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(54) **DIODE DEVICE**

DIODENANORDNUNG

APPAREIL A DIODES

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- **FITZPATRICK G O ET AL: "Close-spaced thermionic converters with active spacing control and heat-pipe isothermal emitters" ENERGY CONVERSION ENGINEERING CONFERENCE, 1996. IECEC 96., PROCEEDINGS OF THE 31ST INTERSOCIETY WASHINGTON, DC, USA 11-16 AUG. 1996, NEW YORK, NY, USA,IEEE, US, 11 August 1996 (1996-08-11), pages 920-927, XP010197852 ISBN: 0-7803-3547-3**
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- DATABASE WPI Section Ch, Week 198227 Derwent Publications Ltd., London, GB; Class J08, AN 1982-56774E XP002229603 -& SU 861 916 A (BURMISTROV V M) 10 September 1981 (1981-09-10)

Description

Technical Field

[0001] The present invention is related to diode devices, embodiments are related to diode devices in which the separation of the electrodes is set and controlled using piezo-electric, electrostrictive or magnetostrictive positioning elements. These include thermionic converters and generators, photoelectric converters and generators, and vacuum diode heat pumps. Embodiments are also related to thermotunnel converters.

Background Art

Thermionic Generators

[0002] One form of thermionic vacuum diode is the thermionic converter. A problem associated with the design of these is the space-charge effect, which is caused by the electrons themselves as they leave the cathode. The emitted electrons have a negative charge that deters the movement of other electrons towards the anode. Theoretically the formation of the space-charge potential barrier may be prevented in at least two ways: positive ions may be introduced into the cloud of electrons in front of the cathode, or the spacing between the electrodes may be reduced to the order of microns.

[0003] The use of positive ions to reduce space charge is not without problems. Although cesium and auxiliary discharge thermionic converters have been described, they do not have high efficiency, are costly to fabricate, and, particularly in the high-pressure ignited mode, do not have a long life. The technique of introducing a cesium plasma into the electrode space brings with it further disadvantages. These include heat exchange reactions within the plasma during the operation of the device, and the reactivity of the plasma, which can damage the electrodes.

[0004] Although Fitzpatrick (U.S. Pat. No. 4,667,126) teaches that "maintenance of such small spacing with high temperatures and heat fluxes is a difficult if not impossible technical challenge", in an article entitled "Demonstration of close-spaced thermionic converters", 28th Intersociety Energy Conversion Engineering Conference, Vol. 1, pages 1573 - 1580, he goes on to disclose a close spaced thermionic energy converter which operates at temperatures of 1100 to 1500 K at a variety of cesium pressures. Electrodes are maintained at a separation of the order of 10 μm by 3 ceramic spacers mounted on the collector. With electrodes at 1300 and 800 K, conversion efficiencies of 11.6% were obtained. It utilizes advanced monocrystal materials to achieve reliable operation and long life, and produces a reasonable output power with good efficiency at lower temperatures where typical ignited mode devices would produce no useful power at all. It is therefore useful at the bottom end of cascaded thermionic systems, with a very high temperature barium-cesium thermionic converter at the top end.

[0005] To operate a converter with a gap spacing of less than 10 μm, the electrode surface must be very flat and smooth, with no deformation larger than about 0.2 μm. This places a limitation on the practical size of electrodes for the emitter and collector, because heat flux through the surfaces causes a differential thermal expansion from one side relative to the other, leading to thermal expansion-caused deformation into a "dome-like" shape. This issue is even more important in high power operation. Although this deformation can be tolerated if the diameter of the electrodes is very small, the devices described by Fitzpatrick have diameters of several centimeters. Another issue is degradation of the in-gap spacers at high emitter temperatures.

[0006] Fitzpatrick addresses both these in a later paper, entitled "Close-spaced thermionic converter with active control and heat-pipe isothermal emitters", 31st Intersociety Energy Conversion Engineering Conference, Vol. 2, pages 920 - 927. He proposes a device having a large isothermal emitter, utilizing a heat pipe built into its structure with a single crystal emitting surface. The proposed device avoids degradation of the in-gap spacers at high emitter temperatures by using active spacing control, utilizing piezo electric actuators in conjunction with feedback control for continuously adjusting the gap size.

[0007] The proposed device, however, is relatively large, expensive and not amenable to mass-production. There remains a need, therefore, for a thermionic generator that is easy to fabricate, inexpensive, reliable, of high efficiency, modular, compact and having an extended life.

[0008] For example, the alternator of the automobile could be replaced by a thermionic generator using the heat contained in the exhaust gases as a source of energy, which would lead to an increase in the efficiency of the engine. Svensson and Holmlid, in their paper entitled: TEC as Electric Generator in an Automobile Catalytic Converter" 31st Intersociety Energy Conversion Engineering Conference, Vol. 2, pages 941 - 944, propose the possible use of carbon covered electrodes which become coated with Rydberg matter, resulting in the reduction of the interelectrode distance. They report that such a device might be expected to have an efficiency of 25 - 30% at temperatures of 1500 -1600 K. To obtain the high temperatures required, a fuel mixture would be injected into the device. Different configurations are discussed, but it is not clear how such a device would be economically constructed.

[0009] Another application is in domestic and industrial heating systems. These need a pump to circulate heated water around the system, which requires a source of power. The control circuitry regulating the temperature of the building being heated also requires power. These could both be supplied by means of a thermionic generator powered by the hot flue gases.

[0010] A further application utilizes heat generated by solar radiation. This could either be in space or earthbased solar power stations, or on the roof of buildings to supply or augment the power requirements of the building.

[0011] In Edelson's Patent Application, filed 1997 January 27, titled "Method and

[0012] Apparatus for Thermionic Converter", U.S. Patent No. 5,994,638, assigned to the same assignee as the present invention, a thermionic converter having close spaced electrodes is disclosed which is fabricated using micromachining techniques. This device addresses many of the problems described above, particularly those relating to economic fabrication and how to achieve close spaced electrode design. However, in operation, temperature differences between the hot emitter and cooler collector may cause high thermal stresses leading to the shape of the region between the electrodes being altered.

[0013] The present invention extends the robustness of Edelson's previous device without detracting from its ease and economy of fabrication by allowing it actively to respond to these high thermal stresses by means of active piezoelectric, electrostrictive or magnetostrictive elements incorporated to produce a micro-electromechanical thermionic converter.

Thermotunnel Converter

[0014] The thermotunnel converter is a means of converting heat into electricity that uses no moving parts. It has characteristics in common with both thermionic and thermoelectric converters. Electron transport occurs via quantum mechanical tunneling between electrodes at different temperatures.

[0015] This is a quantum mechanical concept whereby an electron is found on the opposite side of a potential energy barrier. This is because a wave determines the probability of where a particle will be, and when that probability wave encounters an energy barrier most of the wave will be reflected back, but a small portion of it will 'leak' into the barrier. If the barrier is small enough, the wave that leaked through will continue on the other side of it. Even though the particle does not have enough energy to get over the barrier, there is still a small probability that it can 'tunnel' through it.

[0016] The thermotunneling converter concept was disclosed in U.S. Patent No. 3,169,200 to Huffman. In a later paper entitled "Preliminary Investigations of a Thermotunnel Converter", [23rd Intersociety Energy Conversion

[0017] Engineering Conference vol. 1, pp. 573-579 (1986)] Huffman and Haq disclose chemically spaced graphite layers in which cesium is intercalated in highly orientated pyrolitic graphite to form a multiplicity of thermotunneling converters in electrical and thermal series. In addition they teach that the concept of thermotunneling converter was never accomplished because of the impossibility of fabricating devices having electrode spacings of less than 10 μm. The current invention addresses this shortcoming by utilizing one or more piezo-electric, electrostrictive or magnetostrictive elements to control the separation of the electrodes so that thermotunneling between them occurs.

[0018] A further shortcoming of the devices described by Huffman is thermal conduction between the layers of the converter, which greatly reduces the overall efficiency of these thermotunnelling converters.

Photoelectric Converter

[0019] In Edelson's application filed 12th May 1997, titled "Method and Apparatus for Photoelectric Generation of Electricity", U.S. Patent No. 5,973,259, assigned to the same assignee as the present invention, is described a

[0020] Photoelectric Generator having close spaced electrodes separated by a vacuum.

[0021] Photons impinging on the emitter cause electrons to be emitted as a consequence of the photoelectric effect. These electrons move to the collector as a result of excess energy from the photon: part of the photon energy is used escaping from the metal and the remainder is conserved as kinetic energy moving the electron. This means that the lower the work function of the emitter, the lower the energy required by the photons to cause electron emission. A greater proportion of photons will therefore cause photo-emission and the electron current will be higher. The collector work function governs how much of this energy is dissipated as heat: up to a point, the lower the collector work function, the more efficient the device.

[0022] However there is a minimum value for the collector work function: thermionic emission to the collector will become a problem at elevated temperatures if the collector work function is too low,

[0023] Collected electrons return via an external circuit to the cathode, thereby powering a load. One or both of the electrodes are formed as a thin film on a transparent material, which permits light to enter the device. A solar concentrator is not required, and the device operates efficiently at ambient temperature.

Vacuum Diode-Based Devices

[0024] In Edelson's disclosure, filed 1995 July 5, titled "Method and Apparatus for Vacuum Diode Heat Pump", U.S. Patent No. 6,089,311, assigned to the same assignee as the present invention, a new use for thermionic vacuum diode technology is disclosed wherein a vacuum diode is constructed using very low work function electrodes. A negative potential bias is applied to the cathode relative to the anode, and electrons are emitted. In the process of emission, the electrons carry off kinetic energy, carrying heat away from the cathode and dissipating it at an opposing anode. The resulting heat pump is more efficient than conventional cooling methods, as well as being substantially scaleable over a wide range of applications. Fabrication using conventional techniques is possible.

[0025] In Edelson's Patent Application, filed 1995 December 15, titled "Method and apparatus for improved vacuum diode heat pump", U.S. Patent No. 5,722,242, A Vacuum Diode Heat Pump is optimized for the most efficient pumping of heat by utilizing a cathode and anode of very low work function. The relationship of the work functions of cathode and anode are shown to be optimized when the cathode work function is the minimum value required to maintain current density saturation at the desired temperature, while the anode's work function is as low as possible, and in any case lower than the cathode's work function. When this relationship is obtained, the efficiency of the original device is improved. It is further shown that contact potential difference between cathode and anode may be set against the effects of space charge, resulting in an improved device whereby anode and cathode may be set at a greater distance from each other than has been previously envisaged.

[0026] In Edelson's Patent Application, filed 1996 September 25, titled "Method and apparatus for vacuum diode-based devices with electride-coated electrodes", U.S. Patent No. 5,675,972, vacuum diode-based devices, including Vacuum Diode Heat Pumps and vacuum Thermionic Generators, are described in which the electrodes are coated with an electride. These materials have low work functions, which means that contact potential difference between cathode and anode may be set against the effects of space charge, resulting in an improved device whereby anode and cathode may be set at a greater distance from each other than has been previously envisaged.

Piezoelectric Positioning Elements

[0027] Piezoelectric worm-type shifting mechanisms, or piezo motors, can move extremely short distances of the order of a tenth of a nanometer (nm), while having a stroke of several tens of millimeters.

[0028] Scanning Tunneling Microscopes are well known for employing piezoelectric devices to maintain tip distance from a surface to an accuracy of 0.1 nm.

[0029] U.S. Pat. No. 4,423,347 to Kleinschnidt et al. discloses a type of electrically actuated positioning element formed of piezo-electric bodies, which may, for example, be used to operate a needle valve.

[0030] U.S. Pat. No. 5,351,412 to Furuhata and Hirano discloses a device that provides micro-positioning of the sub-micron order.

[0031] U.S. Pat. No. 5,049,775 to Smits discloses an integrated micro-mechanical piezo-electric motor or actuator. This has two parallel cantilever beams coated with a piezo-electric material and attached to a body to be moved at one end, and to a V-shaped foot at the other. By applying an electric field, the foot may be raised, twisted, lowered and straightened, providing movement. An example has a device with cantilever beams 1 x 10 x 200 μm, which can move at 1 cm/s.

[0032] The above illustrate that piezo-electric elements may be fabricated and used at micron and submicron scale and that they are useful for positioning objects with great accuracy. Fitzpatrick takes advantage of these features in his proposed close spaced thermionic converter. He does not teach, however, that micro-mechanical devices such as that disclosed by Smits may be adapted to form a useful function in positioning the electrodes in a micromachined thermionic vacuum diode.

Electostrictive and Magnetostrictive Positioning Elements

[0033] Razzaghi (U.S. Pat. No. 5,701,043) teaches that some commercially available magnetostrictive materials readily produce strains 10 times higher than that of electroactive materials such as piezoelectric or electrostrictive elements. They are also superior with respect to load, creep, sensitivity to temperature and working temperature range. He discloses a high-resolution actuator using a magnetostrictive material able to achieve displacements with subnanometer resolution and a range of about 100 μm.

[0034] Visscher (U.S. Pat. No. 5,465,021) disclose an electromechanical displacement device which uses piezoelectric, electrostrictive or magnetostrictive clamping and transport elements.

[0035] Takuchi (U.S. Pat. No. 5,592,042) disclose a piezoelectric or electrostrictive actuator of bi-morph or uni-morph type, and teach that it may be useful as a displacement controllable element, an ink jet ejector, a VTR head, a switching element, a relay, a print head, a pump, a fan or blower.

[0036] Kondou (U.S. Pat. No. 5,083,056) disclose an improved circuit for controlling a bimorph-type electrostriction actuator.

[0037] Hattori (U.S. Pat. No. 4937489) disclose an electrostrictive actuator for controlling fine angular adjustments of specimens under microscopic scrutiny.

Surface Polishing

[0038] It is known to the art that over a 1 cm distance length, a surface can be polished to a fraction of a micron. However, the art provides no methods for providing surfaces that are flat to the order of nanometers. Additionally, the art provides no methods of making electrodes that match each other's surface features, thus providing 2 surfaces which are flat relative to one another. The present invention discloses and claims such a technique, which allows for very close spacing between electrodes.

Disclosure of Invention

[0039] The invention is defined by the features of the independent claim. Preferred embodiments are defined by the dependent claims. The present invention discloses, in one preferred embodiment, a Gap Diode fabricated by micromachining techniques in which the separation of the electrodes is controlled by piezo-electric, electrostrictive or magnetostrictive actuators. Another preferred embodiment is a Gap Diode built and operated by Micro-EngineeringMechanicalSystems, or MEMS, and its equivalents, in which the separation of the electrodes is controlled by piezo-electric, electrostrictive or magnetostrictive actuators.

[0040] The present invention further discloses in an embodiment a Gap Diode in which the separation of the electrodes is controlled by piezo-electric, electrostrictive or magnetostrictive actuators. Preferred embodiments include Cool Chips, Power Chips, and photoelectric converters. In further embodiments, Gap Diodes may be fabricated using micromachining techniques, and include MicroEngineeringMechanicalSystems, or MEMS versions, or their equivalents, in which the electrode separation is controlled by piezo-electric, electrostrictive or magnetostrictive actuators.

[0041] In a further embodiment, the present embodiment Gap Diodes in which the separation of the electrodes is controlled by piezo-electric, electrostrictive or magnetostrictive actuators, and where the space between the electrodes is filled with an inert gas: according to this embodiment the separation of the electrodes is less than the free mean path of the electrons in the inert gas. This means that thermal conduction between the electrodes is almost entirely eliminated.

[0042] In operation, temperature differences between the emitter or cathode electrode, and the collector or anode electrode, of the Gap Diode may cause high thermal stresses leading to the space between electrodes being altered. These thermal stresses may also cause the electrodes to flex, buckle or otherwise change their shape. The present invention addresses these problems by utilizing a piezo-electric, electrostrictive, or magnetostrictive element to control the separation of the electrodes. Furthermore the present invention discloses utilizing a piezo-electric, electrostrictive, or magnetostrictive element to alter the shape of the electrodes to overcome flexing, buckling or shape-changing thermal stresses.

[0043] The present application further discloses a method for fabricating a pair of electrodes in which any minor variations in the surface of one electrode are replicated in the surface of the other. This permits the electrodes to be spaced in close proximity.

[0044] A method of selecting materials is disclosed which can be used to compensate for thermal expansion. This method is optimal for use in thermotunneling Power Chips and Cool Chips, and also has uses in especially close-spaced thermionic Power Chips and Cool Chips.

[0045] The present application further discloses the concept of employing electron tunneling in a Cool Chip.

[0046] These devices overcome disadvantages of prior art systems such as economy and ease of fabrication and problems introduced by heat distortion at high temperature operation.

[0047] The present application comprises one or more of the following objects and advantages:

It is an object to provide Gap Diodes or Power Chips or Cool Chips in which the separation of the electrodes is controlled by piezo-electric, electrostrictive or magnetostrictive actuators.
An advantage is that alterations to the spacing of the electrodes that may happen as a consequence of the large temperature difference between the electrodes may be nullified.
A further advantage is that a less demanding manufacturing specification is required.
A further advantage is that the resulting Gap Diode will be extremely resistant to vibration and shock, as the actuators can rapidly counteract any such stresses.

It is a further object to provide Power Chips or Cool Chips or Gap Diodes in which the separation of the electrodes is reduced to micron or sub-micron distances, and is maintained at this small distance through the action of piezo-electric, electrostrictive or magnetostrictive actuators.
An advantage is that space charge effects are reduced.
Another advantage is that changes in electrode separation due to thermal changes occurring as the device is operated may be compensated.

It is a further object to provide Gap Diodes or Cool Chips or Power Chips in which the separation of the electrodes is small enough to allow electrons to tunnel between cathode and anode, and in which this small separation between electrodes is maintained through the action of piezo-electric, electrostrictive or magnetostrictive actuators.
An advantage is that the efficiency of the inter-converter is substantially increased.
An advantage is that heat can be efficiently pumped from one electrode to another.
An advantage is that a temperature differential can be used to generate electricity.
An advantage is that a low work function electrode is not required.
An advantage is that, when it is used to pump heat, it can cool down to 1 degree Kelvin.

It is a further object to provide Gap Diodes in which the separation of the electrodes is less than the free mean path of an electron, and in which this small separation between electrodes is maintained through the action of piezo-electric, electrostrictive or magnetostrictive actuators.
An advantage is that the space between the electrodes may be filled with an inert gas.
An advantage is that thermal conduction between the electrodes is substantially reduced, and the effi-

ciency of the device is substantially increased.

It is a still further object to provide Gap Diodes fabricated using micromachining techniques in which the separation between electrodes is maintained through the action of piezo-electric, electrostrictive or magnetostrictive actuators.
An advantage is that the devices may be constructed inexpensively and reliably.

It is a still further object to provide Power Chips and Cool Chips fabricated and operated by MicroEngineeringMechanicalSystems, or MEMS in which the separation between electrodes is maintained through the action of piezo-electric, electrostrictive or magnetostrictive actuators.
An advantage is that the devices may be constructed cheaply and reliably.

It is a yet further object to provide pairs of electrodes in which any minor imperfections in the surface of one are replicated in the surface of the other.
An advantage is that electrodes may be positioned such that the separation between them is of a very small magnitude.
An advantage is that a larger surface area can be used for pumping heat, converting heat to electricity, or any other functions of a diode.

Definitions

[0048] "Power Chip" is hereby defined as a device which uses a thermal gradient of any kind to create an electrical power or energy output. Power Chips may accomplish this using thermionics, thermotunneling, or other methods as described in this application.
[0049] "Cool Chip" is hereby defined as a device which uses electrical power or energy to pump heat, thereby creating, maintaining, or degrading a thermal gradient. Cool Chips may accomplish this using thermionics, thermotunneling, or other methods as described in this application.
[0050] "Gap Diode" is defined as any diode which employs a gap between the anode and the cathode, or the collector and emitter, and which causes or allows electrons to be transported between the two electrons, across or through the gap. The gap may or may not have a vacuum between the two electrodes, though Gap Diodes specifically exclude bulk liquids or bulk solids in between the anode and cathode. The Gap Diode may be used for Power Chips or Cool Chips, for devices that are capable of operating as both Power Chips and Cool Chips, or for other diode applications.
[0051] Surface features of two facing surfaces of electrodes "matching" each other, means that where one has an indentation, the other has a protrusion and vice versa. Thus the two surfaces are substantially equidistant from each other throughout their operating range.

Brief Description of Drawings

[0052]

Figure 1 is a diagrammatic representation of one embodiment of the electrode configuration of a Gap Diode, Power Chip or Cool Chip showing a piezo-electric actuator supporting an electrode.

Figure **2** is a diagrammatic representation of one embodiment of the electrode configuration of a Gap Diode, Power Chip or Cool Chip, showing piezo-electric actuators at intervals along the under-surface of an electrode.

Figure 3 is a diagrammatic representation of one embodiment of a photoelectric Power Chip with electrode separation controlled by piezo-electric actuators.

Figure **4** is a diagrammatic representation of one embodiment of a device illustrating how heat transfer is facilitated.

Figure 5 is a schematic showing a process for the manufacture of pairs of electrodes that have approximately matching surface details.

[0053] It should be noted in all cases that the emitter is the hot side, in a Power Chip, and the collector is the cold side, in a Power Chip. A Cool Chip, however, emits from the cold side, and collects from the hot side. Thus, each thermal interface can be either the hot side or the cold side, depending on whether the device is operating as a Cool Chip, or as a Power Chip.

Reference Numerals in Drawings

[0054]

1. Emitter electrode

5. Collector electrode

10. Region between an Emitter and a Collector

15. Housing

20. Piezo-electric actuator

27. Power supply/Electrical load

29. Capacitance controller

30. Thermal interface

35. Thermal interface

40. Connecting wires

70. Light beam

80. Corrugated sealing tubes

82. Metal powder infill

100. First step

102. Polished monocrystal of first electrode material

110. Second step

112. Layer of material

120. Third step

122. Thin layer of second electrode material

130. Fourth step

132. Electrochemically-grown layer of second electrode material

140. Fifth step

Best Modes for Carrying Out the Invention

[0055] The following description describes a number of preferred embodiments of the invention and should not be taken as limiting the invention.

[0056] The actuating element is often described as being connected to the collector electrode, however, in some embodiments it could by applied to the emitter electrode instead.

[0057] Referring now to Figure 1, two electrodes **1** and **5** are separated by a region between an emitter and a collector **10** and housed in a housing **15.** Electrode **1** is functionally connected to a piezo-electric actuator **20.** An electric field is applied to the piezo-electric actuator via connecting wires **40** which causes it to expand or contract longitudinally, thereby altering the distance of the Region **10** between electrodes **1** and **5.** Electrodes **1** and **5** are connected to a capacitance controller **29** which both modifies the piezo actuator **20,** and can give feedback to a power supply/electrical load **27** to modify the heat pumping action, and generating action, respectively. The electrodes **1** and **5** are connected to power supply/electrical load **27** via connecting wires **40,** which may also be used to connect the electrodes **1** and **5** with capacitance controller **29.**

[0058] Referring now to Figure 2, two electrodes **1** and **5** are separated by a region **10** and housed in a housing **15.** Electrode **1** is attached to a number of piezo-electric actuators **20** at intervals. An electric field is applied to the piezo-electric actuators via connecting wires **40** which causes them to expand or contract longitudinally, thereby altering the longitudinal distance of region **10** between electrodes **1** and **5.** Electrodes **1** and **5** are connected to capacitance controller **29** which both modifies the piezo actuator **20,** and can give feedback to a power supply/ electrical load **27** to modify the heat pumping action, and generating action, respectively. The longitudinal distance of region **10** between electrodes **1** and **5** is controlled by applying an electric field to piezo-electric actuators **20.** The capacitance between emitter **1** and collector **5** is measured and controlling circuitry **29** adjusts the field applied to piezo-electric actuators **20** to hold the capacitance, and consequently the distance between the electrodes **10,** at a predetermined fixed value. Alternatively the controller may be set to maximize the capacitance and thereby minimize the distance **10** between the electrodes. The diagram shown in Figure 2 can be used as a thermionic device and/or as a tunneling device, and can be used to function as a Power Chip and/or as a Cool Chip. Capacitance controller **29** may be composed of multiple elements, and each piezo actuator **20** may receive its own distinct signal, independent from the control of surrounding elements.

[0059] If it is used as a thermionic device, then electrodes **1** and **5** are made from, or are coated with, a thermionically emissive material having a work function consistent with the copious emission of electrons at the temperature of thermal interface **30.** The specific work functions can be determined by calculation, or by consulting the art.

[0060] When functioning as a Cool Chip, electrons emitted from emitter **1** move across an evacuated space **10** to a collector **5,** where they release their kinetic energy as thermal energy which is conducted away from collector **5** through housing **15** to thermal interface **35,** which is, in this case, hotter than thermal interface **30** which the electron emission serves to cool.

[0061] When functioning as a Power Chip, electrons emitted from emitter **1** move across an evacuated space **10** to a collector **5,** where they release their kinetic energy as thermal energy which is conducted away from collector **5** through housing **15** to thermal interface **35,** and a current is generated for electrical load **27.** The feedback loop from the capacitance controller to the piezo elements allows for the device to adjust for varying conditions, including vibration, shock, and thermal expansion.

[0062] When functioning as a tunneling Gap Diode, as one side of the device becomes hot and its components expand, the distance between the electrodes can be maintained at a fixed distance with the feedback loop between capacitance controller **29** and piezo elements **20.** Provided the surface of emitter **1** and collector **5** are made sufficiently smooth (or, as discussed below, matching one another), emitter **1** may be moved into such close proximity to collector **5** that quantum tunneling between the electrodes occurs. As mentioned above, this device can be used as a Gap Diode, a Power Chip, or a Cool Chip. Under these conditions, it is not necessary that region **10** should be evacuated.

[0063] When the gap distance between the electrodes is in the order nanometers, thermal conduction through a gas is considerably lessened. In all tunneling embodiments disclosed in this application, this advantage is noted, especially for applications where thermal conduction is a concern, such as

[0064] Power Chips and Cool Chips. Hence the region 10 is in some embodiments filled with an inert gas.

[0065] When functioning as a diode that is not designed to facilitate heat flow, thermal interface **30** and thermal interface **35,** are not necessary, and the resulting device could be integrated into, and used for ordinary diode applications.

[0066] It is to be understood that the term evacuated signifies the substantial removal of the atmosphere between the electrodes, but does not preclude the presence of atoms such as cesium.

[0067] Referring now to Figure 3, which shows in a diagrammatic form a thermal interface 35, electrical connectors **40,** and electrical load/power supply **27** for a photoelectric generator embodiment of the device shown in Figure 2. For the sake of clarity, the controlling circuitry comprising connecting wires **40,** and capacitance controller **29,** and additional connecting wires **40** shown in Figure 2 has been omitted. A light beam **70** passes through housing **15** and impinges on an emitter **1.** Emitter **1** is made from, or is coated with, a photoelectrically emissive material having a work function consistent with the copious emission of electrons at the wavelengths of light beam **70.**

[0068] Electrons emitted from emitter **1** move across an evacuated space **10** to a collector **5,** where they release their kinetic energy as thermal energy which is conducted away from collector **5** through piezo-electric actuators **20** and housing **15** to thermal interface **35.** The electrons return to emitter **1** by means of external circuit **40** thereby powering electrical load/power supply **27.** The spacing of region **10** between electrodes **1** and **5** is controlled as described above (see Figure 2). This means that as Power Chip becomes hot and its components expand, the distance between the electrodes can be maintained at a fixed distance. Provided the surface of emitter **1** and collector **5** are made sufficiently smooth, the collector **5** may be moved into such close proximity to emitter **1** that quantum tunneling between the electrodes occurs. Under these conditions, it is not necessary that region **10** should be evacuated, and the device operates as a tunneling Power Chip. It should be noted that a photoelectric Power Chip may use a temperature differential, by collecting some of the solar energy in heat form. In this embodiment, the device would function as the Power Chip in Figure 2, the only difference being that the heat energy provided would be solar in origin. The device in Figure 3 may alternatively be primarily photoelectric, where direct photon-electron contact results in the electron either topping the work-function barrier and emitting thermionically, or, in the tunneling version, the incident photon may cause the electron to tunnel. The device may also be a combination of the above, providing any combination of thermionic emission caused by solar heat, thermionic emission caused by direct photoelectric effects, thermotunneling from solar heat, or tunneling emission caused by direct photoelectric effects.

[0069] Referring now to Figure **4,** which shows a preferred embodiment for facilitating heat transfer between a thermal interface **30** and an electrode **1,** corrugated tubes **80,** preferably fabricated from stainless steel, form part of the structure between electrode **1** and thermal interface **30.** These tubes may be positioned with many variations, and act to allow for the movement of the positioning elements **20** and of the electrode **1** whilst maintaining support, or containment, etc, for the device, by being able to be stretched and/or compressed longitudinally. In some embodiments, corrugated tubes **80** may form the walls of a depository of a metal powder **82,** preferably aluminum powder with a grain size of 3-5 microns. More metal powder **82** would be used to receive heat transferred to the collector electrode 1, but the surroundings of the metal powder would be made smaller as the positioning elements **20** would cause the electrode to move upwards. Hence the use of an expandable depository, made from corrugated tubing **80.** Corrugated tubes **80** may also enclose the entire device, to allow for movement, as well as individual piezo actuators **20.**

[0070] For currently available materials, a device having electrodes of the order of 1 x 1 cm, surface irregularities are likely to be such that electrode spacing can be no closer than 0.1 to 1.0 μm, which is not sufficiently close for quantum tunneling to occur. However for smaller electrodes of the order of 0.05 x 0.05 cm, surface irregularities will be sufficiently small to allow the electrodes to be moved to a separation of 5 nm or less, which is sufficiently close for quantum tunneling to occur. It is likely that continued developments in electrodes having smoother surfaces will eventually allow large (1 x 1 cm) electrodes to be brought into close proximity so that electron tunneling may occur. One such approach is illustrated and disclosed in Figure 5, which describes in schematic form a method for producing pairs of electrodes having substantially smooth surfaces in which any topographical features in one are matched in the other. The method involves a first step **100** in which a polished monocrystal of material **102** is provided. This forms one of the pair of electrodes. Material 102 may also be polished tungsten, or other materials. In a step **110** a thin layer of a second material **112,** is deposited onto the surface of the material **102.** This layer is sufficiently thin so that the shape of the polished surface **102** is repeated with high accuracy. A thin layer of a third material **122** is deposited on layer **112** in a step **120,** and in a step **130** this is grown electrochemically to form a layer **132.** This forms the second electrode. In one preferred embodiment, second material **112** has a melting temperature approximately 0.8 that of first material **102** and third material **122.** In a particularly preferred embodiment, second material **112** is lead and third material **122** is aluminum.

In a step **140** the composite formed in steps **100** to **130** is heated up to a temperature greater than the melting temperature of layer 112 but which is lower than the melting temperature of layers **102** and **132.** In a particularly preferred embodiment where second material **112** is lead and third material **122** is aluminum, the composite is heated to about 800K. As layer **112** melts, layers **102** and **132** are drawn apart, and layer **112** is allowed to evaporate completely. In another preferred embodiment, layer **112** may be removed by introducing a solvent that dissolves it, or by introducing a reactive solution that causes the material to dissolve. This leaves two electrodes **102** and **132** whose surfaces replicate each other. This means that they may be positioned in very close proximity, as is required, for example, for the thermotunnel Power Chip and Cool Chip. In a variation of the method shown in Figure 3, piezoelectric elements may be attached to one or both of the electrodes **102** and **132** and used to draw the two apart as the intervening layer **112** melts. This ensures that the two electrodes are then in the correct orientation to be moved back into close juxtaposition to each other by the piezoelectric elements. Typically the distance separating the electrodes is 5 - 20 nm.

[0071] When considering a Gap Diode wherein the two electrodes are close enough to one another to allow for electron tunneling to occur, thermal expansion considerations are quite important. If thermal expansion is not taken into account, then the two electrodes could touch, causing the device to fail. The present invention discloses that if the cold side of the Gap Diode has a thermal expansion coefficient larger than that of the hot side, then the risk of touching is minimized. A preferred embodiment for this selection process, depending on the design temperature ratios of the device, is that the cold side should have a thermal expansion coefficient that is a multiple of the hot side. Specific embodiments include the use of Aluminum on the cold side and Titanium on the hot side. The thermal expansion coefficient of aluminium is 6 times that of titanium, and it is disclosed that these two materials for the electrodes, when combined with the electrode matching invention shown in Figure 5, will tolerate a difference in temperature between the two sides of up to 500 degrees Kelvin.

Industrial Applicability

[0072] Embodiments of the present invention are Power Chips and Cool Chips, utilizing a Gap Diode, in which the separation of the electrodes is set and controlled using piezo-electric, electrostrictive or magnetostrictive or other electroactive positioning elements.

[0073] Included is a method for constructing electrodes with matching topologies, the use of thermotunneling to produce a cooling effect, the use of solar energy as the motive energy for Power Chips, the use of small, and sub-nanometer-scale gaps for insulation.

[0074] Although the above specification contains many specificities, these should not be construed as limiting the scope of the invention but as merely providing illustrations of some of the presently preferred embodiments of this invention.

[0075] For example, the piezo-electric, electrostrictive or magnetostrictive actuators could be used to position either or both electrodes.

[0076] Such actuators, which are necessary for accurate separation between the electrodes of any tunneling Power Chip or tunneling Cool Chip, do not need to be active once the device has been manufactured.

[0077] For small temperature variations, it is conceivable that the capacitance loop and power supply for the actuators themselves will not be necessary, and the electrodes can be locked into place in the manufacturing or packaging process. Thus in operation the actuators would not be necessary, as the gap would not be compromised with smaller temperature fluctuations.

[0078] In the above specification, capacitance is used to measure the distance between the electrodes. Other methods known in the art may be used, including measuring the tunneling current and optical interferometry. The generated current produced by a thermionic, thermotunneling or photoelectric Power Chip may also be measured to assess the separation of the electrodes.

[0079] Other properties that may be measured include heat, for example the temperature of one or both of the electrodes may be used to initiate programmed actuation of the piezo-electric, electrostrictive or magnetostrictive elements. The position of the electrodes may also be set according to the length of time the device has been in operation. Thus it may be envisaged that the electrodes are set at a certain distance when the device is first turned on, and then the positioning of the electrodes is adjusted after certain predetermined time intervals.

[0080] In addition, if the inter-converters are constructed using micro-machining techniques, the controlling circuitry for the separation of the electrodes may be deposited on the surface of the wafer next to the piezo-electric, electrostrictive or magnetostrictive actuators.

[0081] Although no specific construction approaches have been described, the devices of the invention may be constructed as MicroElectroMechanicalSystems (MEMS) devices using micro-machining of an appropriate substrate. Integrated circuit techniques and very large scale integration techniques for forming electrode surfaces on an appropriate substrate may also be used to fabricate the devices. Other approaches useful in the construction of these devices include vapor deposition, fluid deposition, electrolytic deposition, printing, silk screen printing, airbrushing, and solution plating.

[0082] Substrates that may be used in the construction of these devices are well known to the art and include silicon, silica, glass, metals, and quartz.

[0083] Additionally, the active control elements may be pulsed, which will generate AC power output when the device is used as a power generator. The pulsing speeds of piezo elements are well within the requirements necessary for standard alternating current outputs.

Claims

1. An apparatus for the conversion of energy, comprising:

   a) a source of energy;
   b) an emitter electrode (1) connected to said source of energy;
   c) a collector electrode (5), said emitter electrode and said collector electrode each having a surface for positioning facing the other;
   d) electrical circuit means (40) connected to said electrodes, for the circulation of electrons;
   e) manipulating means (20) for controlling the relative electrode positioning, connected to one or both of said electrodes;

   and **characterized in that** topographical features of said emitter electrode surface match topographical features of said collector electrode surface in order to have a gap size between said emitter electrode surface and said collector electrode surface of the order of 20 nm.

2. The apparatus of claim 1 further comprising housing means (15) for said apparatus.

3. The apparatus of claim 2 wherein said housing means is thermally conductive.

4. The apparatus of claim 2 wherein said housing is flexible to allow the movement of said manipulating means and of said electrodes.

5. The apparatus of claim 2 further comprising thermally conductive metal powder (82) connected to said emitter electrode (1) for the transferral of thermal energy.

6. The apparatus of claim 5 further comprising an extendable depository (80) for said metal powder (82), for providing room for the metal powder as the emitter (1) electrode is moved to the area previously occupied by the metal powder.

7. The apparatus of claim 1, additionally comprising:

   a) a first thermal interface (30) thermally connecting said source of energy to said emitter electrode (1); and
   b) a second thermal interface (35) thermally connecting a heat sink means to said collector electrode (5).

8. The apparatus of claim 7 wherein the conversion of energy is the conversion of thermal energy to electrical energy, additionally comprising: an electrical load (27), electrically connected by said circuit (40) between said collector electrode (5) and said emitter electrode (1), and wherein said source of energy comprises a source of thermal energy.

9. The apparatus of claim 8 wherein said source of thermal energy is of solar origin.

10. The apparatus of claim 7 wherein the conversion of energy is the conversion of light energy to electrical energy, additionally comprising: an electrical load (27), electrically connected by said circuit (40) between said collector electrode (5) and said emitter electrode (1), wherein said source of energy comprises a source of photons (70), directed at said emitter electrode (1).

11. The apparatus of claim 10 wherein said conversion of energy additionally comprises the conversion of heat energy to electrical energy and wherein said source of photons is also a source of thermal energy.

12. The apparatus of claim 7, wherein the conversion of energy is the conversion of electrical energy to heat pumping capacity, additionally comprising: an electrical power supply (27), electrically connected by said circuit (40) between said collector electrode (5) and said emitter electrode (1), wherein said source of energy comprises said electrical power supply (27), and wherein heat is pumped from said heat source to said heat sink.

13. The apparatus of any of the preceding claims in which said emitter electrode (1) and said collector electrode (5) have differing thermal expansion coefficients.

14. The apparatus of claim 13 wherein a ratio of said thermal expansion coefficients is greater than four to one.

15. The apparatus of claim 13 wherein one of said collector and emitter electrodes is for higher temperature operation than the other electrode, and said electrode for higher temperature operation has a lower thermal expansion coefficient than said other electrode.

16. The apparatus of claim 15 wherein said electrode for higher temperature operation is composed of titanium.

17. The apparatus of claim 15 wherein said other electrode is composed of aluminium.

18. The apparatus of any of the preceding claims where-

in said manipulating means is selected from the group comprising piezo electric, electrostrictive, and magnetostrictive actuators.

19. The apparatus of any of the preceding claims wherein said manipulating means comprises multiple actuators.

20. The apparatus of claim 5 comprising means for controlling said multiple actuators independently.

21. The apparatus of any of the preceding claims further comprising control means (29) for assessing the electrode distance, and for actuating said manipulating means based on such assessment.

22. The apparatus of any of the preceding claims further comprising measuring means to enable the measurement of the distance separating said electrodes.

23. The apparatus of claim 22 wherein said measuring means comprises apparatus for measuring capacitance.

24. The apparatus of claim 22 wherein said measuring means comprises apparatus for measuring tunnelling current.

25. The apparatus of claim 22 wherein said measuring means comprises optical interferomety.

26. The apparatus of any of the preceding claims wherein said distance separating said electrodes is controlled at an initial value by said controlling means.

27. The apparatus of any of the preceding claims wherein said distance separating said electrodes is 5 nm.

28. The apparatus of any of the preceding claims wherein said distance separating said electrodes is 10 nm or less.

29. The apparatus of any of the preceding claims wherein a region between said electrodes is evacuated.

30. The apparatus of any of the preceding claims wherein a region between said electrodes comprise an inert gas.

31. The apparatus of any of the preceding claims wherein said distance separating said emitter electrode and said collector electrode is sufficiently small for electrons to tunnel from said emitter electrode to said collector electrode.

Patentansprüche

1. Vorrichtung zur Energieumwandlung, die aufweist:

a) eine Energiequelle;
b) eine mit der Energiequelle verbundene Emitterelektrode (1);
c) eine Kollektorelektrode (5), wobei die Emitterelektrode und die Kollektorelektrode jeweils eine Oberfläche aufweisen, die so positioniert werden kann, daß sie der anderen gegenüberliegt;
d) eine mit den Elektroden verbundene elektrische Schaltungseinrichtung (40) für den Elektronenkreislauf;
e) eine mit einer oder beiden Elektroden verbundene Stelleinrichtung (20) zur Steuerung der relativen Elektrodenpositionierung;

dadurch gekennzeichnet, daß topographische Merkmale der Emitterelektrodenfläche mit topographischen Merkmalen der Kollektorelektrodenfläche übereinstimmen, um eine Spaltgröße zwischen der Emitterelektrodenfläche und der Kollektorelektrodenfläche in der Größenordnung von 20 nm zu erreichen.

2. Vorrichtung nach Anspruch 1, die ferner eine Gehäuseeinrichtung (15) für die Vorrichtung aufweist.

3. Vorrichtung nach Anspruch 2, wobei die Crehäuseeinrichtung wärmeleitend ist.

4. Vorrichtung nach Anspruch 2, wobei das Gehäuse flexibel ist, um die Bewegung der Stelleinrichtung und der Elektroden zu ermöglichen.

5. Vorrichtung nach Anspruch 2, die ferner wärmeleitfähiges Metallpulver (82) aufweist, das zur Übertragung von Wärmeenergie mit der Emitterelektrode (1) verbunden ist.

6. Vorrichtung nach Anspruch 5, die ferner einen erweiterungsfähigen Speicherbehälter (80) für das Metallpulver aufweist, um Raum für das Metallpulver zu bieten, während die Emitterelektrode (1) zu der Fläche bewegt wird, die vorher von dem Metallpulver bedeckt war.

7. Vorrichtung nach Anspruch 1, die zusätzlich aufweist:

a) eine erste thermische Schnittstelle (30), welche die Energiequelle thermisch mit der Emitterelektrode (1) verbindet; und
b) eine zweite thermische Schnittstelle (35), die eine Wärmesenkeneinrichtung thermisch mit der Kollektorelektrode (5) verbindet.

8. Vorrichtung nach Anspruch 7, wobei die Energieumwandlung die Umwandlung von Wärmeenergie in elektrische Energie ist, wobei die Vorrichtung zusätzlich aufweist: eine elektrische Last (27), die durch die Schaltung (40) elektrisch zwischen die Kollektorelektrode (5) und die Emitterelektrode (1) geschaltet wird, und wobei die Energiequelle eine Wärmeenergiequelle aufweist.

9. Vorrichtung nach Anspruch 8, wobei die Wärmeenergiequelle solaren Ursprungs ist.

10. Vorrichtung nach Anspruch 7, wobei die Energieumwandlung die Umwandlung von Lichtenergie in elektrische Energie ist, wobei die Vorrichtung zusätzlich aufweist: eine elektrische Last (27), die durch die Schaltung (40) elektrisch zwischen die Kollektorelektrode (5) und die Emitterelektrode (1) geschaltet wird, und wobei die Energiequelle eine Photonenquelle (70) aufweist, die auf die Emitterelektrode (1) gerichtet ist.

11. Vorrichtung nach Anspruch 10, wobei die Energieumwandlung zusätzlich die Umwandlung von Wärmeenergie ein elektrische Energie aufweist, und wobei die Photonenquelle auch eine Wärmeenergiequelle ist.

12. Vorrichtung nach Anspruch 7, wobei die Energieumwandlung die Umwandlung von elektrischer Energie in Wärmepumpenkapazität ist, wobei die Vorrichtung zusätzlich aufweist: eine elektrische Stromversorgung (27), die durch die Schaltung (40) elektrisch zwischen die Kollektorelektrode (5) und die Emitterelektrode (1) geschaltet wird, wobei die Energiequelle die elektrische Stromversorgung (27) aufweist, und wobei Wärme von der Wärmequelle zur Wärmesenke gepumpt wird.

13. Vorrichtung nach einem der vorstehenden Ansprüche, wobei die Emitterelektrode (1) und die Kollektorelektrode (5) unterschiedliche Wärmeausdehnungskoeffizienten aufweisen.

14. Vorrichtung nach Anspruch 13, wobei das Verhältnis der Wärmeausdehnungskoeffizienten größer als vier zu eins ist.

15. Vorrichtung nach Anspruch 13, wobei von der Kollektor- und der Emitterelektrode eine Elektrode für Betrieb bei höherer Temperatur als die andere Elektrode ausgelegt ist, und wobei die Elektrode für Betrieb bei höherer Temperatur einen niedrigeren Wärmeausdehnungskoeffizienten als die andere Elektrode aufweist.

16. Vorrichtung nach Anspruch 15, wobei die Elektrode für Betrieb bei höherer Temperatur aus Titan besteht.

17. Vorrichtung nach Anspruch 15, wobei die andere Elektrode aus Aluminium besteht.

18. Vorrichtung nach einem der vorstehenden Ansprüche, wobei die Stelleinrichtung aus der Gruppe ausgewählt ist, die aus piezoelektrischen, elektrostriktiven und magnetostriktiven Stellelementen besteht.

19. Vorrichtung nach einem der vorstehenden Ansprüche, wobei die Stelleinrichtung mehrere Stellelemente aufweist.

20. Vorrichtung nach Anspruch 5, die eine Einrichtung zur unabhängigen Steuerung der mehreren Stellelemente aufweist.

21. Vorrichtung nach einem der vorstehenden Ansprüche, die ferner eine Steuereinrichtung (29) zum Schätzen des Elektrodenabstands und zur Betätigung der Stellelemente auf der Basis dieser Schätzung aufweist.

22. Vorrichtung nach einem der vorstehenden Ansprüche, die ferner eine Meßeinrichtung aufweist, um die Messung des Abstands zwischen den Elektroden zu ermöglichen.

23. Vorrichtung nach Anspruch 22, wobei die Meßeinrichtung eine Vorrichtung zur Kapazitätsmessung aufweist.

24. Vorrichtung nach Anspruch 22, wobei die Messeinrichtung eine Vorrichtung zur Tunnelstrommessung aufweist.

25. Vorrichtung nach Anspruch 22, wobei die Meßeinrichtung optische Interferometrie aufweist.

26. Vorrichtung nach einem der vorstehenden Ansprüche, wobei der Elektrodenabstand durch die Steuereinrichtung auf einen Anfangswert gesteuert wird.

27. Vorrichtung nach einem der vorstehenden Ansprüche, wobei der Elektrodenabstand 5 nm beträgt.

28. Vorrichtung nach einem der vorstehenden Ansprüche, wobei der Elektrodenabstand 10 nm oder weniger beträgt.

29. Vorrichtung nach einem der vorstehenden Ansprüche, wobei ein Bereich zwischen den Elektroden evakuiert wird.

30. Vorrichtung nach einem der vorstehenden Ansprüche, wobei ein Bereich zwischen den Elektroden ein Inertgas aufweist.

31. Vorrichtung nach einem der vorstehenden Ansprüche, wobei der Abstand zwischen der Emitterelektrode und der Kollektorelektrode hinreichend klein für eine Elektronentunnelung von der Emitterelektrode zur Kollektorelektrode ist.

Revendications

1. Dispositif pour la conversion d'énergie, comprenant:

a) une source d'énergie;
b) une électrode d'émetteur (1) raccordée à ladite source d'énergie;
c) une électrode de collecteur (5), ladite électrode d'émetteur et ladite électrode de collecteur ayant chacune une surface pour positionnement en regard l'une de l'autre;
d) un moyen de circuit électrique (40) raccordé auxdites électrodes, pour la circulation des électrons;
e) un moyen de manipulation (20) pour commander le positionnement d'électrode relatif, raccordé à l'une ou l'autre desdites électrodes;

et **caractérisé en ce que** les caractéristiques topographiques de ladite surface d'électrode d'émetteur correspondent aux caractéristiques topographiques de ladite surface d'électrode de collecteur afin d'avoir une dimension d'espace entre ladite surface d'électrode d'émetteur et ladite surface d'électrode de collecteur de l'ordre de 20 nm.

2. Dispositif selon la revendication 1, comprenant en outre un moyen de boîtier (15) pour ledit dispositif.

3. Dispositif selon la revendication 2, dans lequel ledit moyen de boîtier est thermiquement conducteur.

4. Dispositif selon la revendication 2 dans lequel ledit boîtier est souple pour permettre le déplacement dudit moyen de manipulation et desdites électrodes.

5. Dispositif selon la revendication 2 comprenant en outre de la poudre de métal thermiquement conductrice (82) raccordée à ladite électrode d'émetteur (1) pour le transfert de l'énergie thermique.

6. Dispositif selon la revendication 5 comprenant en outre un dépôt extensible (80) pour ladite poudre métallique (82), pour fournir de la place pour la poudre métallique quand l'électrode d'émetteur (1) est déplacée à la surface précédemment occupée par la poudre métallique.

7. Dispositif selon la revendication 1, comprenant additionnellement:

a) une première interface thermique (30) raccordant thermiquement ladite source d'énergie à ladite électrode d'émetteur (1); et
b) une seconde interface thermique (35) raccordant thermiquement un moyen de dissipateur thermique à ladite électrode de collecteur (5).

8. Dispositif selon la revendication 7 dans lequel la conversion de l'énergie est la conversion de l'énergie thermique en énergie électrique, comprenant additionnellement: une charge électrique (27), raccordée électriquement par ledit circuit (40) entre ladite électrode de collecteur (5) et ladite électrode d'émetteur (1), et dans lequel ladite source d'énergie comprend une source d'énergie thermique.

9. Dispositif selon la revendication 8 dans lequel ladite source d'énergie thermique est d'origine solaire.

10. Dispositif selon la revendication 7 dans lequel la conversion d'énergie est la conversion d'énergie de lumière en énergie électrique, comprenant additionnellement: une charge électrique (27), raccordée électriquement par ledit circuit (40) entre ladite électrode de collecteur (5) et ladite électrode d'émetteur (1), dans lequel ladite source d'énergie comprend une source de photons (70), dirigée sur ladite électrode d'émetteur (1).

11. Dispositif selon la revendication 10 dans lequel ladite conversion d'énergie comprend additionnellement la conversion d'énergie thermique en énergie électrique et dans lequel ladite source de photons est aussi une source d'énergie thermique.

12. Dispositif selon la revendication 7, dans lequel la conversion d'énergie est la conversion d'énergie électrique en capacité de pompage thermique, comprenant additionnellement: une alimentation électrique (27), raccordée électriquement par ledit circuit (40) entre ladite électrode de collecteur (5) et ladite électrode d'émetteur (1), dans lequel ladite source d'énergie comprend ladite alimentation électrique (27), et dans lequel la chaleur est pompée à partir de ladite source de chaleur vers ledit dissipateur thermique.

13. Dispositif selon l'une quelconque des revendications précédentes dans lequel ladite électrode d'émetteur (1) et ladite électrode de collecteur (5) ont différents coefficients de dilatation thermique.

14. Dispositif selon la revendication 13 dans lequel un rapport desdits coefficients de dilatation thermique est plus grand que quatre à un.

15. Dispositif selon la revendication 13 dans lequel une desdites électrodes de collecteur et d'émetteur est pour un fonctionnement à température plus élevée que l'autre électrode, et ladite électrode pour un fonctionnement à température plus élevée a un coefficient de dilatation thermique inférieur à ladite autre électrode.

16. Dispositif selon la revendication 15 dans lequel ladite électrode pour un fonctionnement à température plus élevée est composée de titane.

17. Dispositif selon la revendication 15 dans lequel ladite autre électrode est composée d'aluminium.

18. Dispositif selon l'une quelconque des revendications précédentes dans lequel ledit moyen de manipulation est sélectionné à partir du groupe se composant d'actionneurs piézo-électriques, électrostrictifs et magnétostrictifs.

19. Dispositif selon l'une quelconque des revendications précédentes dans lequel ledit moyen de manipulation comprend de multiples actionneurs.

20. Dispositif selon la revendication 5 comprenant un moyen pour commander lesdits multiples actionneurs indépendamment.

21. Dispositif selon l'une quelconque des revendications précédentes comprenant en outre un moyen de commande (29) pour estimer la distance d'électrode, et pour actionner ledit moyen de manipulation sur la base d'une telle estimation.

22. Dispositif selon l'une quelconque des revendications précédentes comprenant en outre un moyen de mesure pour permettre la mesure de la distance séparant lesdites électrodes.

23. Dispositif selon la revendication 22 dans lequel ledit moyen de mesure comprend un dispositif pour mesurer la capacité.

24. Dispositif selon la revendication 22 dans lequel ledit dispositif de mesure comprend un dispositif pour mesurer le courant d'effet tunnel.

25. Dispositif selon la revendication 22 dans lequel ledit moyen de mesure comprend un interféromètre optique.

26. Dispositif selon l'une quelconque des revendications précédentes dans lequel ladite distance séparant lesdites électrodes est commandée à une valeur initiale par ledit moyen de commande.

27. Dispositif selon l'une quelconque des revendications précédentes dans lequel ladite distance séparant lesdites électrodes est 5 nm.

28. Dispositif selon l'une quelconque des revendications précédentes dans lequel ladite distance séparant lesdites électrodes est 10 nm ou moins.

29. Dispositif selon l'une quelconque des revendications précédentes dans lequel une région entre lesdites électrodes est mise sous vide.

30. Dispositif selon l'une quelconque des revendications précédentes dans lequel une région entre lesdites électrodes comprend un gaz inerte.

31. Dispositif selon l'une quelconque des revendications précédentes dans lequel ladite distance séparant ladite électrode d'émetteur et ladite électrode de collecteur est suffisamment petite pour que des électrons passent par effet tunnel de ladite électrode d'émetteur à ladite électrode de collecteur.

Fig. 1

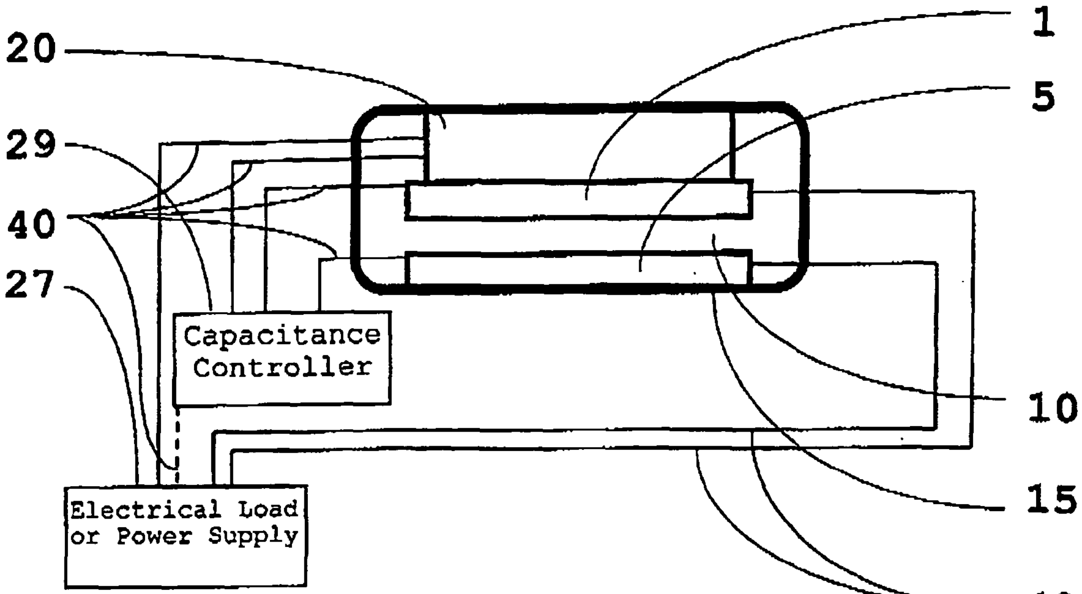
1
5
20
29
40
27
Capacitance Controller
Electrical Load or Power Supply
10
15
40

Fig. 2

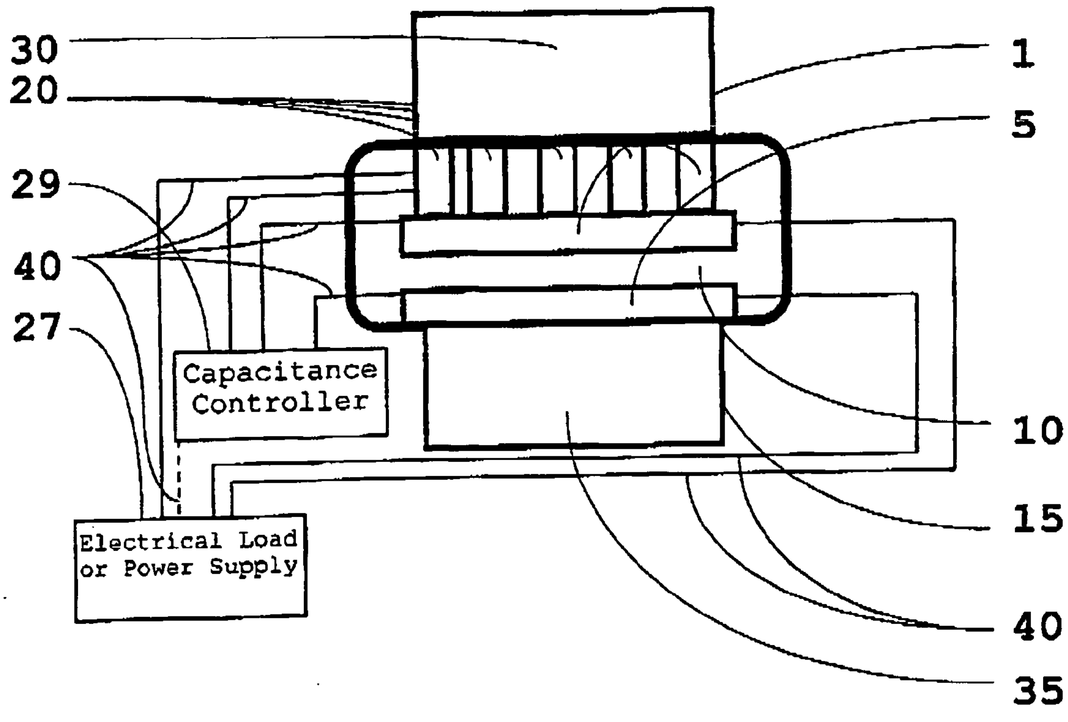
30
20
29
40
27
Capacitance Controller
Electrical Load or Power Supply
1
5
10
15
40
35

Fig. 3

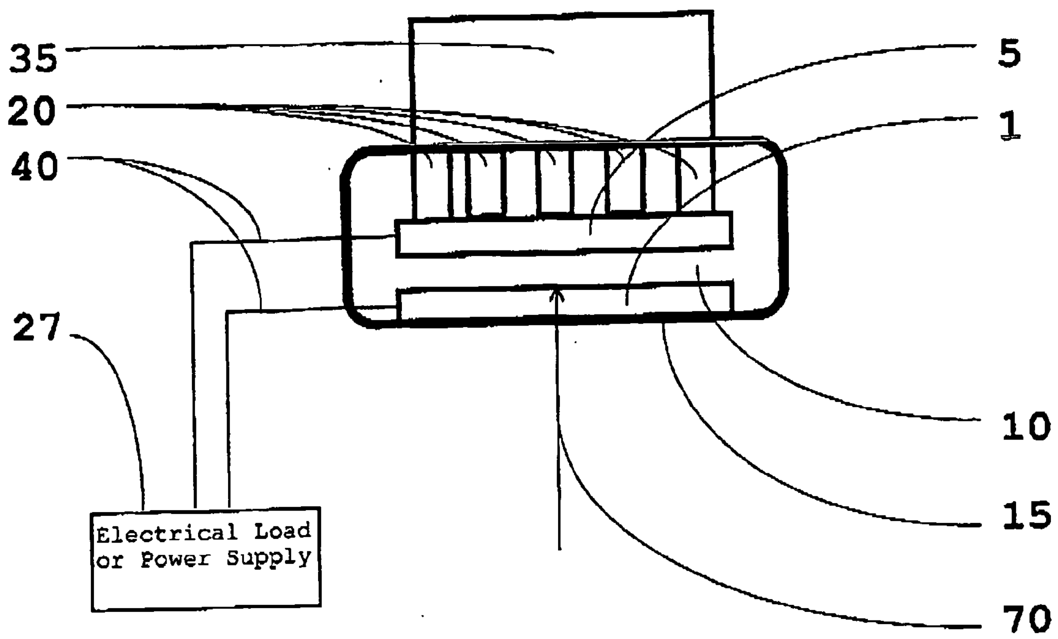

Fig. 4

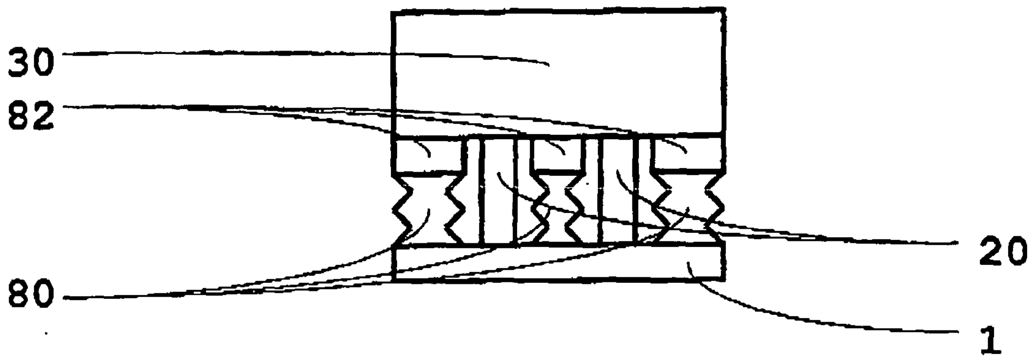

Fig.5