	Examiner Peters, Volker
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
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