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(72) Inventor: **Akamatsu, Norio**
Tokushima-shi
Tokushima 770-0813 (JP)

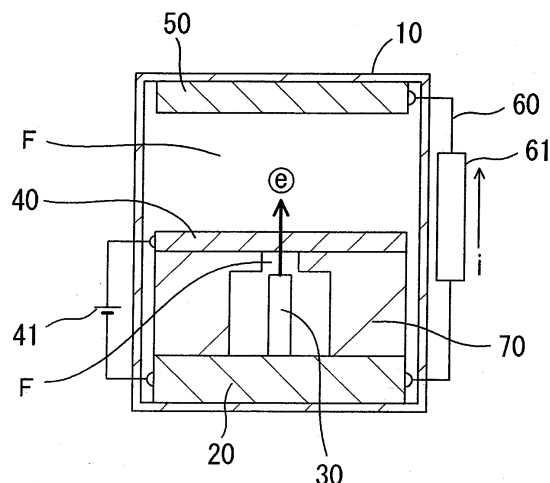
(71) Applicant: **Akamatsu, Norio**
Tokushima-shi
Tokushima 770-0813 (JP)

(74) Representative: **Skuhra, Udo et al**
Reinhard, Skuhra, Weise & Partner GbR
Patent- und Rechtsanwälte
Friedrichstraße 31
80801 München (DE)

(54) **FIELD EMITTING/ELECTRIC-POWER GENERATING DEVICE**

(57) Stable generation of electricity can be achieved based on a new concept different from those of the conventional electricity generating methods, with a small external energy input, with high efficiency, and without apprehension of exhaustion, while paying due consideration to the environment. The electricity generating apparatus includes an electron supplier (20) made of a metal or a free-electron material, an electron emitting port (30) provided electrically conductive with the electron supplier (20), an electron extracting electrode (40) provided opposite to the electron emitting port (30) via an electrical insulation region (F) and for applying an electrical field to cause electrons to be attracted and emitted from the electron emitting port (30), an electron collector (50) for collecting the electrons emitted by the electron extracting electrode (40), and an electron absorption preventing means for preventing the electrons emitted from the electron emitting port (30) from being absorbed by the electron extracting electrode (40), wherein a positive voltage is applied to the electron extracting electrode (40) to cause the electrons to be field-emitted from the electron emitting port (30), and the emitted electrons are received and collected by the electron collector (50).

Fig.1



Description

Disclosure of the Invention

Technical Field

Problems to be Solved by the Invention

[0001] The present invention relates to an electricity generating apparatus which utilizes field emission.

Background Art

[0002] In electricity generation, as a method of attaining electrical energy, hydroelectricity and wind-powered generation have been known since a long time ago, and solar-powered and tidal-powered generations using natural energy are known as well. Further, thermal electricity generation using fossil fuels and nuclear electricity generation using nuclear energy are also known.

In the case of electricity generation using fossil fuels, there exists an imminent problem that fossil fuels of raw materials are a limited natural resource, so that they are going to be exhausted before long. Thus, it is impossible to meet the needs of the world over the long term.

Further, in the case of electricity generation using natural energy such as sunlight, wind power and the like, there is a drawback that it is not guaranteed that electricity can be surely supplied whenever we need, because natural energy such as sunlight and wind power is varied depending on the natural conditions.

Still further, in the case of nuclear electricity generation using nuclear energy, there is a big problem regarding safety and facilities.

[0003] On the other hand, the present inventor has provided a method of generating electricity by converting thermal energy into electrical energy, which is described in the following Patent Documents 1 through 4. In the method of generating electricity, sunlight is applied to a material and converted into thermal energy, thermal electrons are emitted from within the heated material, and thermal energy is converted into electrical energy by thermal electron emission.

Further, the following Patent Document 5 discloses an apparatus for converting thermal energy into electrical energy.

Still further, the following Patent Document 6 discloses an apparatus which adopts a method of emitting electrons by field effect.

Patent Document 1: Japanese Patent No. 3449623

Patent Document 2: Japanese Patent Laid-Open No. 2003-189646

Patent Document 3: Japanese Patent Laid-Open No. 2003-250285

Patent Document 4: Japanese Patent Laid-Open No. 2004-140288

Patent Document 5: Japanese Patent Laid-Open No. 2003-258326

Patent Document 6: Japanese Patent National Publication No. 11-510307

[0004] The inventions disclosed in Patent Documents 1 through 4, however, all adopt a method of generating electricity by supplying thermal energy to a material, causing thermal electrons to be emitted from within the heated material, and collecting the emitted electrons. Specifically, these are electricity generating apparatuses of the type that convert externally provided thermal energy to electrical energy. To attain large electrical energy, correspondingly a large thermal energy input is required. Patent Document 5 discloses a device and an apparatus utilizing field emission. However, the device and apparatus are nothing but a converter for converting thermal energy into electrical energy. In respect of generating electricity, they are limited to an electricity generator that adopts thermal electron emission by heating.

Patent Document 6 discloses a material and an apparatus for emitting electrons by field effect. However, disclosed therein are a discharging apparatus, an electron gun, and a display using emitted electrons themselves, which completely lack the technical idea of utilizing the field emission of electrons for generating electricity.

[0005] In view of the foregoing, an object of the present invention is to provide a novel electricity generating apparatus, based on a new concept entirely different from the concepts of the conventional electricity generating methods, which is capable of stably generating electricity with high efficiency, with a small external energy input, and without apprehension of exhaustion, while paying due consideration to the environment.

Means for Solving the Problems

[0006] To achieve the above object, the present inventor has diligently carried out various kinds of experiments and examinations. As a result, he has acquired that novel electricity generation different from and more efficient than the electricity generation using thermal electron emission can be obtained by using a field emission phenomenon in which an electrical field acting on a material causes electrons in the material to be emitted from the surface thereof, and finally, he has achieved the present invention.

When an electrical field is concentrated on a small area in a free-electron material, for example, electrons are emitted from the surface of the material into a vacuum or the like. This phenomenon is known as field emission. In this case, the electrons are emitted by the electrical field without the need to apply thermal energy from the outside. By collecting the emitted electrons successfully, the electrical energy by the electrons can be taken out to the outside.

As for the electrical field to be applied to the material, increasing the degree of concentration of the electrical field makes it possible to restrict the intensity of the ap-

plied positive charges low.

The material to be applied with the electrical field preferably holds a large amount of free electrons. Lowering the potential energy in its electron emission area can facilitate field emission.

As for the source of generating an electrical field, consumption of charges, i.e., energy consumption therein is theoretically negligible as long as it just applies the electrical field to the material and no current flows therein. In other words, as long as the electrons field-emitted from a material are prevented from reaching and being absorbed into the electrical field generating source, no energy would be consumed at the electrical field generating source.

As such, according to the present invention, the free electrons within the material are field-emitted efficiently and the field-emitted electrons are suitably collected and stored in an electron receiving material other than the electrical field generating source, to realize practicable electricity generation. At this time, energy consumption at the electrical field generating source that applies an electrical field to the electron emitting material is restricted to the minimum.

[0007] The field emission electricity generating apparatus according to the present invention has a first feature that it includes: an electron supplier made of a metal or a free-electron material; an electron emitting port provided electrically conductive with the electron supplier; an electron extracting electrode provided opposite to the electron emitting port via an electrical insulation region and for applying an electrical field to cause electrons to be attracted and emitted from the electron emitting port; an electron collector for collecting the electrons emitted by the electron extracting electrode; and an electron absorption preventing means for preventing the electrons emitted from the electron emitting port from being absorbed by the electron extracting electrode; wherein a positive voltage is applied to the electron extracting electrode to cause the electrons to be field-emitted from the electron emitting port, and the field-emitted electrons are received and collected by the electron collector provided separately, without being absorbed by the electron extracting electrode.

In addition to the first feature described above, the field emission electricity generating apparatus of the present invention has a second feature that the electron emitting port is made of a material and/or in a shape exhibiting a low potential barrier with respect to electron emission.

In addition to the first feature described above, the field emission electricity generating apparatus of the present invention has a third feature that the electron emitting port is formed by vertically planting a quasi-one-dimensional material on a surface of the electron supplier in such a manner that a longitudinal direction of the quasi-one-dimensional material corresponds to a direction of electron emission.

In addition to the third feature described above, the field emission electricity generating apparatus of the present

invention has a fourth feature that the quasi-one-dimensional material is a carbon nanotube.

In addition to the first feature described above, the field emission electricity generating apparatus of the present invention has a fifth feature that the electrical insulation region is made up of an insulation space or an insulating material.

In addition to the first feature described above, the field emission electricity generating apparatus of the present invention has a sixth feature that the electron absorption preventing means is configured by forming the electron extracting electrode with a quasi-two-dimensional material, to cause the electrons emitted from the electron emitting port to penetrate through the electron extracting electrode by the quantum tunneling effect, without being absorbed by the electron extracting electrode.

In addition to the first feature described above, the field emission electricity generating apparatus of the present invention has a seventh feature that the electron absorption preventing means is an electron orbit changing electrode for changing orbits of the electrons that are emitted from the electron emitting port and move towards the electron extracting electrode.

In addition to the first feature described above, the field emission electricity generating apparatus of the present invention has an eighth feature that the electron absorption preventing means is configured by arranging the electron collector in front of the electron extracting electrode, to collect the electrons emitted from the electron emitting port and moving towards the electron extracting electrode before they reach the electron extracting electrode.

In addition to the first feature described above, the field emission electricity generating apparatus of the present invention has a ninth feature that it further includes an accelerating electrode for accelerating the electrons moving towards the electron collector.

In addition to the first feature described above, the field emission electricity generating apparatus of the present invention has a tenth feature that it further includes an electron reaching position dispersion means for dispersing orbits of the electrons moving towards the electron collector to prevent the electrons from concentratedly reaching a same position in the electron collector.

In addition to the first feature described above, the field emission electricity generating apparatus of the present invention has an eleventh feature that the electron collector includes a plurality of electron collectors provided electrically insulated from each other, and the apparatus further includes an electron distribution means for distributing the electrons emitted from the electron emitting port to the plurality of electron collectors.

In addition to the first feature described above, the field emission electricity generating apparatus of the present invention has a twelfth feature that it further includes a secondary emission preventing means for preventing the electrons having reached the electron collector from being emitted secondarily.

In addition to the first feature described above, the field emission electricity generating apparatus of the present invention has a thirteenth feature that the electron collector and the electron supplier are electrically connected to each other, and an electrical load is provided between the electron collector and the electron supplier.

In addition to the first feature described above, the field emission electricity generating apparatus of the present invention has a fourteenth feature that an alternating voltage is applied to the electron extracting electrode to change the amount of the electrons emitted from the electron emitting port for generation of alternating current.

Effects of the Invention

[0008] According to the field emission electricity generating apparatus recited in claim 1, when a positive voltage is applied to the electron extracting electrode, an electrical field is generated between the electron extracting electrode and the electron emitting port of the electron supplier, which increases the Coulomb force applied to the free electrons confined in the electron emitting port, and hence, increases the kinetic energy of the electrons. When the energy of the electrons surmounts the potential barrier at the surface of the electron emitting port, the electrons are emitted from the electron emitting port into the electrical insulation region. For the conditions at this time, it is important to pay due consideration to the material and the shape of the electron emitting port so that the potential barrier at the port is as low as possible. Further, in order to increase the Coulomb force generated in the electrical field by the electron extracting electrode to the level required for the electron emission, and in order to restrict the applied positive voltage low, it is important to place the electron extracting electrode as close to the electron emitting port as possible.

The electrons field-emitted from the electron emitting port by application of a positive voltage by the electron extracting electrode fly in the electrical insulation region while being attracted towards the electron extracting electrode. The electron absorption preventing means, however, prevents the electrons from reaching and being absorbed into the electron extracting electrode, and instead, the electrons are received by the electron collector. Accordingly, the field-emitted electrons are collected at the electron collector, which increases the amount of electrons in the electron collector. This is a state of electricity generation.

For efficient electricity generation, it is desirable to keep the electron collector in an electrically neutral or negative state, to prevent binding of the electrons with the atomic nuclei. On the other hand, a repulsion force would increase as the negative charges in the electron collector increase, causing the electron collector to have great difficulty in receiving electrons. To solve this problem, it is important to increase the electron kinetic energy by enhancing the flying speed of the electrons, or to keep the amount of negative charges on the surface of the electron

collector small by transferring the negative charges from the surface thereof to another position.

As long as the field-emitted electrons do not reach the electron extracting electrode, the consumed amount of the positive charges applied to the electron extracting electrode is negligible in theory. Therefore, it is possible to drastically reduce the energy consumption in the power supply.

As can be appreciated from the foregoing description, according to the field emission electricity generating apparatus recited in claim 1 of the present invention, it is possible to efficiently generate electricity by using the field emission phenomenon of electrons, by collecting the field-emitted electrons in the electron collector while restricting the energy consumption required for the field emission small.

Further, according to the field emission electricity generating apparatus recited in claim 1 of the present invention, compared to the conventional method where thermal energy is applied to cause thermal electrons to be emitted by the thermal energy for generating electricity, that is, compared to the conventional electricity generation in which thermal energy is converted to electrical energy, electricity can be generated with much less energy.

Still further, according to the field emission electricity generating apparatus recited in claim 1 of the present invention, stable electricity supply can be achieved with easy operational control, unlike the unstable electricity generation using natural resources such as sunlight and the like.

[0009] Further, according to the field emission electricity generating apparatus recited in claim 2, in addition to the effects obtained by the structure recited in claim 1 above, the electron emitting port is made of a material and/or in a shape exhibiting a low potential barrier with respect to electron emission, to facilitate field emission. The electrons within a solid object are bound like the electrons within the atoms, so that the electrons would not be unbound from within the solid object in a normal state. The minimum energy required for causing the electrons to be emitted from within a solid object into a vacuum by an electrical field or the like is called a work function E_w . This work function E_w corresponds to the potential barrier possessed by the solid object with respect to electron emission.

The materials exhibiting a low potential barrier, i.e., the materials having a small work function E_w , include: atoms of cesium ($E_w = 1.81$ eV), calcium ($E_w = 3.2$ eV), thorium ($E_w = 3.4$ eV), molybdenum ($E_w = 4.3$ eV), and tungsten ($E_w = 4.52$ eV). Further, the compounds having a small work function E_w include: barium oxide ($E_w = 1.6$ eV), calcium oxide ($E_w = 1.61$ eV), and thorium oxide ($E_w = 1.66$ eV).

The work function depends on the surface structure of field-emission materials. Therefore, the nano-structured materials, such as carbon nanotube, carbon wall, carbon nanohorn, nano-structured diamond, and BN nanowhisker, have a low potential barrier for electron emis-

sion.

The materials and/or the shapes exhibiting a low potential barrier may include the electron emitting port having a surface layer formed with a laminated structure expected to exhibit the quantum tunneling effect.

[0010] According to the field emission electricity generating apparatus recited in claim 3, in addition to the effects obtained by the structure recited in claim 1 above, the electron emitting port is formed by vertically planting a quasi-one-dimensional material so that its longitudinal direction corresponds to the direction of electron emission.

The quasi-one-dimensional material refers to a material that exhibits effects substantially the same as those of a one-dimensional material in respect of electron emission. While a carbon nanotube for example may be used as the quasi-one-dimensional material, an electrically conductive material having undergone sufficiently fine processing (of nano-order to micron-order) may be used as well.

In the case of the quasi-one-dimensional material, the electrons migrate only in a one-dimensional direction, and are field-emitted from its tip end. Matching the longitudinal direction of the quasi-one-dimensional material with the electron emission direction facilitates the field emission of electrons. It is considered that this also reduces the potential barrier of the quasi-one-dimensional material with respect to the field emission of electrons. A large number of quasi-one-dimensional materials may be vertically planted to form the electron emitting port. When the electron emitting port is configured with the large number of quasi-one-dimensional materials, the electrons are field-emitted from each of them, and as a whole, a large number of electrons may be field-emitted efficiently.

[0011] According to the field emission electricity generating apparatus recited in claim 4, in addition to the effects obtained by the structure recited in claim 3 above, the carbon nanotube used as the quasi-one-dimensional material ensures sufficiently high mobility of the electrons. Further, by forming the electron emitting port by vertically planting the carbon nanotube with its longitudinal direction corresponding to the electron emission direction, efficient electron emission is ensured.

[0012] According to the field emission electricity generating apparatus recited in claim 5, in addition to the effects obtained by the structure recited in claim 1 above, the electrical insulation region is configured with an insulation space or an insulating material. In the case of the insulation space, the electrons are field-emitted to the insulation space to fly therein. By making the insulation space with a vacuum or similar space, it is possible to construct a vacuum tube-type electricity generating apparatus or electricity generating module.

Further, when the electrical insulation region is made up of an insulating material, an electricity generating module of a solid chip can be readily formed.

Combining a large number of such electricity generating

modules can increase an output of generated electricity.

[0013] According to the field emission electricity generating apparatus recited in claim 6, in addition to the effects obtained by the structure recited in claim 1 above, the electron absorption preventing means is configured by forming the electron extracting electrode with a quasi-two-dimensional material to cause the electrons emitted from the electron emitting port to penetrate through the electron extracting electrode by the quantum tunneling effect, without being absorbed therein. Accordingly, even if the electrons emitted from the electron emitting port reach the electron extracting electrode, they are not bound to the atomic nuclei or the like (i.e., the electrons are not absorbed) in the electron extracting electrode; they rather pass therethrough to the back to be received by the electron collector. Accordingly, arranging the electron collector at the back of the electron extracting electrode ensures that the field-emitted electrons are surely received by the electron collector, without provision of a special means for collecting the electrons. Since it is unnecessary to apply a positive voltage to the electron collector, it is possible to prevent the undesirable situation where the received electrons are not usable as free electrons, and accordingly, efficiency in generating electricity is increased.

The quasi-two-dimensional material refers to a material that exhibits effects substantially the same as those of a two-dimensional material in respect of penetration of electrons. More specifically, it refers to a material that is very thin and expected to exhibit the quantum tunneling phenomenon for electrons. In order to enhance the quantum tunneling effect, it is important to increase the speed (kinetic energy) of the flying electrons, and to reduce the thickness of the quasi-two-dimensional material so as to reduce the probability of the electrons being confined therein.

[0014] According to the field emission electricity generating apparatus recited in claim 7, in addition to the effects obtained by the structure recited in claim 1 above, the electron absorption preventing means is configured with the electron orbit changing electrode which changes the orbits of the electrons emitted from the electron emitting port and moving towards the electron extracting electrode. This ensures that the electrons emitted from the electron emitting port have their flying orbits changed in the middle way before reaching the electron extracting electrode, to be collected by the electron collector. Although this apparatus additionally requires the electron orbit changing electrode, it is beneficial in that the electron extracting electrode does not need to be made of a special material such as a quasi-two-dimensional material. Further, the electron orbit changing electrode does not need to be made of a special material, as long as it can hold a positive voltage and a negative voltage.

[0015] According to the field emission electricity generating apparatus recited in claim 8, in addition to the effects obtained by the structure recited in claim 1 above, the electron absorption preventing means is configured

by arranging the electron collector in front of the electron extracting electrode so that the electrons emitted from the electron emitting port and moving towards the electron extracting electrode are received before they reach the electron extracting electrode. This ensures that the electrons emitted from the electron emitting port are received by the electron collector, instead of reaching the electron extracting electrode. Although this apparatus requires a space for arranging the electron collector, no special means is necessary for collecting the electrons as long as such a space is secured, and the field-emitted electrons can surely be received by the electron collector. Since it is unnecessary to apply a positive voltage to the electron collector, the ratio of the collected electrons that are absorbed by the atomic nuclei and cannot be used as free electrons can be restricted low, leading to increased efficiency in generating electricity.

[0016] According to the field emission electricity generating apparatus recited in claim 9, in addition to the effects obtained by the structure recited in claim 1 above, an accelerating electrode for accelerating the electrons moving towards the electron collector is provided, which can increase kinetic energy of the electrons with the increase in speed of the electrons approaching the electron collector. Even in the state where the electron collector is charged negatively, the electrons will overcome the repulsive action according to the Coulomb's law generated by the negative voltage, and the probability of the electrons reaching the electron collector is increased. That is, the efficiency in generating electricity is increased.

[0017] According to the field emission electricity generating apparatus recited in claim 10, in addition to the effects obtained by the structure recited in claim 1 above, an electron reaching position dispersion means is provided for dispersing the orbits of the electrons moving towards the electron collector to prevent the electrons from concentratedly reaching the same position in the electron collector. By disposing the electron reaching position dispersion means, damages to the electron collector due to the electrons colliding with the same position of the electron collector can be prevented, and thus, the durability of the apparatus is enhanced.

[0018] According to the field emission electricity generating apparatus recited in claim 11, in addition to the effects obtained by the structure recited in claim 1 above, a plurality of electron collectors are provided electrically insulated from each other, and an electron distribution means is provided for distributing the electrons emitted from the electron emitting port to the plurality of electron collectors. The electrons emitted from the electron emitting port are distributed to the plurality of electron collectors by the electron distribution means, and received by each of the electron collectors, which can reduce the repulsive action against the flying electrons due to the electrons stored in the electron collectors. Accordingly, each electron collector can receive and collect the electrons readily and efficiently.

In the case that only one electron collector is used to receive all the emitted electrons, the amount of negative charges stored in the electron collector increases abruptly as it receives a large number of electrons at a time, which causes the undesirable situation where the coming electrons are repulsed, resulting in a decreased rate of reception of the electrons. In contrast, when a plurality of electron collectors are used to receive the electrons in a distributed manner, the increase in number of the electrons in each electron collector is slow, and thus, the increase of the negative charges in each electron collector can be properly controlled by transferring the received electrons to another place or by using them for electricity. Accordingly, it is possible to efficiently collect the field emitted electrons continuously by the electron collectors, without the repulsion owing to the negative charge of electrons.

[0019] According to the field emission electricity generating apparatus recited in claim 12, in addition to the effects obtained by the structure recited in claim 1 above, a secondary emission preventing means is provided for preventing secondary emission of the electrons in the electron collector. This ensures that the field-emitted electrons are surely captured and collected by the electron collector, whereby highly efficient electricity generation is achieved.

[0020] According to the field emission electricity generating apparatus recited in claim 13, in addition to the effects obtained by the structure recited in claim 1 above, the electron collector and the electron supplier are electrically connected to each other, and an electrical load is provided therebetween. This allows the electrons received in the electron collector to be supplied to the electrical load for use in working. The electrons having passed through the electrical load return to the electron collector in order to enable the electron circulation.

[0021] According to the field emission electricity generating apparatus recited in claim 14, in addition to the effects obtained by the structure recited in claim 1 above, an alternating voltage is applied to the electron extracting electrode to change the amount of the electrons emitted from the electron emitting port to thereby generate alternating current. It is possible to generate desired alternating current by adjusting the period and amplitude of the alternating voltage applied to the electron extracting electrode.

Brief Description of the Drawings

[0022]

Fig. 1 is a schematic cross-sectional view showing the field emission electricity generating apparatus according to a first embodiment of the present invention.

Fig. 2 is a schematic cross-sectional view showing an example where an accelerating electrode is added to the configuration of the field emission electricity

generating apparatus according to the first embodiment of the present invention.

Fig. 3 illustrates the state where electrons penetrate through the electron extracting electrode when the electron extracting electrode is configured with carbon nanotubes.

Fig. 4 shows specific configuration examples of the electron emitting port and the electron extracting electrode.

Fig. 5 illustrates the state in the middle of forming the electron extracting electrode using a bridge phenomenon of carbon nanotubes.

Fig. 6 shows a specific example of the electron extracting electrode formed by bridging of carbon nanotubes.

Fig. 7 illustrates a specific configuration example of the electron collector.

Fig. 8 illustrates an example of an electron reaching position dispersion means added to the configuration of the field emission electricity generating apparatus according to the first embodiment of the present invention.

Fig. 9 illustrates an example of an electron distribution means added to the configuration of the field emission electricity generating apparatus according to the first embodiment of the present invention.

Fig. 10 illustrates a specific configuration example of an electricity extracting circuit which is configured corresponding to the case where the electron distribution means is added to the configuration of the field emission electricity generating apparatus according to the first embodiment of the present invention.

Fig. 11 illustrates an example of a secondary emission preventing means added to the configuration of the field emission electricity generating apparatus according to the first embodiment of the present invention.

Fig. 12 illustrates another example of the secondary emission preventing means added to the configuration of the field emission electricity generating apparatus according to the first embodiment of the present invention.

Fig. 13 illustrates a still further example of the secondary emission preventing means added to the configuration of the field emission electricity generating apparatus according to the first embodiment of the present invention.

Fig. 14 is a schematic cross-sectional view showing an example of the field emission electricity generating apparatus according to a second embodiment of the present invention to which the secondary emission preventing means shown in Fig. 12 is applied.

Fig. 15 is a schematic cross-sectional view showing another example of the field emission electricity generating apparatus according to the second embodiment of the present invention to which the secondary emission preventing means shown in Fig. 13 is ap-

plied.

Fig. 16 is a schematic cross-sectional view showing a still further example of the field emission electricity generating apparatus according to the second embodiment of the present invention in which an alternating current power supply is used to alternately change the directions of the field-emitted electrons. Fig. 17 illustrates the movement of the field-emitted electrons in the apparatus shown in Fig. 16 in the state where the alternating current power supply is in a positive half cycle.

Fig. 18 illustrates the movement of the field-emitted electrons in the apparatus shown in Fig. 16 in the state where the alternating current power supply is in a negative half cycle.

Fig. 19 is a schematic configuration diagram illustrating the field emission electricity generating apparatus according to a third embodiment of the present invention.

Fig. 20 is a cross-sectional view illustrating a specific example of the field emission electricity generating apparatus according to the third embodiment of the present invention.

Fig. 21 is a partially enlarged view of Fig. 20.

Fig. 22 is a schematic configuration diagram illustrating the field emission electricity generating apparatus according to a fourth embodiment of the present invention.

Fig. 23 illustrates threshold voltages for field emission of electrons.

Description of the Reference Characters

[0023]

10	vacuum vessel
20	electron supplier
30	electron emitting port
31	quasi-one-dimensional material
40	electron extracting electrode
41	electron extracting power supply
42	quasi-one-dimensional material
50	electron collector
60	electricity extracting circuit
61	electrical load
70	insulating member
80	accelerating electrode
90	electron reaching position dispersion means
100	electron distribution means
110	secondary emission preventing means
130	electron collecting port
140	electron collecting electrode
151, 152	first electron orbit changing electrode
154, 155	second electron orbit changing electrode
157	electron orbit changing electrode
160	frame
F	electrical insulation region
e	electron

n atomic nucleus
S lead-in space

Best Modes for Carrying Out the Invention

[0024] A field emission electricity generating apparatus according to a first embodiment of the present invention will be described with reference to Fig. 1.

In the first embodiment, field-emitted electrons *e* penetrate through an electron extracting electrode 40 by the quantum tunneling effect, to reach an electron collector 50.

[0025] Fig. 1 is a schematic cross-sectional view of the field emission electricity generating apparatus.

An electron supplier 20, an electron emitting port 30, the electron extracting electrode 40, and the electron collector 50 are provided in a vacuum vessel 10. Further, an electron extracting power supply 41 and an electricity extracting circuit 60 are provided outside the vacuum vessel 10.

[0026] The vacuum vessel 10 is a vessel which has its interior maintained in a vacuum or at a sufficiently reduced pressure, with the kind of material therefor not restrictive.

The electron supplier 20 is made of a material serving as a source of supplying electrons, which may be a metal or a free-electron material.

The electron emitting port 30 is for field-emitting electrons therefrom, which is provided so as to be electrically conductive with the electron supplier 20.

The electron emitting port 30 is preferably made of a material exhibiting a low potential barrier with respect to field emission of electrons. Further, it is preferably made in a shape ensuring a low potential barrier.

The electron extracting electrode 40 is an electrode for applying an electrical field to the electron emitting port 30 to cause the electrons *e* to be field-emitted from the electron emitting port 30. The electron extracting electrode 40 is disposed opposite to the electron emitting port 30 via an electrical insulation region *F*, by provision of an insulating member 70.

The insulating member 70 may be made of an insulating material.

In the present embodiment, the electron extracting electrode 40 is made of a quasi-two-dimensional material so as to serve as an electron absorption preventing means for preventing the field-emitted electrons *e* from reaching and being absorbed by the electron extracting electrode 40.

The electron collector 50 is for collecting the field-emitted electrons, which is provided at the back of the electron extracting electrode 40 via the electrical insulation region *F*. The electron collector 50 may be made of a metal or a free-electron material.

The electron extracting power supply 41 is for applying a positive voltage to the electron extracting electrode 40. In the present embodiment, it has a negative electrode connected with the electron supplier 20 and a positive

electrode connected with the electron extracting electrode 40.

The electricity extracting circuit 60 is a circuit for externally taking out the electrons *e* collected by the electron collector 50. It is provided between, and electrically connected to, the electron collector 50 and the electron supplier 20, with an electrical load 61 provided in the middle of the circuit.

In the present embodiment, the electrical insulation region *F* is configured with an insulation space which is maintained in a vacuum or at a sufficiently reduced pressure.

[0027] In the field emission electricity generating apparatus according to the first embodiment, the electrons *e* present within the electron supplier 20 disposed in the vacuum vessel 10 are field-emitted from the electron emitting port 30 into the electrical insulation region *F* by a positive voltage applied from the electron extracting electrode 40.

With the electron extracting electrode 40 made of a very thin quasi-two-dimensional material, the electrons *e* field-emitted to the electrical insulation region *F* penetrate through the electron extracting electrode 40 by the quantum tunneling effect. That is, the field-emitted electrons *e* are prevented from being absorbed by the electron extracting electrode 40.

The electrons *e* having penetrated through the electron extracting electrode 40 reach and collide with the electron collector 50, and are absorbed therein.

Provided between the electron collector 50 that have absorbed the electrons *e* and the electron supplier 20 is the electricity extracting circuit 60, through which the electrons *e* are fed from the electron collector 50 back to the electron supplier 20. When the electrons *e* penetrate through the electrical load 61, current *i* flows. Namely, generated electricity is supplied to the electrical load 61 as electrical energy, which is used for work.

[0028] Fig. 2 shows a field emission electricity generating apparatus having an accelerating electrode 80 added to the configuration shown in Fig. 1.

The accelerating electrode 80 is for accelerating the field-emitted electrons moving towards the electron collector 50. The accelerating electrode 80 is provided at the back of the electron extracting electrode 40 via an electrical insulation region *F*, by provision of an insulating member 71.

An accelerating power supply 81 is provided which applies a positive voltage to the accelerating electrode 80. In this example, the accelerating power supply 81 is connected to the electron extracting power supply 41 in series, so that a positive voltage applied to the accelerating electrode 80 is higher than that applied to the electron extracting electrode 40.

The accelerating electrode 80 is made of a quasi-two-dimensional material.

The other configurations and functions in Fig. 2 are identical to those shown in Fig. 1, and therefore, the members and elements having the identical configurations and

functions are denoted by the identical reference characters, and description thereof will not be repeated.

In the apparatus according to the first embodiment, the electrons *e* that have been field-emitted from the electron emitting port 30 of the electron supplier 20 and passed through the electron extracting electrode 40 made of a quasi-two-dimensional material are further accelerated by the Coulomb force of the charges possessed by the accelerating electrode 80 to which the positive voltage has been applied. Passing through the accelerating electrode 80 made of a quasi-two-dimensional material by the quantum tunneling effect, they reach the electron collector 50 with higher kinetic energy. In this case, the higher the kinetic energy of the electrons *e* is, the higher the possibility that the electrons *e* reach the electron collector 50 by overcoming the repulsion force according to the Coulomb's law due to the negative charges stored in the electron collector 50 becomes, so that the efficiency in collecting the electrons *e* in the electron collector 50, i.e., the efficiency in generating electricity is improved.

[0029] Fig. 3 illustrates the field-emitted electrons *e* approaching the electron extracting electrode 40 in the case that the quasi-two-dimensional material used for the electron extracting electrode 40 is configured by arranging carbon nanotubes which are quasi-one-dimensional materials approximately parallel to each other. The carbon nanotube is composed, e.g., of six-membered rings of carbon bonded together. In the case that an electron *e* approaches the electron extracting electrode 40 made of a quasi-two-dimensional material along the electron orbit orb, the electron *e* having kinetic energy passes through the very thin material by the quantum tunneling effect. That is, even if the electron *e* approaches an atomic nucleus *n* within the quasi-two-dimensional material, the electron *e* flying at a certain speed would not likely be captured by the atomic nucleus *n*, and thus, almost all the electrons would penetrate through the material by the quantum tunneling effect and continue to fly without being absorbed owing to the quasi-two-dimensional material.

[0030] Fig. 4 shows configuration examples of the electron emitting port 30 and the electron extracting electrode 40.

In this example, the electron emitting port 30 is made up of a quasi-one-dimensional material 31, and is vertically planted on the surface of the electron supplier 20 so that the longitudinal direction of the quasi-one-dimensional material 31 corresponds to the vertical direction (i.e., the direction of electron emission). A plurality of quasi-one-dimensional materials 31 may be planted to expedite field emission of a large number of electrons *e*.

Further, in this example, the electron extracting electrode 40 is configured by arranging a plurality of quasi-one-dimensional materials 42 spaced apart from and approximately parallel to each other, with their ends connected to a substrate 43 to constitute a quasi-two-dimensional material. An electron extracting power supply 41 is connected between the substrate 43 and the electron sup-

plier 20, which applies a positive voltage to the electron extracting electrode 40.

Although the electrons *e* field-emitted from the electron emitting port 30 made of the quasi-one-dimensional material 31 into the electrical insulation region *F* fly towards the electron extracting electrode 40, they penetrate through the gaps between the quasi-one-dimensional materials 42 in the electron extracting electrode 40 by the quantum tunneling effect. This substantially prevents the field-emitted electrons *e* from being absorbed by the electron extracting electrode 40.

The quasi-two-dimensional material may be formed by arranging quasi-one-dimensional materials into a mesh pattern, instead of arranging the quasi-one-dimensional materials 42 approximately in parallel.

Carbon nanotubes may be used as the quasi-one-dimensional materials 31 and 42.

[0031] An example of forming the electron extracting electrode 40 by bridging of carbon nanotubes will be described with reference to Figs. 5 and 6.

To form the electron extracting electrode 40 over the electron supplier 20 with the insulating member 70 interposed therebetween, a pair of substrates 44 are disposed to face each other. The substrates 44 are made of a catalytic material such as iron, cobalt or nickel, which are layered on the upper surface of the insulating member 70 to be electrically insulated from the electron supplier 20.

With the atmosphere set at a temperature around 650 degrees Centigrade, a carbonaceous gas such as methane or acetylene is supplied as appropriate to maintain proper conditions, to cause a carbon nanotube or a similar quasi-one-dimensional material to grow on the substrate 44, whereby a bridged body 45 is formed between the substrates 44 and 44. While the individual carbon nanotubes are quasi-one-dimensional materials, a large number of carbon nanotubes constitute the bridged body 45 between the pair of substrates 44, so that the electron extracting electrode 40 of a quasi-two-dimensional material is obtained.

The electron extracting power supply 41 is connected between the electron supplier 20 and the substrate 44. With a positive voltage applied from the electron extracting power supply 41 to the substrate 44, the electrons *e* within the electron emitting port 30 (composed of a plurality of vertically planted quasi-one-dimensional materials) are attracted by the Coulomb force by the positive charges within the bridged body 45, so that they are field-emitted therefrom.

Although the field-emitted electrons *e* fly towards the electron extracting electrode 40, they penetrate through the bridged body 45 made of the quasi-two-dimensional material by the quantum tunneling effect, and approach the electron collector 50.

[0032] A specific configuration example of the electron collector 50 will now be described with reference to Fig. 7. In this example, the electron collector 50 is composed of a positive charge member 51, an insulating member 52, an electrically conductive member 53, and an electron

receiving member 54.

The positive charge member 51 is applied with positive charges from an electric power supply (not shown). A layer of the electrically conductive member 53 is stacked on the front surface of the positive charge member 51, with a layer of the insulating member 52 interposed therebetween. A large number of electron receiving members 54 are placed on the electrically conductive member 53 in alignment. The electrically conductive member 53 may be an electrically conductive transparent film (ITO film). The electrons e that have been field-emitted from the electron emitting port 30 of the electron supplier 20 and passed through the electron extracting electrode 40 made of a quasi-two-dimensional material by the quantum tunneling effect are attracted by the positive charge member 51 of the electron collector 50, so that they approach the electron receiving member 54 and are absorbed therein. The electrons e that were not absorbed are absorbed by the electrically conductive member 53. At this time, migration of the electrons between the positive charge member 51 and the electrically conductive member 53 is prohibited by the insulating member 52. Thus, ultimately, the electrons move to the electron receiving member 54. As a result, the electrons e are stored in the electron receiving member 54 as negative charges. The electrons e thus stored may be caused to penetrate through the electrical load 61 of the electricity extracting circuit 60 (see Figs. 1 and 2) for use as electrical energy.

[0033] An example of an electron reaching position dispersion means 90 added to the configuration of the field emission electricity generating apparatus according to the first embodiment will now be described with reference to Fig. 8.

The electron reaching position dispersion means 90 is provided with respect to the electron collector 50 which collects the field-emitted electrons e . It is for preventing the electrons e from concentratedly reaching the same position in the electron collector 50 by dispersing the orbits orb of the electrons e flying towards the electron collector 50.

The electron reaching position dispersion means 90 is provided in front of the electron collector 50 to change the orbits of the electrons e flying towards the electron collector 50 periodically or at random.

In Fig. 8, the electron collector 50 is shown rotated at 90 degrees from the state shown in Fig. 1 or 2, only for the sake of ease of explanation.

The electron reaching position dispersion means 90 is composed of two deflectors 92, 92 provided in a horizontal direction in the figure, two deflectors 94, 94 provided in a perpendicular direction in the figure, an electron scanning circuit 91 in the horizontal direction, and an electron scanning circuit 93 in the perpendicular direction. The electron scanning circuit 91 in the horizontal direction applies electrical signals for scanning in the horizontal direction to the two horizontal deflectors 92, 92, whereas the electron scanning circuit 93 in the perpendicular direction applies electrical signals for scanning in

the perpendicular direction to the two perpendicular deflectors 94, 94. The orbits orb of the electrons e are bent in the horizontal direction due to the horizontal electrical field change caused by the electrical signals for scanning in the horizontal direction, and bent in the perpendicular direction due to the perpendicular electrical field change caused by the electrical signals for scanning in the perpendicular direction. By combining the horizontal scanning with the perpendicular scanning, the orbits orb of the electrons e are changed periodically or at random, and as a result, the electrons e are widely dispersed and received by the electron collector 50. This can prevent destructions of and damages to the electron collector 50 caused by the electrons e concentrating on a small region of the electron collector 50, and can enhance the durability thereof.

[0034] An example of an electron distribution means 100 added to the configuration of the field emission electricity generating apparatus according to the first embodiment will now be described with reference to Fig. 9.

Here, it is assumed that electrons e flying in a vacuum have $-q$ (Coulomb) charges, and approach the electron collector 50 at the velocity of v . If the charges stored in the electron collector 50 are $-Q$ (Coulomb), Coulomb repulsion acts in proportion to the product ($q \times Q$) of both charges of the electrons e and the electron collector 50. The electrons e can overcome the Coulomb repulsion and collide with the electron collector 50 if the velocity v of the electrons e is large. If the velocity v is small, however, they cannot reach the electron collector 50 due to the action of the Coulomb repulsion. Accordingly, the amount of negative charges stored in the electron collector 50 is limited, and the electrons that failed to collide with the electron collector 50 due to the Coulomb repulsion are absorbed into the positive electrode of the power supply, whereby the efficiency in generating electrical energy is lowered. Hence, it is important to cause the electron collector 50 to absorb all of the electrons e flying in a vacuum.

The electron distribution means 100 is provided in front of the electron collector 50 to distribute the electrons e that have penetrated through the electron extracting electrode 40 and move toward the electron collector 50. Namely, a pair of distribution electrodes 101 and 102 are provided opposing to each other within the electrical insulation region F between the electron extracting electrode 40 and the electron collector 50 (see Figs. 1 and 2), so that the electrons e can penetrate through between the electrodes 101 and 102. The pair of distribution electrodes 101 and 102 are connected to an alternating current power supply 103 in such a manner that when a positive voltage is applied to one of the distribution electrodes 101 (102), a negative voltage is applied to the other 102 (101).

In the case that the electron distribution means 100 is provided, the electron collector 50 is made up of a plurality of electron collectors 50 to receive the distributed electrons. That is, referring to Fig. 9, the electron collector

50 includes a first electron collector 56 and a second electron collector 57, with an insulating member 55 sandwiched therebetween to insulate them from each other.

[0035] In the configuration as described above, when the alternating current power supply 103 is turned ON, a positive potential and a negative potential are applied to the pair of distribution electrodes 101 and 102 in a fixed period of time.

In the figure, during the period in which a positive potential is applied to the left distribution electrode 101 and a negative potential is applied to the right distribution electrode 102, the flying electrons *e* have their orbits bent in the direction of the positive potential (to the left), collide with the first electron collector 56 on the left, and are eventually absorbed therein. On the other hand, during the period in which a positive potential is applied to the right distribution electrode 102 and a negative potential is applied to the left distribution electrode 101, the orbits are bent to the right, so that the electrons *e* collide with and are absorbed into the second electron collector 57 on the right. In this manner, the electrons are distributed to and collected by the first and second electron collectors 56 and 57 disposed on the left and right, respectively, in a fixed period of time.

As the electron collectors 56 and 57 are alternately used to collect electrons *e*, the electrons *e* stored in the electron collector 56 and in the electron collector 57 can each be discharged to the outside for generating electricity while the corresponding collector is not in use for collecting electrons. This reduces the amount of the electrons *e* stored within the collector, thereby making it ready to receive the electrons in the next period.

[0036] A specific example of the electricity extracting circuit 60 will now be described with reference to Fig. 10. With the electrons *e* distributed by the electron distribution means 100 and stored in the first electron collector 56 and the second electron collector 57, the electricity extracting circuit 60 removes the electrons *e* from within the electron collectors for supplying electricity.

The electricity extracting circuit 60 is provided with a transformer 62 having a primary winding 63 and a secondary winding 64. The primary winding 63 has one end 63a connected to the first electron collector 56 and the other end 63b connected to the second electron collector 57. Further, an intermediate terminal 63c is provided in the middle of the primary winding 63, and is connected to the electron supplier 20. With this structure, a voltage is output across the ends 64a and 64b of the secondary winding 64 of the transformer 62. Hence, by connecting an electrical load 65 between the ends 64a and 64b, electricity can be supplied to the electrical load for use in working.

[0037] During the period in which the electron distribution means 100 applies a positive potential to the left distribution electrode 101, electrons are received by and stored in the first electron collector 56. The electrons *e* stored in the first electron collector 56 flow into the primary winding 63 of the electricity extracting circuit 60

from the end 63a thereof, and move to the electron supplier 20 via the intermediate terminal 63c (i.e., electron-circulation). At this time, a magnetic flux is generated in the secondary winding 64 of the transformer 62, whereby a voltage is generated. As a general rule, the electrical load 65 is connected on the side of the secondary winding 64, so that reverse electromotive force is generated by the current flowing in the electrical load 65. This reverse electromotive force restricts the amount of the electrons migrating from the first electron collector 56 through the primary winding 63 to the electron supplier 20. For this reason, it takes time for the electrons *e* stored in the first electron collector 56 to be discharged sufficiently.

On the other hand, with alternation of the voltage of the alternating current power supply 103 in a predetermined cycle, when the left distribution electrode 101 of the electron distribution means 100 attains a negative potential and the right distribution electrode 102 attains a positive potential, the flying electrons *e* are received by and stored in the second electron collector 57. The electrons *e* stored in the second electron collector 57 flow into the primary winding 63 of the electricity extracting circuit 60 through the other end 63b thereof, and migrate to the electron supplier 20, passing through the intermediate terminal 63c (i.e., electron-circulation). At this time, a magnetic flux reverse to the previous one is generated in the secondary winding 64 of the transformer 62, whereby a reverse voltage is generated. Namely, the current flows in the electrical load 65 in the opposite direction. Reverse electromotive force is generated by the current flowing in the electrical load 65 of the secondary winding 64. This reverse electromotive force restricts the amount of the electrons migrating from the second electron collector 57 to the electron supplier 20 through the primary winding 63. For this reason, it takes time for the electrons *e* stored in the second electron collector 57 to be discharged sufficiently.

During this period, no electron *e* would reach the first electron collector 56, so that almost all of the electrons *e* stored in the first electron collector 56 can return to the electron supplier 20 via the primary winding 63 of the transformer 62. Namely, the electrons *e* stored in the first electron collector 56 are almost entirely discharged during this period, which makes the first electron collector 56 ready to receive electrons *e* in the next period.

The second electron collector 57 undergoes the similar processes, and becomes ready to receive electrons in the next period.

It is noted that an alternating voltage is generated on the side of the secondary winding 64 of the electricity extracting circuit 60.

[0038] As described above, by virtue of the electron distribution means 100 alternately distributing the field-emitted electrons *e* to the two electron collectors, the first electron collector 56 and the second electron collector 57, the electrons *e* are prevented from being stored in a large amount in an electron collector. This can avoid the undesirable situation where further collection of electrons

e is hindered, and thus, the field-emitted electrons e are efficiently collected and returned to the electron supplier 20.

Therefore, the biggest problem with the electricity generating apparatus of the present invention that efficiency in generating electrical energy is reduced by the electrical charge storage phenomenon can be solved, whereby a highly efficient electricity generating apparatus can be achieved.

[0039] An example of a secondary emission preventing means 110 for preventing secondary emission of the electrons that have reached the electron collector added to the configuration of the field emission electricity generating apparatus according to the first embodiment will now be described with reference to Fig. 11.

In this example, an electrically insulating surrounding wall 111 made of an electrically insulating member is provided to surround the periphery of a front surface 50a of the electron collector 50, i.e., the surface 50a receiving the flying electrons e, and a gate member 112 is disposed at an opening of the electrically insulating surrounding wall 111. The gate member 112 has an electron receiving mouth 113 near the center thereof. Further, the front surface 50a of the electron collector 50 is inclined such that the middle part is high and the circumferential edge is low. Further, an electric power supply 114 is provided to apply a positive voltage to the electron collector 50 and a negative voltage to the gate member 112 isolated by the electrically insulating surrounding wall 111.

The electrons passed through the electron receiving mouth 113 of the gate member 112 collide with the surface 50a of the electron collector 50. The electrons e collided and/or the electrons e secondarily emitted move on the bent electron orbits orb, to be eventually absorbed into the electron collector 50. The electrical field generated between the gate member 112 and the electron collector 50 acts as a power for causing the flying electrons e to approach the electron collector 50, and accordingly, all of the electrons e that have passed through the electron receiving mouth 113 of the gate member 112 are absorbed into the electron collector 50.

The electrons e absorbed into the electron collector 50 return to the electron supplier 20 via the electricity extracting circuit 60, and are used in the electrical load 61 disposed in the middle of the electricity extracting circuit 60.

It is noted that the positive voltage applied to the electron collector 50 is preferably low or close to zero for enhanced use efficiency of the collected electrons.

[0040] Another example of the secondary emission preventing means 110 for preventing secondary emission of the electrons that have reached the electron collector 50 added to the configuration of the field emission electricity generating apparatus according to the first embodiment will now be described with reference to Fig. 12. In this example, a quasi-two-dimensional conductive material 116 is layered on the front surface of the electron collector 50 with a quasi-two-dimensional insulating ma-

terial 115 interposed therebetween. An electric power supply 117a is provided to apply a positive voltage to the electron collector 50 and a negative voltage to the quasi-two-dimensional conductive material 116 isolated by the quasi-two-dimensional insulating material 115.

When the electrons e flying towards the electron collector 50 collide with the quasi-two-dimensional conductive material 116, they penetrate through the quasi-two-dimensional conductive material 116 by the quantum tunneling effect, and further penetrate through the quasi-two-dimensional insulating material 115 again by the quantum tunneling effect, to eventually collide with the electron collector 50 to be absorbed therein.

The electrons e that have collided with the electron collector 50 are reduced in speed, and are affected by Coulomb force of the negative charges stored in the quasi-two-dimensional conductive material 116. This prevents the electrons e from being externally emitted again from the electron collector 50 through the quasi-two-dimensional insulating material 115 and the quasi-two-dimensional conductive material 116. That is, secondary emission of the electrons e that have reached the electron collector 50 can be prevented.

[0041] A still further example of the secondary emission preventing means 110 for preventing secondary emission of the electrons that have reached the electron collector 50 added to the configuration of the field emission electricity generating apparatus according to the first embodiment will now be described with reference to Fig. 13.

In this example, an electrically conductive material 119 is provided at the back of the electron collector 50 via the insulating material 118, and an electric power supply 117b is provided to apply a positive voltage to the electrically conductive material 119.

The positive charges stored in the electrically conductive material 119 induce the negative charges in the electron collector 50 to be guided to its surface (back surface) facing the electrically conductive material 119 and the positive charges to its front surface (surface receiving electrons e).

The positive charges guided to the front surface of the electron collector 50 attract the flying electrons e, thereby ensuring that the electrons e reach the front surface of the electron collector 50. The electrons e thus collected by the electron collector 50 can be used as electrical energy via the electricity extracting circuit 60.

[0042] Now, the field emission electricity generating apparatus according to a second embodiment of the present invention applying the secondary emission preventing means shown in Fig. 12 will be described with reference to Fig. 14.

The field emission electricity generating apparatus of the second embodiment is identical to that of the first embodiment described above in that the electron absorption preventing means for preventing the field-emitted electrons e from being absorbed into the electron extracting electrode 40 is provided by forming the electron extract-

ing electrode 40 with a quasi-two-dimensional material to cause the electrons to penetrate through the electron extracting electrode 40 by the quantum tunneling effect. The apparatus of the second embodiment differs from that of the first embodiment in that, while the electrical insulation region F between the electron supplier 20 and the electron extracting electrode 40 is provided as an insulation space in the first embodiment, it is configured with a layer of an insulating material in the second embodiment. In practice, the electrical insulation region F is configured with a quasi-two-dimensional insulating material layer, to cause the electrons e field-emitted from the electron supplier 20 to penetrate through the electrical insulation region F made up of a quasi-two-dimensional insulating material owing to the quantum tunneling effect.

Configuring the electrical insulation region F with an insulating material rather than a space makes it possible to readily construct an electricity generating apparatus or its module through one form of solid-state chip. Combining a large number of such electricity generating modules can increase an output of generated electricity.

[0043] Although not shown in the figure, an electron emitting port 30 made up of a quasi-one-dimensional material is provided on the surface of the electron supplier 20 facing the electrical insulation region F, to facilitate field emission of the electrons e. In this case, the quasi-one-dimensional material is physically or chemically provided vertically at the central region on the upper surface of the electron supplier 20 to constitute the electron emitting port 30. In the circumferential region of the upper surface of the electron supplier 20, the electrical insulation region F may be stacked directly on the electron supplier 20 by using integrated technology.

An electron extracting power supply 41 applies a voltage across the electron extracting electrode 40 and the electron supplier 20.

An insulating member 72 of silicon dioxide or the like is stacked at the back of the electron extracting electrode 40, to constitute the electrical insulation region F as a vacuum space (pressure-reduced space). The secondary emission preventing means 110 (115, 116, 117a) is provided via the electrical insulation region F and the insulating member 72, and further, the electron collector 50 is provided at the back thereof.

The secondary emission preventing means 110 is composed of the quasi-two-dimensional insulating material 115 stacked on the electron collector 50 and the quasi-two-dimensional conductive material 116 further stacked thereon, as described above in conjunction with Fig. 12, with the electric power supply 117a applying a negative voltage and a positive voltage to the quasi-two-dimensional conductive material 116 and the electron collector 50, respectively.

The electrical insulation region F in a vacuum state surrounded by the insulating member 72, the electron extracting electrode 40, and the quasi-two-dimensional conductive material 116 is completely isolated from the

outside. That is, the apparatus shown in Fig. 14 can be formed as a solid-state apparatus which does not need to be surrounded by the vacuum vessel 10.

[0044] The electrons e are field-emitted from the electron supplier 20 via the electron emitting port 30 by an electrical field generated by the electron extracting electrode 40. The field-emitted electrons e penetrate through the electrical insulation region F made of a quasi-two-dimensional material by the quantum tunneling effect, and also penetrate through the electron extracting electrode 40 made of a quasi-two-dimensional material again by tunneling, to enter the vacuum electrical insulation region F surrounded by the insulating member 72. Further, they fly through the electrical insulation region F to reach the quasi-two-dimensional conductive material 116, which is very thin, and thus, they penetrate there-through by the quantum tunneling effect. They further penetrate through the quasi-two-dimensional insulating material 115 again by the quantum tunneling effect, and eventually reach the electron collector 50 to be absorbed therein. The negative potential of the quasi-two-dimensional conductive material 116 prevents the electrons e that have once reached the electron collector 50 from being emitted secondarily.

The electrons e absorbed into the electron collector 50 still have charges, and therefore, the electricity extracting circuit 60 can be used to externally remove the electrons e for use as electrical energy via the electrical load 61.

[0045] Another example of the field emission electricity generating apparatus according to the second embodiment of the present invention applying the secondary emission preventing means shown in Fig. 13 will now be described with reference to Fig. 15.

In the apparatus shown in Fig. 15, the secondary emission preventing means 110 (115, 116, 117a) shown in Fig. 14 is replaced with the one shown in Fig. 13.

In this apparatus, as in the case of the apparatus shown in Fig. 14, the electrical insulation region F between the electron supplier 20 and the electron extracting electrode 40 is configured with a layer of an insulating material. That is, the configuration including the electron supplier 20, the electron emitting port 30 (not shown), the electrical insulation region F composed of the layer of a quasi-two-dimensional insulating material, the electron extracting electrode 40, and the electron extracting power supply 41 is identical to that shown in Fig. 14.

[0046] At the back of the electron extracting electrode 40, an insulating member 73 of silicon dioxide or the like is stacked to form an electrical insulation region F as a vacuum space (pressure-reduced space), and the electron collector 50 is disposed via the electrical insulation region F and the insulating member 73. Further, the secondary emission preventing means 110 (118, 119, 117b) is disposed at the back of the electron collector 50.

The secondary emission preventing means 110, as described above in conjunction with Fig. 13, has the electrically conductive material 119 disposed at the back of the electron collector 50 via the insulating material 118

and the vacuum electrical insulation region F surrounded by the insulating material 118, with a positive voltage applied to the electrically conductive material 119 by the electric power supply 117b. The electric power supply 117b has a negative electrode connected to a positive electrode of the electron extracting power supply 41, and is connected to the electron extracting electrode 40 in the middle position.

The positive charges stored in the electrically conductive material 119 induce the negative charges in the electron collector 50 to be guided to its (back) surface on the electrically conductive material 119 side, and induce the positive charges to be guided to the front surface (surface receiving the electrons e) of the electron collector 50. The positive charges guided to the front surface of the electron collector 50 attract the electrons e flying in the electrical insulation region F, to ensure that they reach the front surface of the electron collector 50. The electrons e thus collected by the electron collector 50 may be used as electrical energy via the electricity extracting circuit 60.

The vacuum electrical insulation region F surrounded by the insulating member 73, the electron extracting electrode 40, and the electron collector 50, and the vacuum electrical insulation region F surrounded by the insulating material 118, the electron collector 50, and the electrically conductive material 119 are each completely isolated from the outside. That is, the apparatus shown in Fig. 15 can be configured as a solid-state apparatus that does not need to be enclosed by the vacuum vessel 10, as in the case of the apparatus shown in Fig. 14 above.

[0047] A still further example of the field emission electricity generating apparatus according to the second embodiment of the present invention that can alternately change the directions of field-emitted electrons e by using an alternating current power supply will now be described with reference to Fig. 16.

The apparatus of this example includes an electron supplier 20 and an electron extracting electrode 40 made of a quasi-two-dimensional material, with an electrical insulation region F made up of a quasi-two-dimensional insulating material provided between the electron supplier 20 and the electron extracting electrode 40. On the surface of the electron supplier 20 facing the electrical insulation region F, an electron emitting port 30 (not shown) is configured by vertically planting a large number of quasi-one-dimensional materials in the electron emission direction, to facilitate field emission of electrons e. The configurations of the electron supplier 20, the electron emitting port 30, and the electron extracting electrode 40 are identical to those in the apparatuses shown in Figs. 14 and 15.

In front of the electron collector 50, an electron collecting electrode 140 made of a quasi-two-dimensional material is stacked via an electrical insulation region F made up of a quasi-two-dimensional insulating material. On the surface of the electron collector 50 facing the electrical insulation region F, an electron collecting port 130 made

up of a quasi-one-dimensional material (not shown) is provided to facilitate collection of electrons e.

This electron collecting port 130 may be generated or configured in a similar manner as the electron emitting port 30 described above.

[0048] The electron extracting electrode 40 and the electron collecting electrode 140 are joined with each other via an insulating member 74, with an electrical insulation region F made up of a vacuum or pressure reduced space surrounded by the insulating member 74 being provided between the electron extracting electrode 40 and the electron collecting electrode 140.

[0049] An alternating current power supply 121 for extracting and collecting electrons is connected between the electron supplier 20 and the electron extracting electrode 40. Likewise, an alternating current power supply 122 for extracting and collecting electrons is connected between the electron collector 50 and the electron collecting electrode 140.

The alternating current power supplies 121 and 122 have their cycles synchronized with each other, so that when the electron extracting electrode 40 is at a positive potential, the electron collecting electrode 140 is at a negative potential, whereas when the electron extracting electrode 40 is at a negative potential, the electron collecting electrode 140 is at a positive potential.

According to the apparatus having the above-described configuration, the electrical insulation region F provided between the electron supplier 20 and the electron extracting electrode 40 and the electrical insulation region F provided between the electron collector 50 and the electron collecting electrode 140 are both configured with an insulating material, and the electrical insulation region F made up of a vacuum or pressure-reduced space surrounded by the insulating member 74 can also be provided within a solid-state device. This enables a solid-state electricity generating apparatus or a solid-state electricity generating module or element to be configured without the need of a casing such as the vacuum vessel 10.

[0050] Here, the case of alternately applying positive and negative voltages having pulse waveforms as the alternating current power supplies 121 and 122 will be described with reference to Figs. 17 and 18.

[0051] Figure 17 shows the state in a positive half cycle where the alternating current power supplies 121 and 122 firstly apply a positive voltage to the electron extracting electrode 40 and the electron collector 50 and a negative voltage to the electron supplier 20 and the electron collecting electrode 140.

In the case where the positive charge is stored in the electron extracting electrode 40, the electrons e are field-emitted from the electron supplier 20 via the electron emitting port 30 to the electrical insulation region F. Since the electrical insulation region F is made up of a quasi-two-dimensional material, the electrons e penetrate through the electrical insulation region F by the quantum tunneling effect. Further, they penetrate through the elec-

tron extracting electrode 40 made of a quasi-two-dimensional material again by the quantum tunneling effect, and enter into the electrical insulation region F that is made up of a vacuum or pressure-reduced space surrounded by the insulating member 74, such as silicon dioxide and ceramic. In this case, a positive potential and a negative potential are supplied to the electron collector 50 and the electron collecting electrode 140, respectively. The electrons e emitted into the electrical insulation region F reach the electron collecting electrode 140, they penetrate through the electron collecting electrode 140 made of a quasi-two-dimensional material by the quantum tunneling effect. Further, they penetrate through the electrical insulation region F made up of a quasi-two-dimensional insulating material by the quantum tunneling effect, to reach the electron collector 50 via the electron collecting port 130. The electron collecting electrode 140 at a negative potential prevents secondary emission of the electrons e from the electron collector 50.

The electrons e collected in the electron collector 50 are moved to the electricity extracting circuit 60, where they are utilized as electrical energy in the electrical load 61.

[0052] Figure 18 shows the state in a negative half cycle where the alternating current power supplies 121 and 122 apply a positive voltage to the electron collecting electrode 140 and the electron supplier 20 and a negative voltage to the electron collector 50 and the electron extracting electrode 40.

In the half cycle of alternating current, the electron collector 50 can function as the electron supplier, and the electron collecting electrode 140 can function as the electron extracting electrode. Further, the electron collecting port 130 provided on the surface of the electron collector 50 can function as the electron emitting port. The electron supplier 20 behaves as the electron collector, and the electron extracting electrode 40 behaves as the electron collecting electrode. The electron emitting port 30 provided on the surface of the electron supplier 20 behaves as the electron collecting port.

When the positive voltage is applied to the electron collecting electrode 140, electrons e are field-emitted from the electron collector 50 via the electron collecting port 130 to the electrical insulation region F. Because the electrical insulation region F is made up of a quasi-two-dimensional material, the electrons e penetrate through the electrical insulation region F owing to the quantum tunneling effect. Further, they penetrate through the electron collecting electrode 140 made of a quasi-two-dimensional material owing to the quantum tunneling effect, to enter the electrical insulation region F made up of a vacuum or pressure-reduced space surrounded by the insulating member 74, such as silicon dioxide and ceramic. At this time, a positive potential and a negative potential are applied to the electron supplier 20 and the electron extracting electrode 40, respectively. Although the electrons e having entered into and flying within the electrical insulation region F reach the electron extracting electrode 40, they penetrate through the electron extracting

electrode 40 made of a quasi-two-dimensional material by the quantum tunneling effect. Further, they penetrate through the electrical insulation region F made up of a quasi-two-dimensional insulating material again by the quantum tunneling effect, to reach the electron supplier 20 via the electron emitting port 30. The electron extracting electrode 40 at a negative potential prevents secondary emission of the electrons e from the electron supplier 20.

The electrons e collected in the electron supplier 20 are extracted to the electricity extracting circuit 60, where they are utilized as electrical energy at the electrical load 61.

[0053] As described above, in the positive half cycle of the alternating current power supplies 121 and 122, the electrons e within the electron supplier 20 are field-emitted to reach the electron collector 50, so that current i flows in the electricity extracting circuit 60 upward in the figure (from the electron supplier 20 side to the electron collector 50 side). In the negative half cycle of the alternating current power supplies 121 and 122, the electrons e within the electron collector 50 are field-emitted to reach the electron supplier 20, so that current i flows in the electricity extracting circuit 60 downward in the figure (from the electron collector 50 side to the electron supplier 20 side). That is, alternating current i flows through the electrical load 61 of the electricity extracting circuit 60. When a transformer or the like is used as the electrical load 61 to adjust the voltage and current, the apparatus may be utilized as a home-usable or industrial power supply.

According to the present invention described above, unlike the case of using sunlight or the like, it is possible to generate and utilize electricity during night-time or in rainy weather. Further, no heat source is necessary, which eliminates the problem of deterioration due to heat cycles. The apparatus is of course stationary. Accordingly, the apparatus of the present invention is also superior in durability, practicability, and usability to the conventional electricity generating apparatuses.

[0054] The field emission electricity generating apparatus according to a third embodiment of the present invention will now be described with reference to Fig. 19. The apparatus of the third embodiment is characterized in that an electron orbit changing electrode for changing the orbits of the electrons e flying towards the electron extracting electrode 40 is provided as the electron absorption preventing means for preventing the electrons e field-emitted from the electron emitting port 30 of the electron supplier 20 by the electron extracting electrode 40 from being absorbed into the electron extracting electrode 40.

Namely, in the first and second embodiments described above, in order to prevent the field-emitted electrons e from being absorbed by the electron extracting electrode 40, the electron extracting electrode 40 is made of a quasi-two-dimensional material to cause the electrons e to penetrate through the electron extracting electrode 40

owing to the quantum tunneling effect. In contrast, in the third embodiment, the electron orbit changing electrode is used as the electron absorption preventing means. In the third embodiment, the electron extracting electrode 40 does not need to be made of a quasi-two-dimensional material, because it is unnecessary to cause the flying electrons e to penetrate therethrough.

[0055] The electron supplier 20 is disposed within the electrical insulation region F made up of a vacuum or pressure-reduced space. The electron extracting electrode 40 is disposed opposite to the electron supplier 20. An electron extracting power supply 41 applies voltages to the electron extracting electrode 40 and the electron supplier 20 so that the electron extracting electrode 40 attains a positive voltage and the electron supplier 20 attains a negative voltage.

On both sides in the perpendicular direction of the gap between the electron collector 20 and the electron extracting electrode 40, first electron orbit changing electrodes 151 and 152 are provided together with an electric power supply 153. Further, second electron orbit changing electrodes 154 and 155 are separately provided, together with an electric power supply 156. They guide the flying electrons e towards the electron collector 50.

The field-emitted electrons e follow the electron orbits orb as shown in the figure to reach the electron collector 50.

[0056] The electron supplier 20 is made of a metal or a free-electron material, as described in the above embodiments.

Although not shown in Fig. 19, the electron emitting port 30 is provided on the surface of the electron supplier 20 facing the electron extracting electrode 40. The electron emitting port 30 for field-emitting the electrons therefrom is provided electrically conductive with the electron supplier 20. The electron emitting port 30 is preferably made of a material exhibiting a low potential barrier with respect to field emission of electrons. It is also preferably made in a shape for concentrating electrical field and ensuring a low potential barrier. The electron emitting port 30 may be formed by vertically planting a plurality of quasi-one-dimensional materials such as carbon nanotubes on the surface of the electron supplier 20.

The electron extracting electrode 40 is for applying an electrical field to the electron emitting port 30 to cause the electrons e to be field-emitted from the electron emitting port 30.

In the present embodiment, the electron extracting electrode 40 does not need to be made of a quasi-two-dimensional material, which facilitates provision of field-emitted electrons from the electron emitting port 30.

The electron collector 50 is for receiving the field-emitted electrons, and may be made of a metallic or other material having a high capability of capturing the field-emitted electrons. The electron collector 50 may be configured with the elements 51 to 54 described above in conjunction with Fig. 7. Further, the electron reaching position dispersion means 90 as illustrated in Fig. 8, the electron

distribution means 100 as illustrated in Fig. 9, and/or the secondary emission preventing means 110 as illustrated in Figs. 11 to 13 may be additionally provided to the electron collector 50.

[0057] With the positive voltage applied to the electron extracting electrode 40, the electrons e are field-emitted from the electron supplier 20 via the electron emitting port 30 towards the electron extracting electrode 40. At the time when the electrons e fly through the gap between the electron supplier 20 and the electron extracting electrode 40, their movements are affected by the first electron orbit changing electrodes 151 and 152 under the influence of the Coulomb' law, so that the orbits of the electrons e are changed towards the first electron orbit changing electrode 151 applied with the positive voltage. This prevents the field-emitted electrons e from being absorbed by the electron extracting electrode 40.

The second electron orbit changing electrodes 154 and 155 are disposed on both sides of the orbits of the electrons directed to the first electron orbit changing electrode 151 applied with the positive voltage. The second electron orbit changing electrodes 154 and 155 further change the orbits of the flying electrons e, so that they collide with the electron collector 50 and they are absorbed into it, without colliding with the electron orbit changing electrode 151.

It is noted that the two pairs of the first electron orbit changing electrodes 151, 152 and the second electron orbit changing electrodes 154, 155 are not necessarily indispensable. They are needed for providing one or more electron orbit changing electrodes as the means for changing the orbits of the electrons flying towards the electron extracting electrode 40, so that they fly towards the electron collector 50, without colliding with the electron extracting electrode 40.

[0058] The electron collector 50 is charged negatively with the collected electrons e, which may be externally taken out by the electricity extracting circuit 60 for use as electrical energy.

[0059] A specific example of the field emission electricity generating apparatus according to the third embodiment will now be described with reference to Figs. 20 and 21.

A frame 160 made of an electrically insulating material is disposed in a vacuum vessel 10, and an electron supplier 20 is attached to the frame 160. An electron extracting electrode 40 is also attached to the frame 160 opposite to the electron supplier 20. An electron extracting power supply 41 applies a positive voltage and a negative voltage to the electron extracting electrode 40 and the electron supplier 20, respectively. Although not shown in the figure, the electron supplier 20 is provided with an electron emitting port 30 made up of a quasi-one-dimensional material.

The electron extracting electrode 40 causes the electrons e to be field-emitted from the electron supplier 20 via the electron emitting port 30.

[0060] An electron orbit changing electrode 157 is at-

tached to the frame 160, opposite to a side of the gap between the electron supplier 20 and the electron extracting electrode 40. An electric power supply 158 applies voltages to the electron orbit changing electrode 157 and the electron supplier 20 so that the electron orbit changing electrode 157 attains a positive voltage and the electron supplier 20 attains a negative voltage.

The electrons *e* field-emitted from the electron supplier 20 into a vacuum have their orbits changed by the electron orbit changing electrode 157 to fly in the direction shown by an arrow, thereby entering into a lead-in space *S* from an opening 173 configured with a pair of gate members 171 and 172. An electron collector 50 is attached to the frame 160 at the depth of the lead-in space *S*.

The gate members 171 and 172 are attached to the frame 160 and are applied with a negative voltage by the electric power supplies 174 and 175. The electron collector 50 is applied with a positive voltage by the electric power supplies 174 and 175.

[0061] The electrons *e* having entered into the lead-in space *S* are attracted to the electron collector 50 having the positive charges to reach the electron collector 50, while they are repelled by the gate members 171 and 172 and prohibited from coming out of the opening 173. The electrons *e* collected by the electron collector 50 are taken out by the electricity extracting circuit 60 (see the first and second embodiments), in order to feed the collected electrons to the electrical load 61 to be used as electrical energy.

[0062] The field emission electricity generating apparatus according to a fourth embodiment of the present invention will now be described with reference to Figs. 22 and 23.

The fourth embodiment is characterized in that, as the electron absorption preventing means for preventing the electrons *e* field-emitted from the electron emitting port 30 of the electron supplier 20 by the electron extracting electrode 40 from being absorbed by the electron extracting electrode 40, the electron collector 50 is disposed in front of the electron extracting electrode 40 so as to cause the electrons *e* flying towards the electron extracting electrode 40 to be received before they reach the electron extracting electrode 40.

Namely, in order to prevent the field-emitted electrons *e* from being absorbed by the electron extracting electrode 40, the electron extracting electrode 40 is made of a quasi-two-dimensional material in the first and second embodiments, and the electron orbit changing electrode is used in the third embodiment. In contrast, in the fourth embodiment, the electron collector 50 is disposed in front of the electron extracting electrode 40 to serve as the electron absorption preventing means.

In the fourth embodiment, the electron extracting electrode 40 does not need to be made of a quasi-two-dimensional material, because it is unnecessary for the flying electrons *e* to penetrate therethrough.

[0063] Referring to Fig. 22, an electron emitting port

30 is provided at an electron supplier 20 to be electrically conductive therewith. An electron collector 50 is provided opposite to the electron emitting port 30, and an electron extracting electrode 40 is provided at the back of the electron collector 50. The electron supplier 20, the electron emitting port 30, the electron extracting electrode 40, and the electron collector 50 are disposed within a vacuum vessel (not shown) (see the vacuum vessel 10 in Fig. 1), with the atmosphere serving as an electrical insulation region *F* made up of a vacuum or pressure-reduced space.

An electron extracting power supply 41 is disposed between the electron extracting electrode 40 and the electron supplier 20, to apply a positive voltage to the electron extracting electrode 40. An electricity extracting circuit 60 is disposed between the electron collector 50 and the electron supplier 20, with an electrical load 61 provided in the middle of the circuit.

[0064] As already described in conjunction with the apparatus shown in Fig. 1, the electron supplier 20 is made of a material serving as an electron supplying source, which may be a metal or a free-electron material. The electron emitting port 30 for field-emitting electrons therefrom is provided and connected electrically with the electron supplier 20. The electron emitting port 30 is preferably made of a material exhibiting a low potential barrier with respect to field emission of electrons. It is also preferably kept in a surface condition ensuring a low potential barrier for emitting electrons. The electron emitting port 30 is formed with a large number of quasi-one-dimensional materials vertically planted on the surface of the electron supplier 20. Specifically, the quasi-one-dimensional materials such as carbon nanotubes are connected electrically with the surface of the electron supplier 20.

The electron extracting electrode 40 is for applying an electrical field to the electron emitting port 30 to cause the electrons *e* to be field-emitted from the electron emitting port 30.

The electron collector 50 is formed into a conical shape, and disposed such that the tip end of the conical shape is on the electron emitting port 30 side and the rear surface at the back of the conical shape is on the electron extracting electrode 40 side. The electron collector 50 may be made of a metal or a free-electron material.

[0065] When the positive voltage is applied to the electron extracting electrode 40, the electrons *e* are field-emitted from the electron supplier 20 via the electron emitting port 30. The emitted electrons are collided with the electron collector 50 and finally they are absorbed into the electron collector 50. The electrons *e* absorbed by the electron collector 50 are stored therein as negative charges. The stored electrons *e* are fed back through the electricity extracting circuit 60 to the electron supplier 20, via the electrical load 61 where they can be used as electrical energy.

[0066] Figure 23 shows the relationship between the voltage and the current in the case of field emission of electrons *e*. In this figure, two kinds of field emission char-

acteristics are illustrated. The minimum voltage at which electrons are emitted in the presence of an electrical field is called a threshold voltage V_{th} . In the case that current i starts to flow due to field emission upon application of a voltage greater than the threshold voltage V_{th} , this is called a low threshold voltage V_a . In the case that current i starts to flow due to field emission upon application of a voltage greater than the threshold voltage V_b , this is called a high threshold voltage V_b . In Fig. 22, the electron collector 50 of the conical shape is located between the electron extracting electrode 40 and the electron emitting port 30. Since an electrical field is applied to the electron extracting electrode 40 and the electron supplier 20, there exists the electrical field between the electron extracting electrode 40 and the electron collector 50, and also between the electron collector 50 and the electron emitting port 30.

Since the electron extracting electrode 40 and the electron collector 50 have almost flat planes facing each other in the present embodiment, an electrical field is not concentrated within a small area. Therefore, electrons can not be field-emitted from the electron collector 50. Namely, the field emission characteristics of the electrons in that area correspond to the high threshold voltage V_b shown in Fig. 23, with very few electrons e migrating from the electron collector 50 to the electron extracting electrode 40. On the other hand, the electron collector 50 and the electron emitting port 30 have their narrow protrusions facing each other with a small distance therebetween, whereby a highly concentrated electrical field is generated. In this case, the electrons e are field-emitted from the electron emitting port 30 under the application of the low threshold voltage V_a . Accordingly, the field-emitted electrons e are stored in the electron collector 50.

Industrial Applicability

[0067] The apparatus of the present invention utilizing field emission of electrons can be used as an electricity generating means in place of, or in addition to, the conventional electricity generations such as thermal electricity generation, hydroelectricity generation, nuclear electricity generation, and electricity generation using natural energy of sunlight and the like. The apparatus is able to drastically reduce external energy input, and supply stable and sustainable electrical energy at low cost, while paying due consideration to the environment, and accordingly, it offers a better fit to current industrial-field applications.

Claims

1. A field emission electricity generating apparatus comprising:

an electron supplier made of a metal or a free-electron material;

an electron emitting port provided to be electrically conductive with the electron supplier;
 an electron extracting electrode provided opposite to the electron emitting port via an electrical insulation region and for applying an electrical field to cause electrons to be attracted and emitted from the electron emitting port;
 an electron collector for collecting the electrons field-emitted by the electron extracting electrode; and
 an electron absorption preventing means for preventing the electrons emitted from the electron emitting port from being absorbed by the electron extracting electrode;
 wherein a positive voltage is applied to the electron extracting electrode to cause the electrons to be field-emitted from the electron emitting port, and the field-emitted electrons are received and collected by the electron collector provided separately, without being absorbed by the electron extracting electrode.

2. The field emission electricity generating apparatus according to claim 1, wherein the electron emitting port is made of a material and/or in a shape exhibiting a low potential barrier with respect to electron emission.
3. The field emission electricity generating apparatus according to claim 1, wherein the electron emitting port is formed by vertically planting a quasi-one-dimensional material on a surface of the electron supplier in such a manner that a longitudinal direction of the quasi-one-dimensional material corresponds to a direction of electron emission.
4. The field emission electricity generating apparatus according to claim 3, wherein the quasi-one-dimensional material is a carbon nanotube.
5. The field emission electricity generating apparatus according to claim 1, wherein the electrical insulation region is made up of an insulation space or an insulating material.
6. The field emission electricity generating apparatus according to claim 1, wherein the electron absorption preventing means is configured by forming the electron extracting electrode with a quasi-two-dimensional material to cause the electrons emitted from the electron emitting port to penetrate through the electron extracting electrode owing to the quantum tunneling effect, without being absorbed by the electron extracting electrode.
7. The field emission electricity generating apparatus according to claim 1, wherein the electron absorption preventing means is an electron orbit changing elec-

trode for changing orbits of the electrons that are emitted from the electron emitting port and are moved toward the electron extracting electrode.

8. The field emission electricity generating apparatus according to claim 1, wherein the electron absorption preventing means is configured by arranging the electron collector in front of the electron extracting electrode to collect the electrons emitted from the electron emitting port and moving towards the electron extracting electrode before the electrons reach the electron extracting electrode. 5
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9. The field emission electricity generating apparatus according to claim 1, further comprising an accelerating electrode for accelerating the electrons moving towards the electron collector. 15

10. The field emission electricity generating apparatus according to claim 1, further comprising an electron reaching position dispersion means for dispersing orbits of the electrons moving towards the electron collector to prevent the electrons from concentratedly reaching a same position in the electron collector. 20
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11. The field emission electricity generating apparatus according to claim 1, wherein the electron collector includes a plurality of electron collectors provided electrically insulated from each other, further comprising an electron distribution means for distributing the electrons emitted from the electron emitting port to the plurality of electron collectors. 30

12. The field emission electricity generating apparatus according to claim 1, further comprising a secondary emission preventing means for preventing the electrons having reached the electron collector from being emitted secondarily. 35
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13. The field emission electricity generating apparatus according to claim 1, wherein the electron collector and the electron supplier are electrically connected to each other, and an electrical load is provided between the electron collector and the electron supplier. 45

14. The field emission electricity generating apparatus according to claim 1, wherein an alternating voltage is applied to the electron extracting electrode to change the amount of the electrons emitted from the electron emitting port for generation of alternating current. 50

55

Fig.1

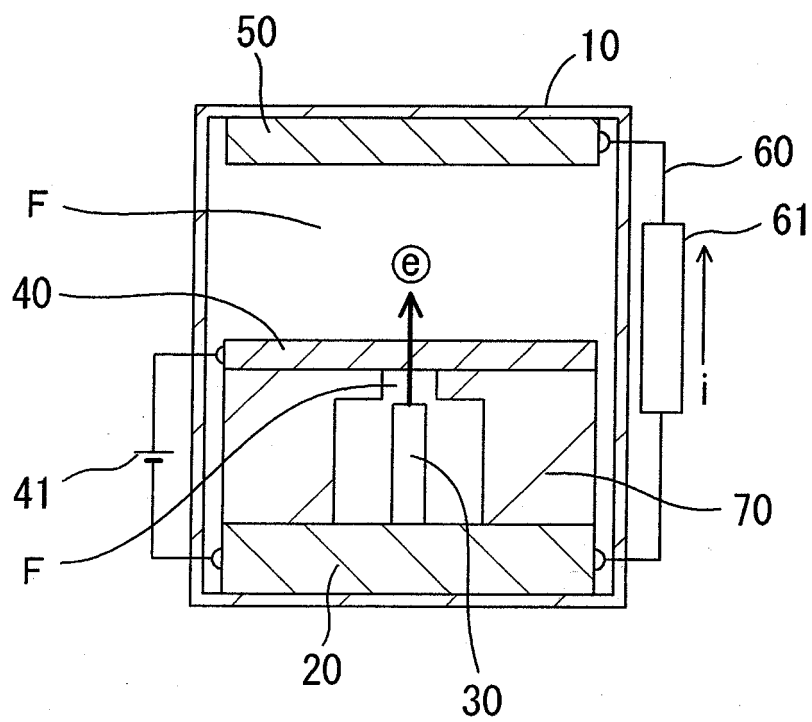


Fig.2

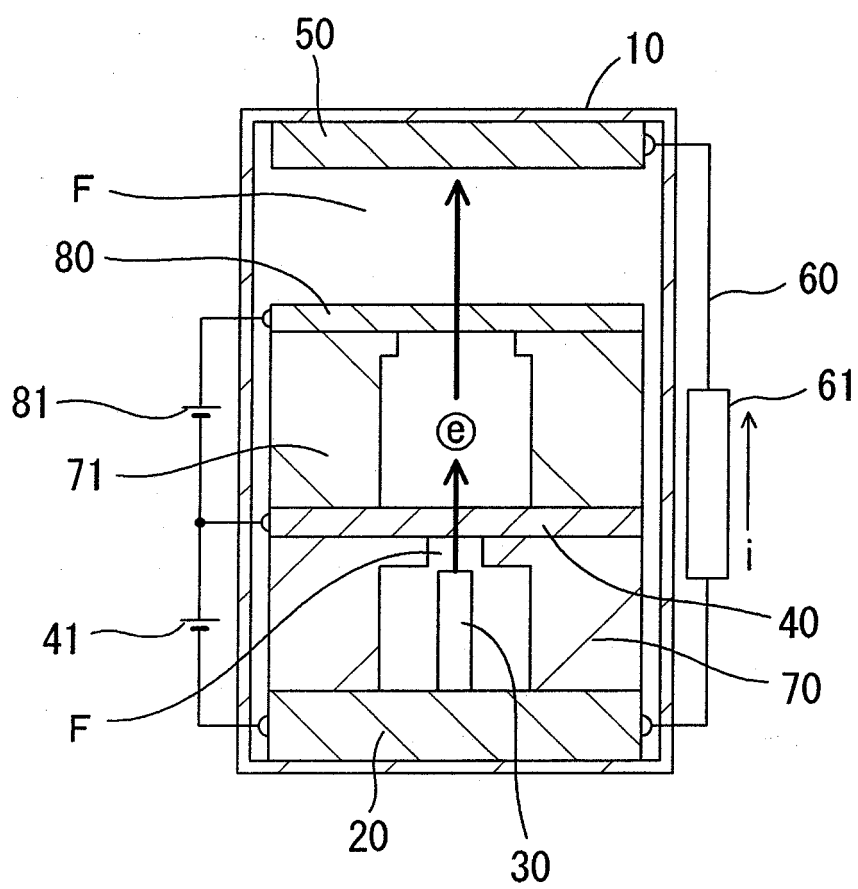


Fig.3

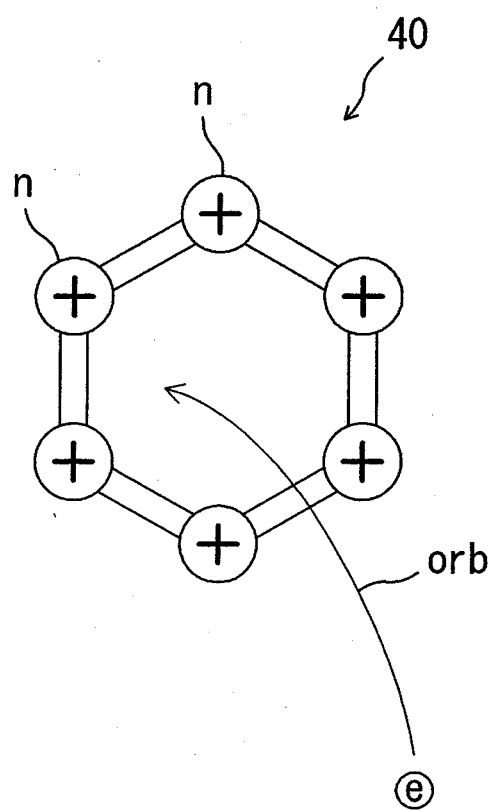


Fig.4

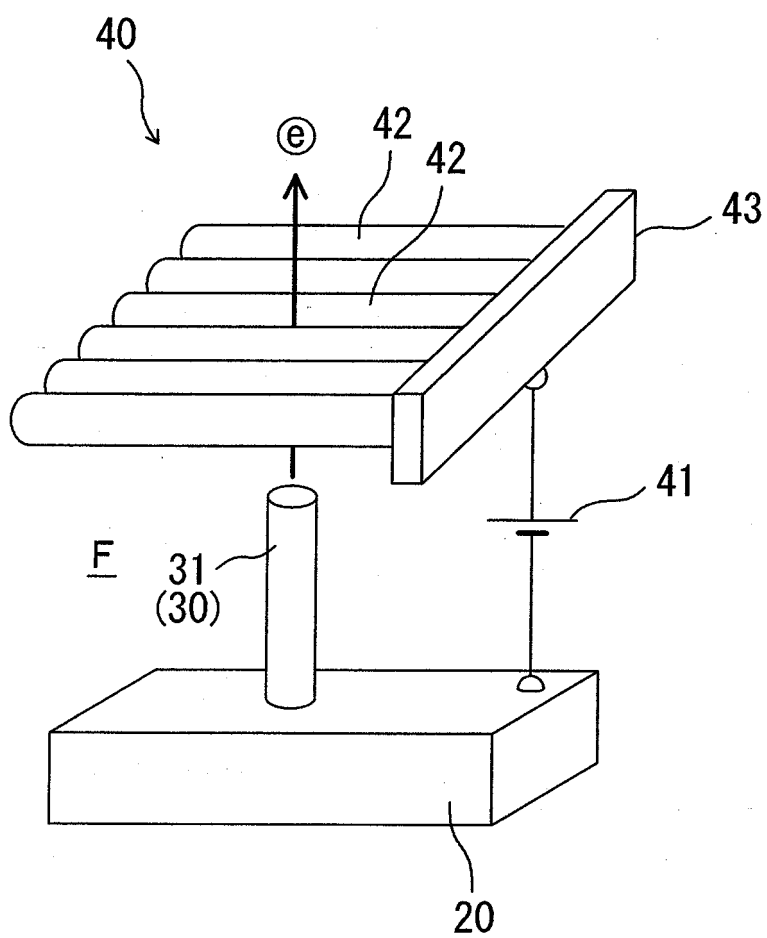


Fig.5

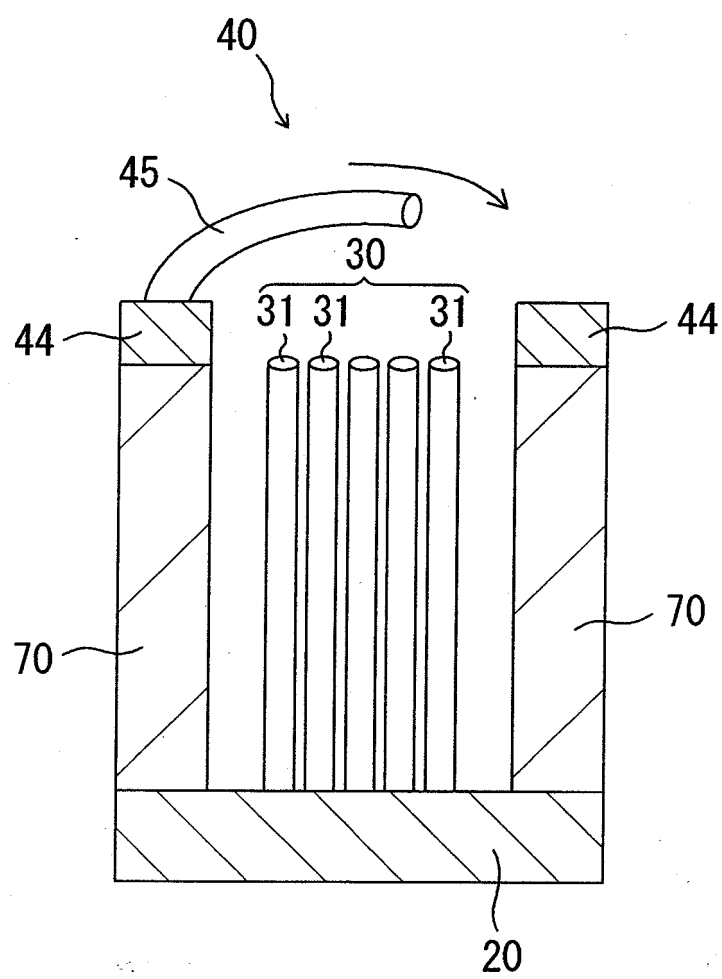


Fig.6

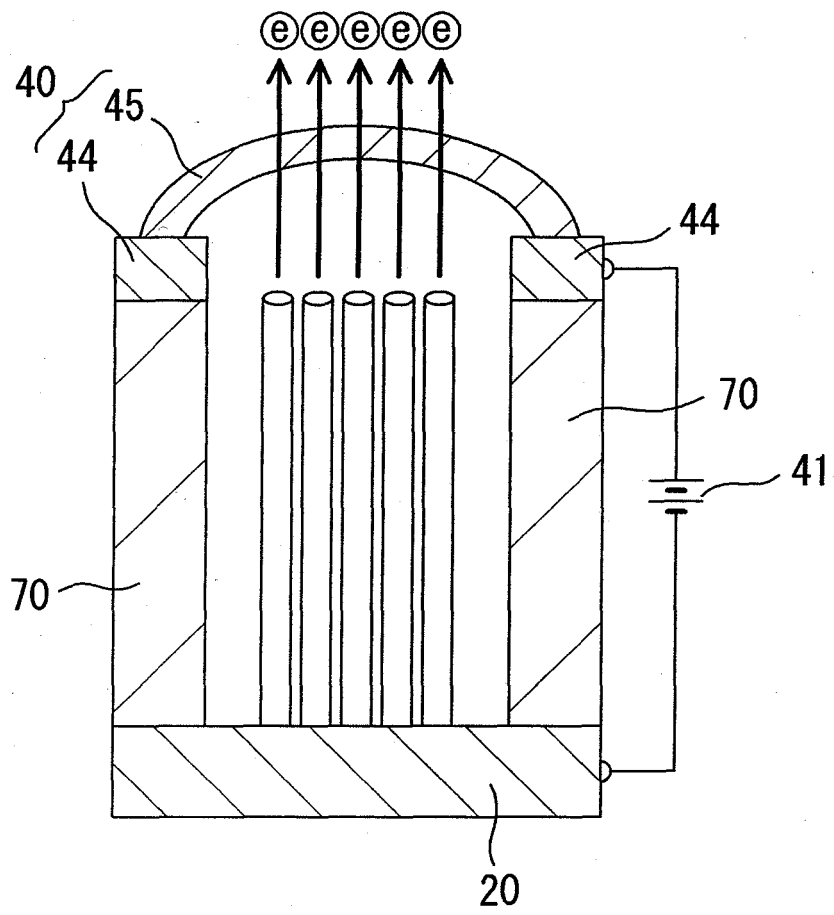


Fig.7

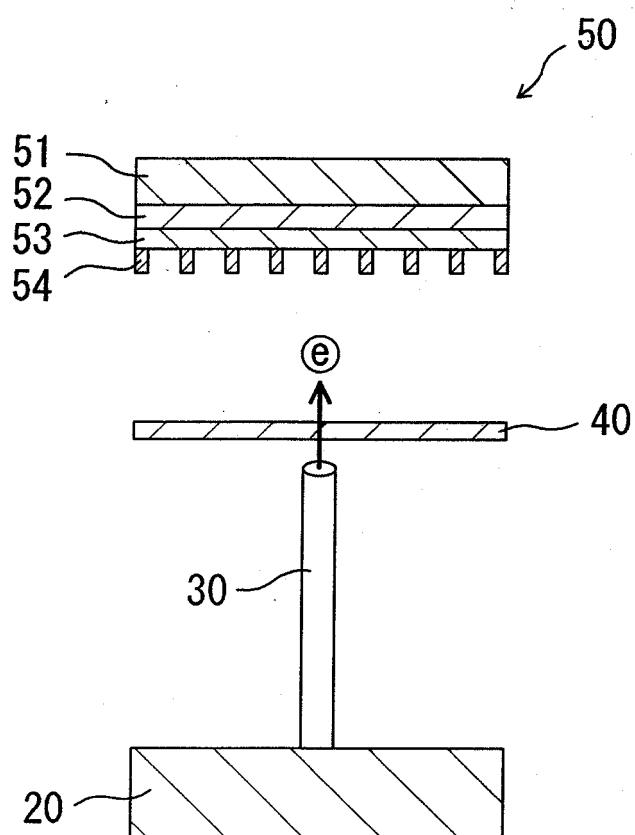


Fig.8

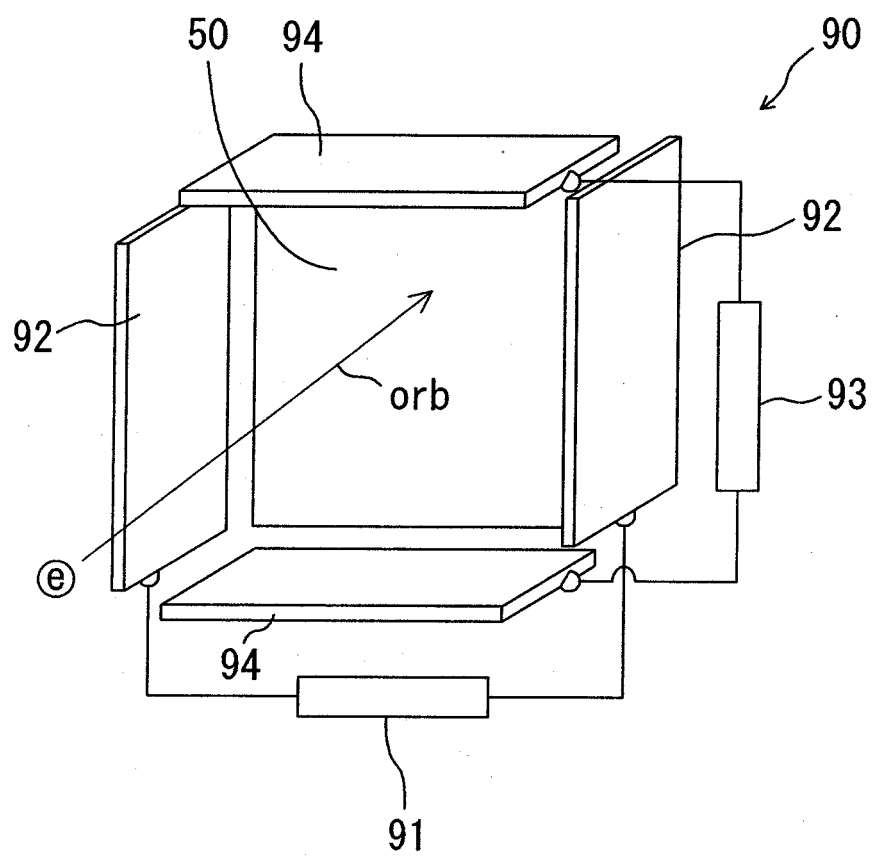


Fig.9

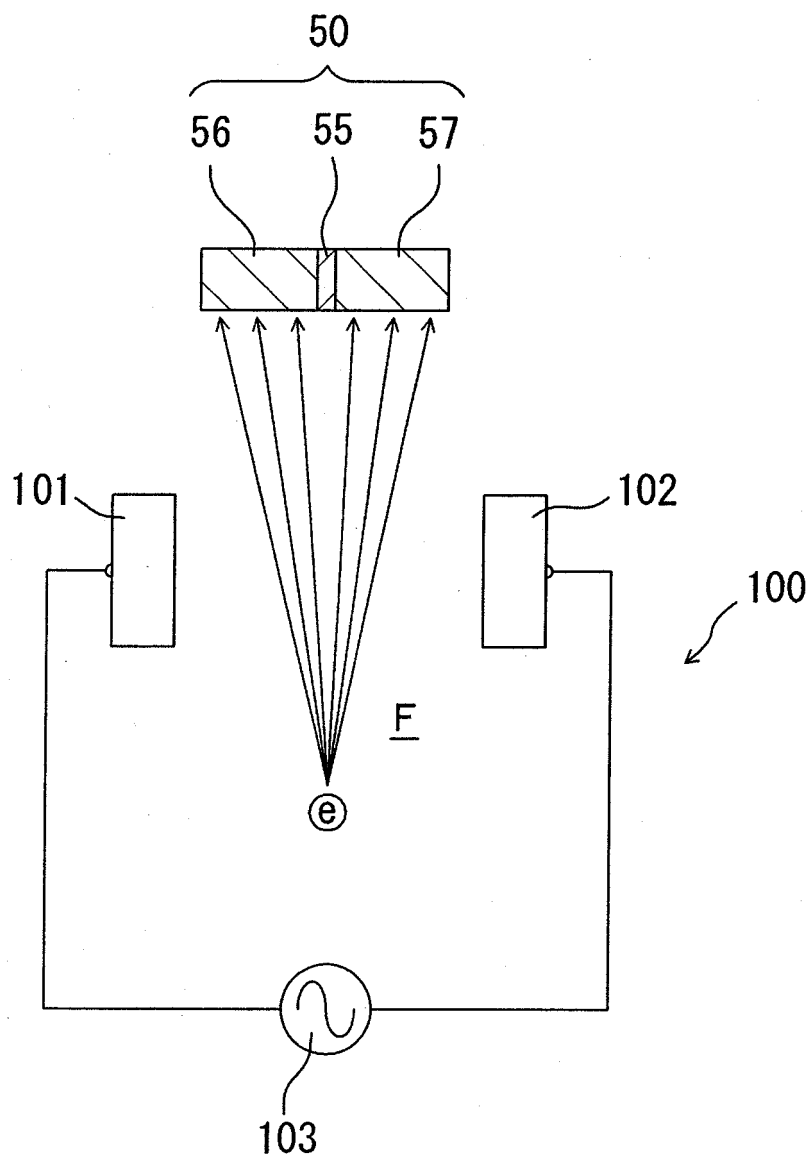


Fig.10

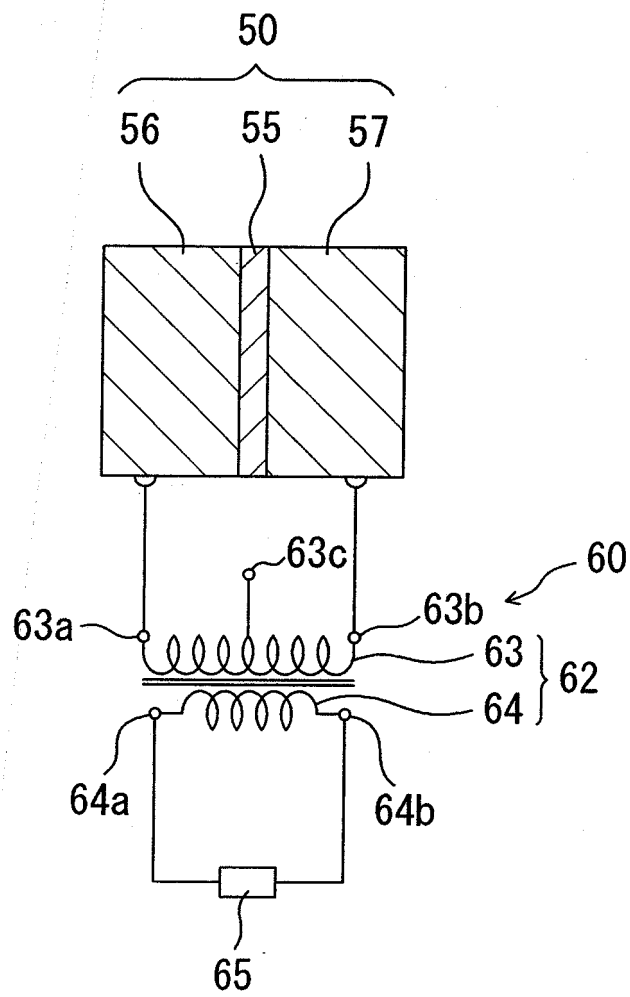


Fig.11

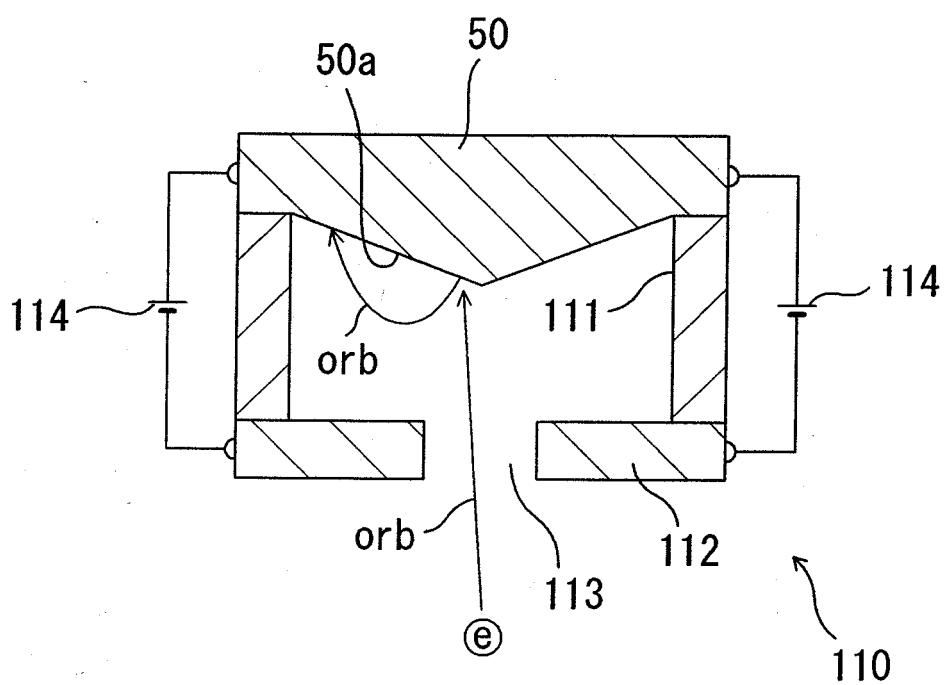


Fig.12

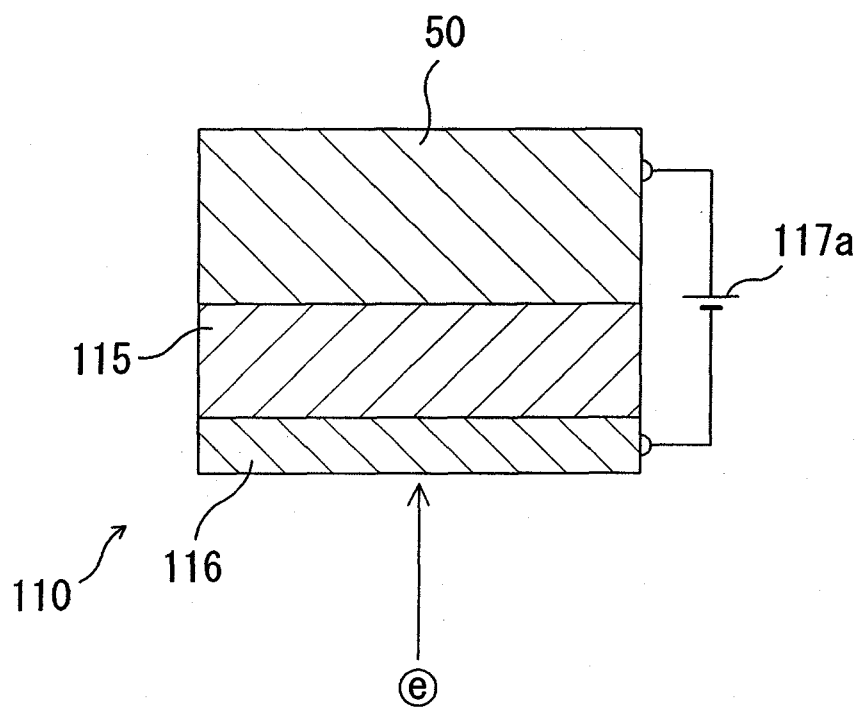


Fig.13

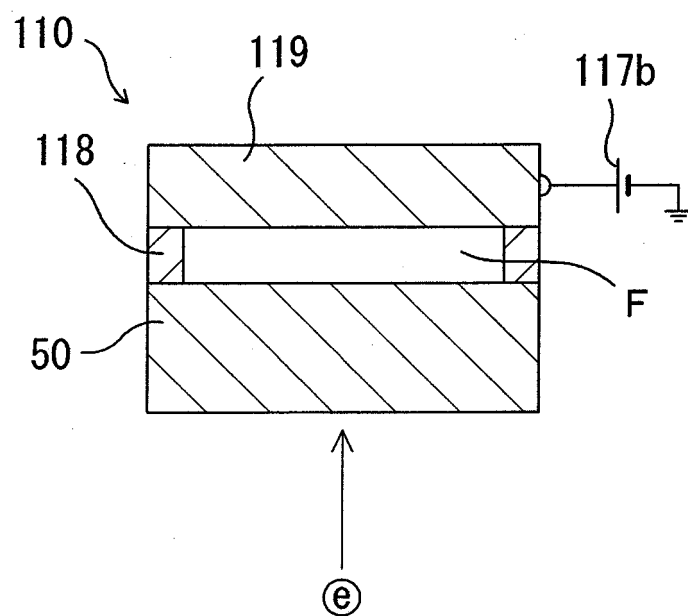


Fig.14

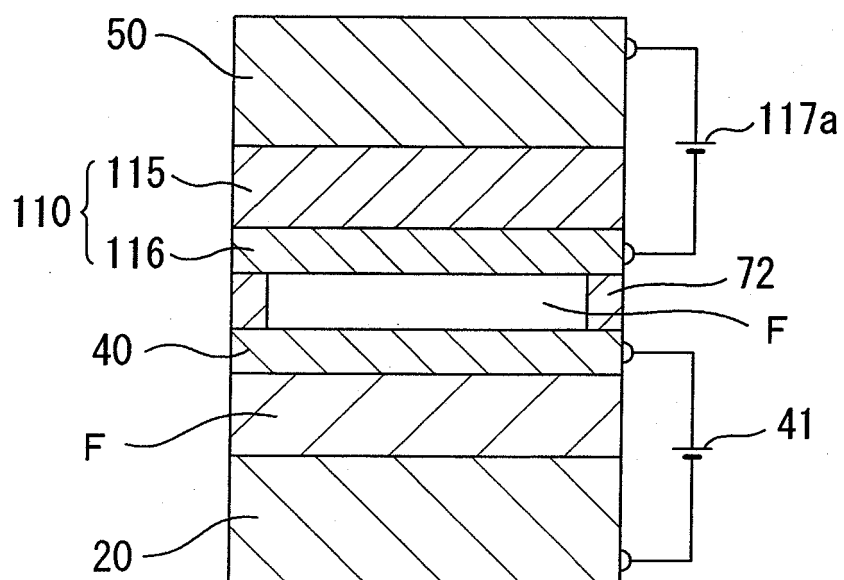


Fig.15

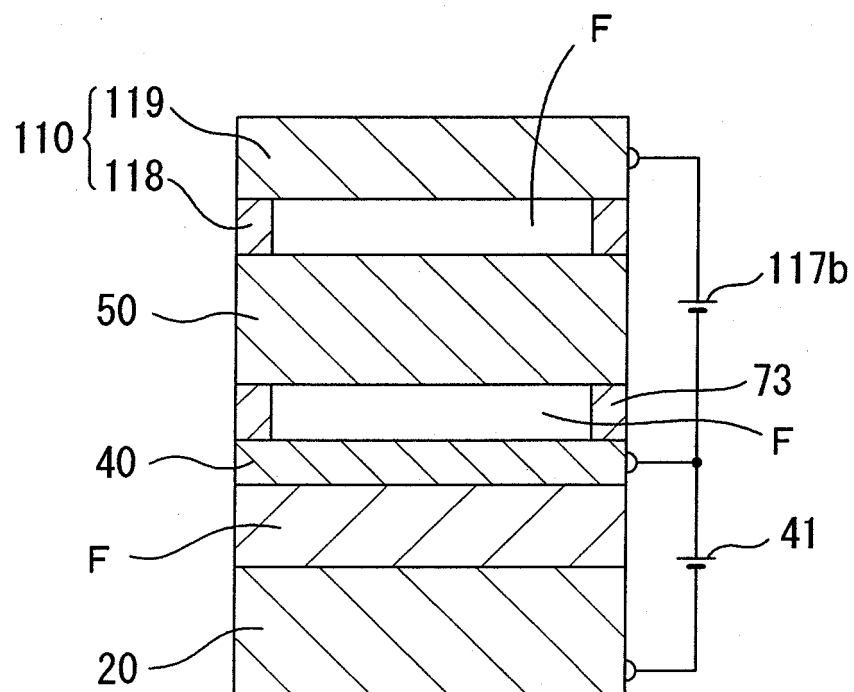


Fig.16

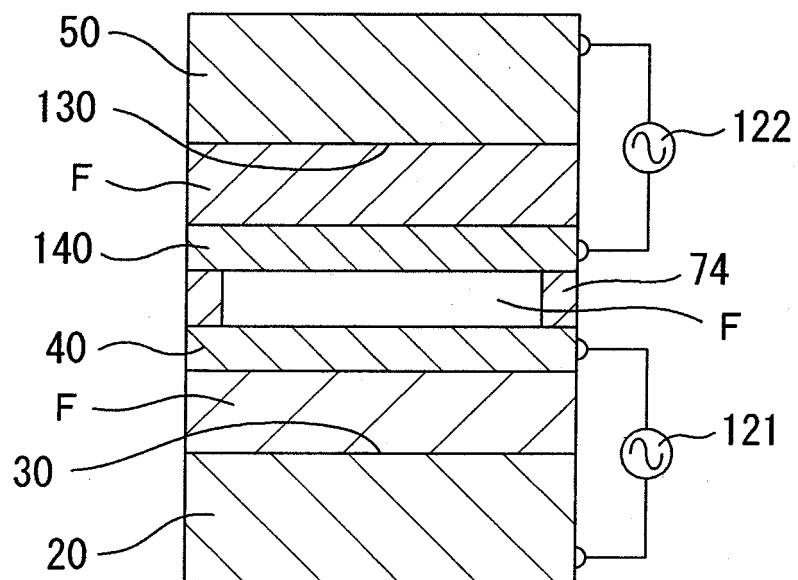


Fig.17

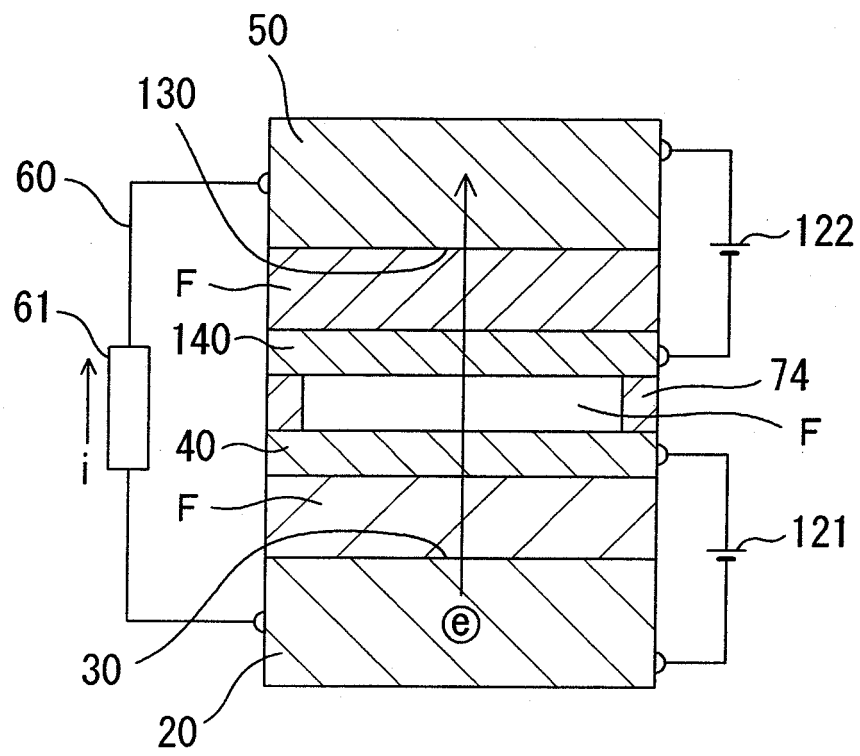


Fig.18

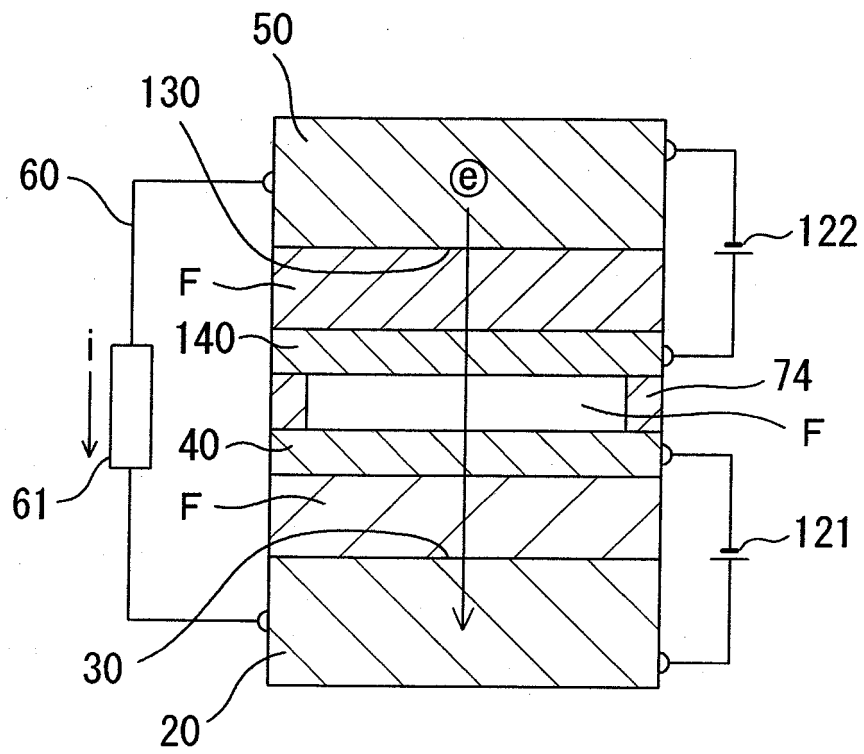


Fig.19

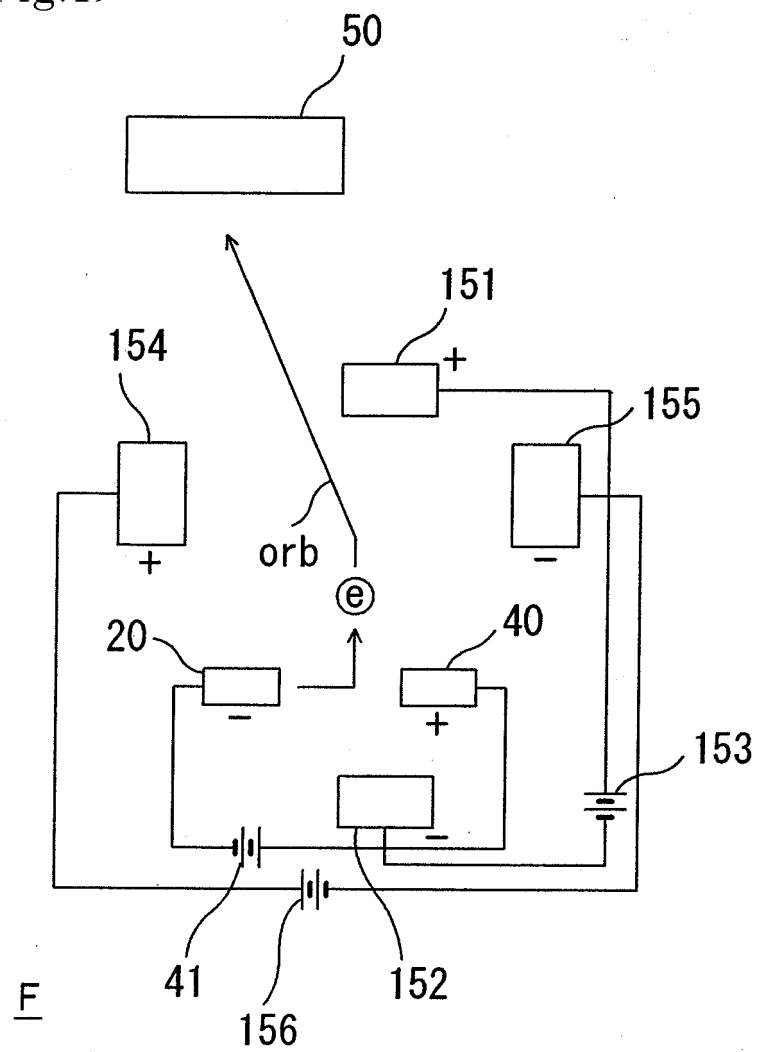


Fig.20

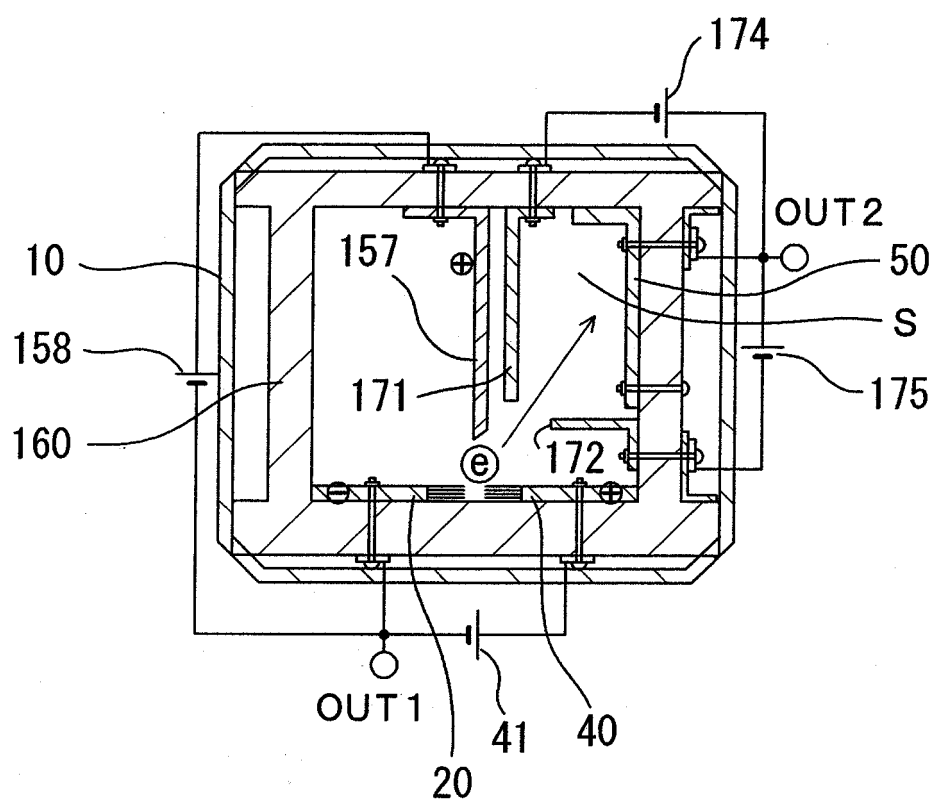


Fig.21

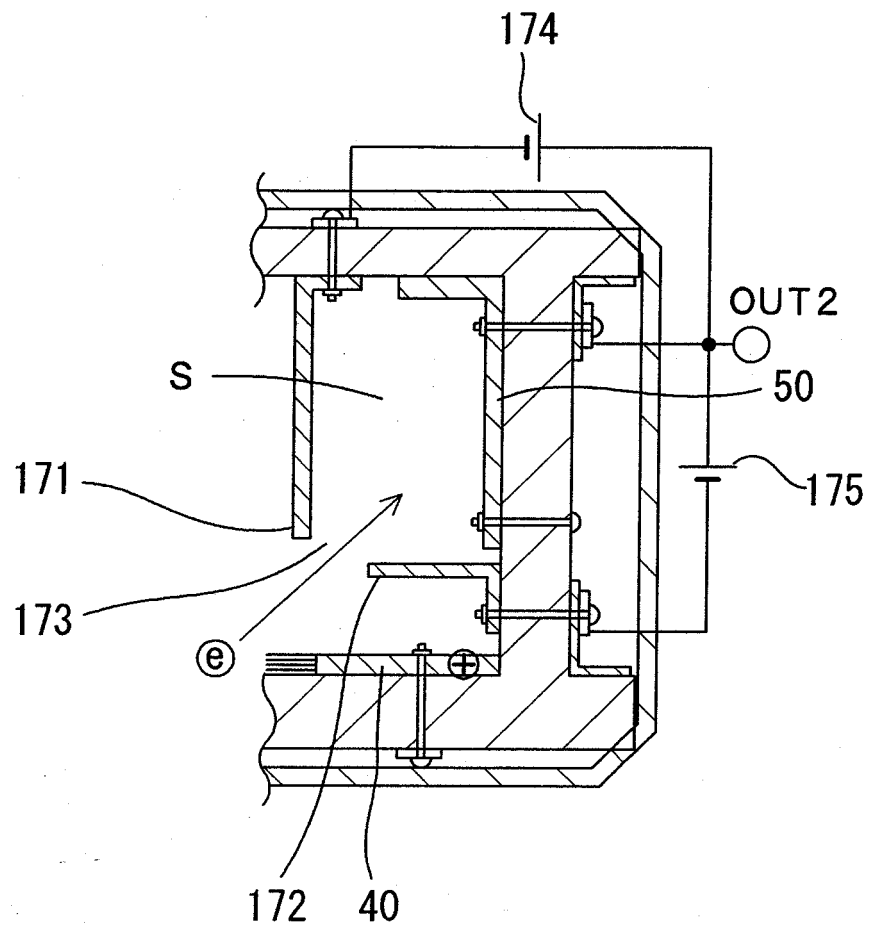


Fig.22

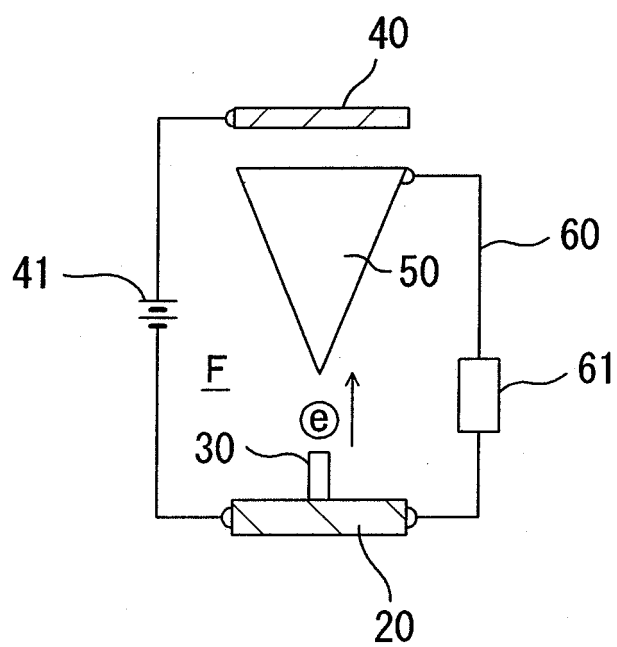
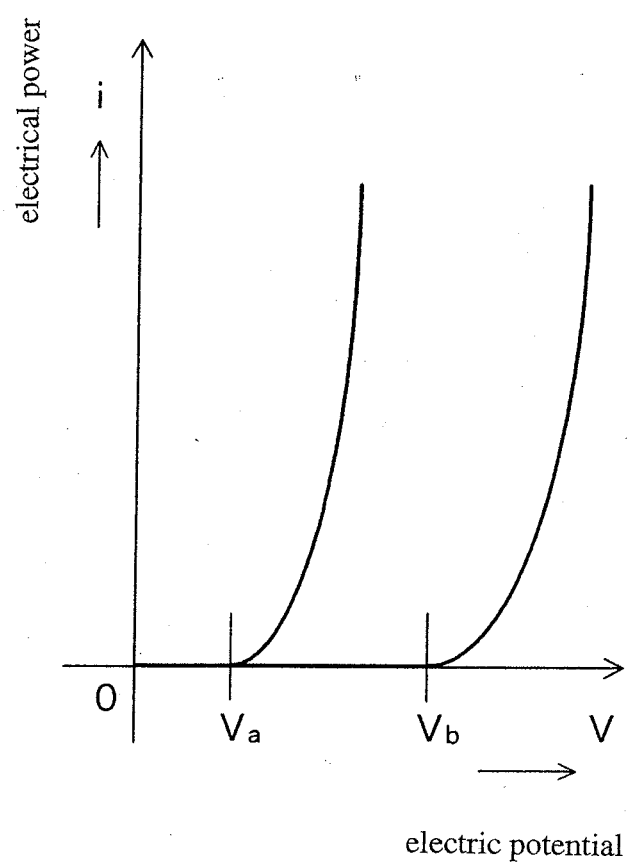


Fig.23



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2006/307607

A. CLASSIFICATION OF SUBJECT MATTER

H02N11/00 (2006.01)

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)

H02N11/00 (2006.01)

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

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2006
Kokai Jitsuyo Shinan Koho	1971-2006	Toroku Jitsuyo Shinan Koho	1994-2006

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 49-67594 A (Toshio HOSOKAWA), 01 July, 1974 (01.07.74), Full text; all drawings (Family: none)	1-14
X	JP 2003-250285 A (Kabushiki Kaisha JGS), 05 September, 2003 (05.09.03), Full text; all drawings (Family: none)	1-14

☐ Further documents are listed in the continuation of Box C.☐ See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search
30 June, 2006 (30.06.06)Date of mailing of the international search report
11 July, 2006 (11.07.06)Name and mailing address of the ISA/
Japanese Patent Office

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