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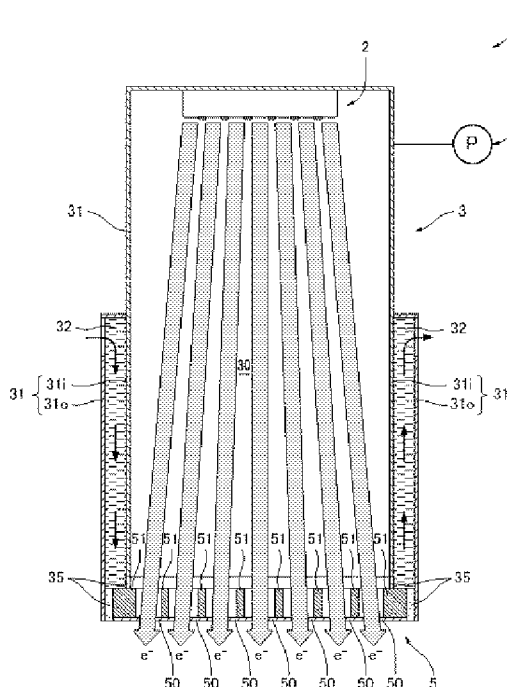
AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA,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

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- (54) **Title:** ELECTRON BEAM EMITTER WITH INCREASED ELECTRON TRANSMISSION EFFICIENCY



- (57) **Abstract:** An electron beam emitter comprises an electron emission source capable of emitting electrons; a vacuum chamber containing the electron emission source; and a transmission window that keeps airtightness of the vacuum chamber and is capable of transmitting the electrons from the electron emission source. The transmission window includes a foil that transmits the electrons and a grid that does not transmit the electrons. The electron emission source includes an emission portion that emits the electrons and a non-emission portion that does not emit the electrons. The emission portion has a lower work function than the non-emission portion. The non-emission portion is prepared so as to prevent the electrons from reaching the grid.

Description

Title of Invention: ELECTRON BEAM EMITTER WITH INCREASED ELECTRON TRANSMISSION EFFICIENCY

Technical Field

[0001] The present invention relates to an electron beam emitter with increased electron transmission efficiency by an electron emission source having both high work function and low work function surfaces, creating emission trajectories that are matched to the transmission pattern of the e-beam window.

Background Art

[0002] Conventionally, an electron beam emitter includes an electron emission source that can emit electrons and a vacuum chamber that contains the electron emission source. The vacuum chamber has a transmission window that can transmit electrons. The transmission window includes foil that transmits electrons and a grid that supports the foil. The grid rises in temperature as it completely absorbs electrons from the electron emission source. Thus, a cooling mechanism is provided on the periphery of the transmission window to remove the excess energy and keep the grid at an acceptable operating temperature. In summary, the electron beam emitter accelerates electrons, which are emitted from the electron emission source, in the vacuum chamber and passes the accelerated electrons through the foil of the transmission window (the e-beam window) so as to emit electron beams to the outside (atmospheric side) of the vacuum chamber.

Citation List

Patent Literature

[0003] Patent Literature 1
US Patent No. 8339024

Summary of Invention

Technical Problem

[0004] Generally, in a typical electron beam emitter shown in FIG. 6, foil 12 absorbs a small proportion of electrons e^- of electron beams 14 having reached the foil 12 and transmits the other proportion of electrons e^- , whereas a grid 10 absorbs all the electrons e^- of electron beams 14 having reached the grid 10(10b). The absorption of electrons e^- into the transmission window 9 increases the temperatures of the grid 10 as well as the foil 12.

[0005] As the electron e^- exposed surface of the grid 10b is comparable to the electron e^- exposed surface of the foil 10a, the fractional foil 12 absorption versus full absorption

at the grid 10 leads to low transmission efficiency of electrons e^- in prior art designs.

[0006] An objective of the present invention is to provide an electron beam emitter that has high electron transmission efficiency that allows for either

[0007] (1) low temperature operation of the transmission window at the same output (high reliability and increased life) or

[0008] (2) increased current density and higher output at the same operating temperature.

[0009] There are prior patents (e.g., see Patent Literature 1) that achieve this goal by intercepting the waste beam with an additional structure, however, these concepts will result in internal high temperatures that would create undesired outgassing and additional thermal management requirements. The novelty of this invention is in eliminating the waste portion of the beam at the source and providing the most efficient solution.

Solution to Problem

[0010] In order to attain the objective, this invention is an electron beam emitter comprising: an electron emission source capable of emitting electrons; a vacuum chamber containing the electron emission source; and a transmission window that keeps airtightness of the vacuum chamber and is capable of transmitting the electrons from the electron emission source, the transmission window including a transmission portion that transmits the electrons and a non-transmission portion that blocks the electrons, the electron emission source including an emission portion that emits the electrons and a non-emission portion that does not emit the electrons, the emission portion having a lower work function than the non-emission portion, the non-emission portion being prepared so as to prevent the electrons from reaching the non-transmission portion.

Advantageous Effect of Invention

[0011] With this configuration, the electron beam emitter can increase electron transmission efficiency allowing either low temperature operations or high current density output within the limits of the system.

Brief Description of Drawings

[0012] FIG. 1 is a schematic cross-sectional view showing an electron beam emitter according to a first embodiment of the present invention;

[0013] FIG. 2 is an enlarged cross-sectional view showing a principal part of the electron beam emitter according to the first embodiment of the present invention;

[0014] FIG. 3 is a schematic perspective view showing a cathode in the electron beam emitter according to the first embodiment of the present invention;

[0015] FIG. 4 is a schematic perspective view showing a cathode in an electron beam emitter according to a second embodiment of the present invention; and

[0016] FIG. 5 is an enlarged cross-sectional view showing a principal part of an electron

beam emitter according to a second embodiment of the present invention.

[0017] FIG. 6 is a schematic cross-sectional view showing a transmission window in a conventional electron beam emitter;

Description of Embodiments

First Embodiment

[0018] An electron beam emitter according to a first embodiment of the present invention will be described below with reference to the accompanying drawings.

[0019] As shown in FIGS. 1 and 2, an electron beam emitter 1 includes an electron emission source 2 that can emit electrons e^- and a vacuum chamber 3 that contains the electron emission source 2 in an interior 30. The vacuum chamber 3 is connected to a vacuum pump 4 (may be detachable) that creates a vacuum in the interior 30. Furthermore, the vacuum chamber 3 has a transmission window 5 that can transmit the electrons e^- from the electron emission source 2. The transmission window 5 keeps airtightness in the vacuum chamber 3 along with walls 31 that constitute the vacuum chamber 3. In the vacuum chamber 3, the walls 31 on a part connected to the transmission window 5 have a double wall construction: an inner shell 31i and an outer shell 31o. In this construction, the inner shell 31i is connected to the edge of the upper face (a surface near the electron emission source 2) of the transmission window 5 while the outer shell 31o is connected to the lower end of the side of the transmission window 5. A space between the inner shell 31i and the outer shell 31o circulates a coolant 32. The inner shell 31i and the edge of the transmission window 5 are connected to each other by methods including but not limited to brazing 35. The outer shell 31o and the lower end of the side of the transmission window 5 are connected to each other by methods including but not limited to brazing 35. The inner shell 31i, the outer shell 31o, and the coolant 32 constitute a cooling unit.

The transmission window 5 will be described below.

[0020] As shown in FIGS. 1 and 2, the transmission window 5 includes foil 50 (an example of a transmission portion) that transmits the electrons e^- and a grid 51 (an example of a non-transmission portion) that supports the foil 50 from the pressure gradient as well as it provides a conductive path for heat removal. The foil 50 absorbs a small proportion of electrons e^- reaching the foil 50 and transmits the other proportion of electrons e^- . The foil 50 is, for example, a titanium film having a thickness on the order of micrometers. The grid 51 has significantly larger thickness than the foil 50 so as to act as a reinforcing member of the transmission window 5. Thus, the grid 51 cannot transmit electrons e^- . This causes the grid 51 to absorb all electrons e^- reaching the grid 51, leading to lower transmission efficiency of electrons e^- and a temperature rise of the transmission window 5. Hence, the electron emission source 2 is configured such that

emitted electrons e^- reach only as far as the foil 50 without reaching the grid 51. This configuration will be specifically described below. For efficient transmission of heat from the transmission window 5 to the cooling unit, the grid 51 is made of a material having a high thermal conductivity, for example, copper. The grid 51 further undergoes a joining process 35 such as brazing.

[0021] The electron emission source 2, that is, the essence of the present invention, is specifically described below.

[0022] As shown in FIG. 2, the electron emission source 2 includes a cathode 21 connected to a power supply (not shown) and a layer part 22 deposited at least on the emitting surface (a surface near the transmission window 5) of the cathode 21. The cathode 21 has a lower work function than the deposited layer part 22. In other words, a material having a higher work function than that of the cathode 21 is prepared as the layer part 22 on the cathode 21. Thus, on the emitting surface of the cathode 21, portions not covered with the layer part 22 serve as emission portions for emitting electrons e^- , whereas portions covered with the layer part 22 serve as non-emission portions that do not emit electrons e^- . The layout of the layer part 22 is designed such that electrons e^- emitted from the emitting surface of the cathode 21 reach only as far as the foil 50 without reaching the grid 51.

[0023] A specific configuration of the electron emission source 2 will be described below.

[0024] The cathode 21 of the electron emission source 2 may be a disc-type cathode (hereinafter, will be called a disc cathode 21D) shown in FIG. 3 or a wire-type cathode (hereinafter, will be called a wire cathode 21W) shown in FIG. 4. One of the two circular surfaces of the disc cathode 21D is prepared as the emitting surface (the surface near the transmission window 5). The electron beam emitter 1 including the disc cathode 21D as the cathode 21 has the noticeable disc-shaped transmission window 5 and thus is suitable for electron beam processing equipment (such as inner container sterilization equipment) for emitting electron beams to a circular subject or into a cylinder. The electron beam emitter 1 including the wire cathode 21W as the cathode 21 has the rectangular transmission window 5 and thus is suitable for electron beam processing equipment (such as outer container sterilization equipment or material surface modification) for emitting electron beams to a subject from the outside.

[0025] For the layout of the layer part 22 on the cathode 21, for example, patterning is selected from (1) to (4):

(1) CVD or PECVD with a mask

[0026] The cathode 21 covered with a mask is subjected to CVD or PECVD (Plasma-Enhanced CVD) using the material of the layer part 22. The material is not deposited on portions covered with the mask and thus the portions serve as the emission portions. The material forms the layer part 22 on portions not covered with

the mask, the portions serving as the non-emission portions.

(2) Etching after vapor deposition

[0027] The cathode 21 is deposited with the material of the layer part 22. After that, on a film formed by vapor deposition, portions corresponding to the emission portions are removed by etching so as to expose the cathode 21. Thus, the portions corresponding to the exposed cathode 21 serve as the emission portions, whereas the unremoved portions of the film serve as the non-emission portions.

(3) Mechanical removal after coating

[0028] The cathode 21 is coated with the material of the layer part 22. After that, on a film formed by coating, portions corresponding to the emission portions are removed by mechanical scraping so as to expose the cathode 21. Thus, the portions corresponding to the exposed cathode 21 serve as the emission portions, whereas the unremoved portions of the film serve as the non-emission portions.

(4) Spray coating with a mask

[0029] The cathode 21 is covered with a mask and then undergoes spray coating with the material of the layer part 22. Portions covered with the mask are not deposited with the material and thus serve as the emission portions, whereas the material forms the layer part 22 on portions not covered with the mask, the portions serving as the non-emission portions.

[0030] For example, the cathode 21 and the layer part 22 are made of the following materials: if the cathode 21 is composed of crystals of Hafnium Carbide (HfC) or Lanthanum Hexa-Boride (LaB₆), the layer part 22 is made of pyrolytic graphite. The crystal of Hafnium Carbide or Lanthanum Hexa-Boride has a lower work function than pyrolytic graphite.

For example, the layout of the layer part 22 is designed as follows:

[0031] First, the trajectories of electrons e^- emitted from the single cathode 21 are simulated. Subsequently, the electrons e^- with the simulated trajectories are tracked after being categorized into the electrons e^- reaching the foil 50 of the transmission window 5 and the electrons e^- reaching the grid 51 of the transmission window 5. According to the tracking, the cathode 21 is categorized into portions for emitting the electrons e^- reaching the foil 50 (hereinafter, will be called indispensable portions) and portions for emitting the electrons e^- reaching the grid 51 (hereinafter, will be called dispensable portions). These steps are repeated to increase the accuracy of categorization. The layer part 22 is located on the dispensable portions. The layout of the layer part 22 does not need to completely match with the dispensable portions as long as the layout contains all the dispensable portions.

The effects of the electron beam emitter 1 will be discussed below.

[0032] When a proper voltage is applied from the power supply to the cathode 21 of the

electron emission source 2, as shown in FIGS. 1 and 2, electrons e^- are emitted from the portions where the layer part 22 is not deposited on the emitting surface of the cathode 21, whereas electrons e^- are not emitted from the portions where the layer part 22 is deposited. The emitted electrons e^- reach only as far as the foil 50 without reaching the grid 51. The foil 50 absorbs a small proportion of electrons e^- reaching the foil 50 and transmits the other proportion of electrons e^- . Electrons e^- transmitted through the foil 50 are scattered into an electron beam plume that is emitted on the atmospheric side of the transmission window 5.

[0033] Thus, according to the electron beam emitter 1, all electrons e^- emitted from the electron emission source 2 reach the foil 50, thereby increasing the transmission efficiency of electrons e^- .

[0034] Moreover, according to the electron beam emitter 1, electrons e^- emitted from the electron emission source 2 do not reach the grid 51, thereby suppressing a temperature rise of the transmission window 5.

[0035] Due to higher transmission efficiency of electrons e^- and suppression of a temperature rise of the transmission window 5, the configuration of the cooling unit is simplified more than a conventional device with the same maximum irradiation amount of electron beams.

[0036] Furthermore, due to higher transmission efficiency of electrons e^- and suppression of a temperature rise of the transmission window 5, the maximum irradiation amount of electron beams is larger than that of the conventional device including the cooling unit with an identical configuration.

[0037] In the first embodiment, the specific materials of the cathode 21 and the layer part 22 were described. The materials are not particularly limited. The cathode 21 may be made of any material as long as the material has a lower work function than the material of the layer part 22. In other words, the layer part 22 may be made of any material as long as the material has a higher work function than the material of the cathode 21.

Second Embodiment

[0038] As shown in FIG. 5, in an electron beam emitter 1 according to a second embodiment of the present invention, the relationship between an emission portion/non-emission portion and a portion having a layer part 23/other portions on the emitting surface of a cathode 21 is reversed from that of the first embodiment.

[0039] Differences from the first embodiment will be mainly described below. The same configurations as those of the first embodiment will be indicated by the reference numerals and the explanation thereof is omitted.

[0040] The cathode 21 according to the second embodiment of the present invention has a higher work function than the layer part 23. In other words, a material having a lower

work function than the cathode 21 is deposited as the layer part 23 on the cathode 21. Thus, on the emitting surface of the cathode 21, portions having the layer part 23 serve as emission portions for emitting electrons e^- while portions not having the layer part 23 serve as non-emission portions that do not emit electrons e^- . The layout of the layer part 23 is designed such that emitted electrons e^- reach only as far as the foil 50 without reaching a grid 51.

[0041] For example, the cathode 21 and the layer part 23 according to the second embodiment of the present invention are made of the following materials: if a disc cathode 21D is made of Iridium (Ir) or a wire cathode 21W is made of Tungsten (W), the layer part 23 is made of Barium Oxide (BaO). Naturally, Iridium or Tungsten has a higher work function than Barium Oxide.

[0042] Also in the electron beam emitter 1 according to the second embodiment of the present invention, emitted electrons e^- reach only as far as the foil 50 without reaching the grid 51. Thus, the electron beam emitter 1 according to the second embodiment of the present invention has the same effect as the electron beam emitter 1 according to the first embodiment.

[0043] In the second embodiment, the specific materials of the cathode 21 and the layer part 23 were described. The materials are not particularly limited. The cathode 21 may be made of any material as long as the material has a higher work function than the material of the layer part 23. In other words, the layer part 23 may be made of any material as long as the material has a lower work function than the material of the cathode 21.

[0044] In the first and second embodiments, the disc cathode 21D and the wire cathode 21W were described as examples of the cathode 21. The cathode 21 is not particularly limited as long as the non-emission portions are deposited such that electrons e^- do not reach the grid 51.

[0045] The vacuum pump 4 connected to the vacuum chamber 3 in the first and second embodiments may not be connected to the vacuum chamber 3.

[0046] In the first and second embodiments, the coolant 32 is used for the cooling unit. The coolant 32 may be replaced with cooling air, that is, the cooling unit may be an air-cooled unit. In the case of an air-cooled unit, cooling air may be caused to impinge on the overall transmission window 5 or only the foil 50.

[0047] In the first and second embodiments, the transmission window 5 includes the foil 50 and the grid 51. The transmission window 5 is not limited to this configuration as long as the transmission window 5 has a transmission portion that transmits electrons and a non-transmission portion that does not transmit electrons. The transmission window may be formed by patterning a material (e.g., etching a pattern on a Silicon disk) with a certain thickness so as to have recessed portions. In this case, the recessed portions

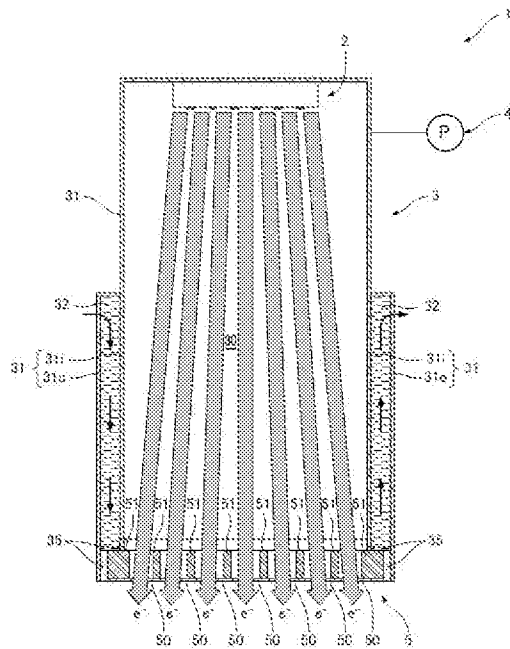
serve as transmission portions while other portions serve as non-transmission portions.

[0048] Furthermore, although detailed description is omitted in the first and second embodiments, an electrostatic lens is disposed near the cathode 21 such that electrons emitted from the emitting surface of the cathode 21 travel in straight lines.

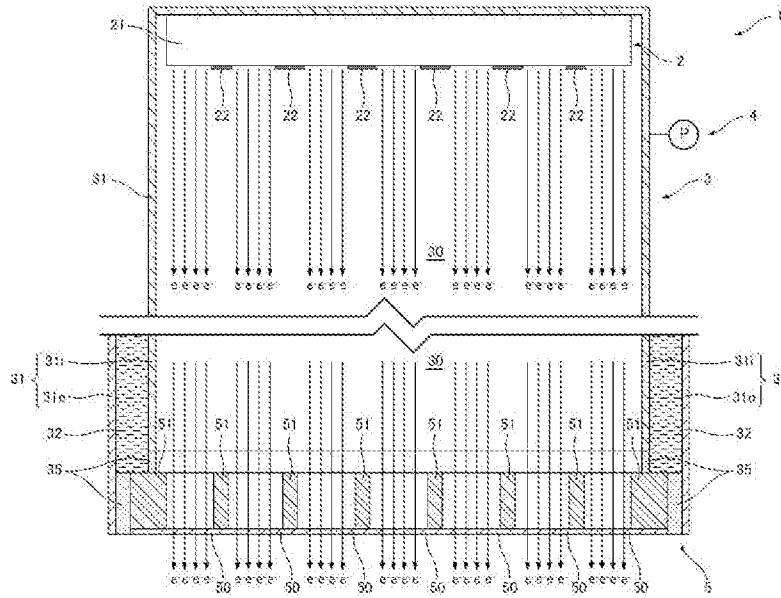
Claims

- [Claim 1] An electron beam emitter comprising:
an electron emission source capable of emitting electrons;
a vacuum chamber containing the electron emission source; and
a transmission window that keeps airtightness of the vacuum chamber and is capable of transmitting the electrons from the electron emission source,
the transmission window including a transmission portion that transmits the electrons and a non-transmission portion that does not transmit the electrons,
the electron emission source including an emission portion that emits the electrons and a non-emission portion that does not emit the electrons,
the emission portion having a lower work function than the non-emission portion,
the non-emission portion being created so as to prevent the electrons from reaching the non-transmission portion.
- [Claim 2] The electron beam emitter according to claim 1, wherein the non-emission portion is patterned on the emission portion.
- [Claim 3] The electron beam emitter according to claim 1, wherein the emission portion is patterned on the non-emission portion.
- [Claim 4] The electron beam emitter according to one of claims 2 and 3, wherein the patterning is removal of a film by etching or mechanical scraping, the film being formed by CVD with a mask or coating, or vapor evaporation or coating.
- [Claim 5] The electron beam emitter according to any one of claims 1 to 3, wherein the electron emission source is shaped like a disc.
- [Claim 6] The electron beam emitter according to any one of claims 1 to 3, wherein the electron emission source is a wire.

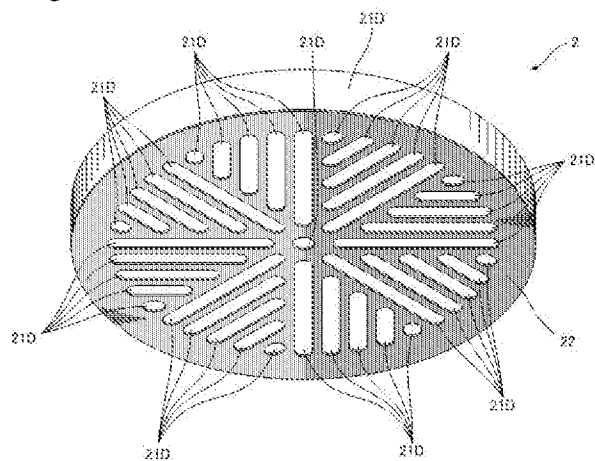
[Fig. 1]



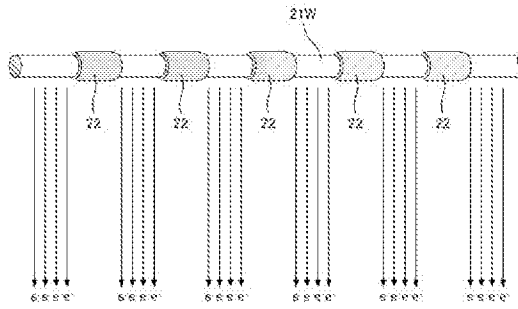
[Fig. 2]



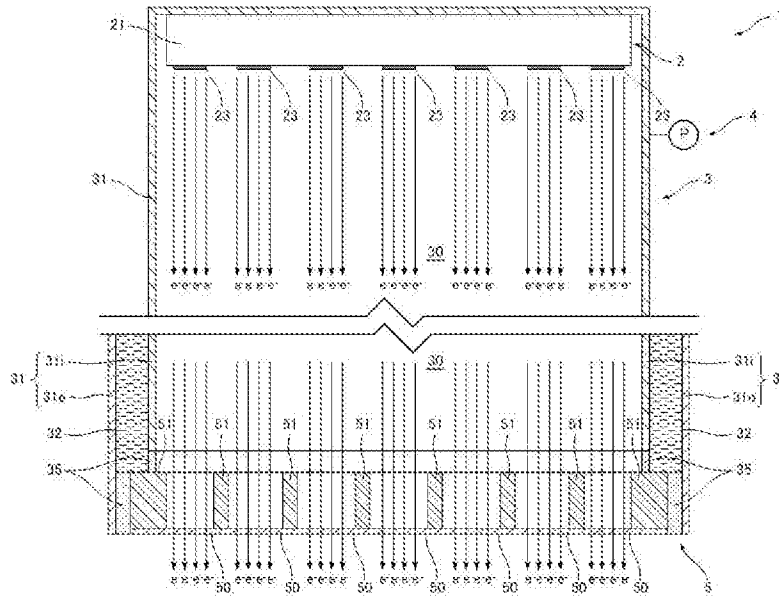
[Fig. 3]



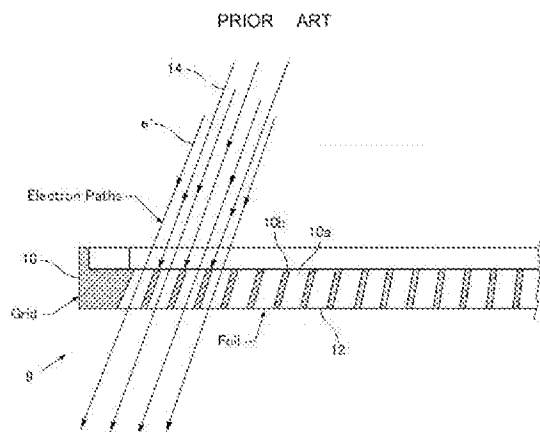
[Fig. 4]



[Fig. 5]



[Fig. 6]



INTERNATIONAL SEARCH REPORT

International application No
PCT/JP2015/002321

A. CLASSIFICATION OF SUBJECT MATTER
INV. H01J1/16 H01J33/00
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H01J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 873 468 A (MIRAM GEORGE V [US] ET AL) 10 October 1989 (1989-10-10)	1-3,5
Y	abstract; figures 1,2 column 1, line 44 - line 47 column 3, line 28 - line 32	4
X	US 2004/183032 A1 (FINK RICHARD LEE [US] ET AL) 23 September 2004 (2004-09-23) abstract; figure 4 paragraph [0020]	1,3
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Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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Date of the actual completion of the international search

21 July 2015

Date of mailing of the international search report

30/07/2015

Name and mailing address of the ISA/

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Tano, Valeria

INTERNATIONAL SEARCH REPORT

International application No

PCT/JP2015/002321

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 3 967 150 A (LIEN ERLING L ET AL) 29 June 1976 (1976-06-29) abstract	4
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

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