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

(11) **EP 3 497 382 B1**

(12) # EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention of the grant of the patent:
25.12.2019 Bulletin 2019/52

(21) Application number: **16784999.1**

(22) Date of filing: **09.08.2016**

(51) Int Cl.:
F24V 40/00 *(2018.01)*

(86) International application number:
PCT/TR2016/050281

(87) International publication number:
WO 2018/030967 (15.02.2018 Gazette 2018/07)

(54) **AN ENERGY HARVESTING DEVICE**

ENERGIEGEWINNUNGSVORRICHTUNG

DISPOSITIF DE COLLECTE D'ÉNERGIE

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR

(43) Date of publication of application:
19.06.2019 Bulletin 2019/25

(73) Proprietor: **Sabanci Üniversitesi**
34956 Tuzla/Istanbul (TR)

(72) Inventor: **KOSAR, Ali**
34956 Tuzla/Istanbul (TR)

(74) Representative: **Sevinç, Erkan**
Istanbul Patent A.S.
Plaza-33, Büyükdere Cad. No: 33/16
Sisli
34381 Istanbul (TR)

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Description

Technical Field of the Invention

[0001] The present invention relates to an energy harvesting device based on cavitation and heat generation through collapsing cavitating bubbles.

Background of the Invention

[0002] Batteries have always been the primary source of energy for powering many electronic appliances in households and offices. To achieve energy savings and clean technologies, energy harvesting from ambient sources such as solar power, mechanical vibrations, and thermal energy should be exploited. This approach is needed to offer solutions for solving individual increasing energy consumption problem in the world using renewable energy resources. Thus, energy harvesting is becoming more and more attractive in a wide variety of self-powered micro devices or systems including sensors, monitoring devices, biomedical devices, and implantable biodevices. The market size of energy harvesting is projected to increase to $4.2 billion in 2019 [Energy Harvesters: Market Shares, Strategies, and Forecasts, Worldwide, 2013 to 2019 (2013) Winter Green Research Code: MRS - 872]. This huge budget is mostly based on demand for power generation in small scale and should be wisely managed in order to meet global energy need.

[0003] Piezoelectric, thermoelectric and pyroelectric energy harvesting, and microengines mostly involve expensive materials and moving parts.

[0004] The patent documents WO 95/16995 A1, CN 2 930 573 Y, US 2011/139405 A1, US 2012/186672 A1, US 5 526 408 A, EP 1 706 679 A1, US 2006/159561 A1, US 2006/034705 A1, US 2011/139203 A1, US 2002/009015 A1, WO 2008/108596 A1, are related to cavitation-related technologies or systems which can be arranged for provision of cavitation bubbles.

Objects of the Invention

[0005] Primary object of the present invention is to overcome the abovementioned shortcomings of the prior art.

[0006] Another object of the present invention is provision of a device and method for sustainable energy generation with low investment and operational costs.

Summary of the Invention

[0007] The present invention proposes a device comprising a liquid's flow path having an upstream side and a downstream side, a plurality of flow restrictive elements providing material communication between the upstream side and the downstream side. Accordingly, the present invention further proposes an energy harvesting method from liquid streams.

Brief Description of the Figures

[0008] The figures, whose brief explanation is herewith provided, are solely intended for providing a better understanding of the present invention and are as such not intended to define the scope of protection or the context in which said scope is to be interpreted in the absence of the description.

Figure 1 shows schematic illustrations of (a) an embodiment of the device according to the present invention, and (b) energy harvesting by a thermoelectric generator from heat generated around collapsing bubbles at the downstream side of the device.

Figure 2 shows schematic illustrations of (a) another embodiment of the device according to the present invention, and (b) energy harvesting by a thermophotovoltaic (TPV) cell from heat generated around collapsing bubbles at the downstream side of the device.

Figure 3 shows an exemplary fashion of use of the device according to the present invention, where a liquid stream passing through the device can be directed to target tanks, which can thus be filled with heated liquid.

Detailed Description of the Invention

[0009] Referring now the figures outlined before, the present invention proposes a device (100) comprising a liquid's flow path having an upstream side (10) and a downstream side (20), a plurality of flow restrictive elements (30) providing material communication between the upstream side and the downstream side.

[0010] According to the invention, the device further comprises a thermoelectric generator (40) or a (micro-) thermo-photovoltaic cell (50) in thermal connection with a portion (21) of the device located at the downstream side with respect to the flow restrictive elements.

[0011] Thermoelectric generators have two sides, namely a hot side and a cold side. The hot side (41) of a thermoelectric generator to be employed in the device according to the present invention is the side in thermal connection with the downstream side of the device, where, in use, cavitation bubbles collapse and generate heat. The cold side (42) of the thermoelectric generator is in thermal contact with a colder medium, e.g. surrounding air or a fluid stream to be directed towards the upstream side. The temperature difference between two sides is correlated with the amount of electric energy generated through the thermoelectric generator. Accordingly, in order to keep the cold side of the thermoelectric generator, the cold side may preferably be provided with a heat sink (not shown) in order to enhance heat removal from the cold side.

[0012] According to the invention, said portion (21) is provided with roughness elements (22), in use, contacting a fluid flowing through the device facilitating collapse of any cavitation bubbles.

[0013] Said portion (21) may preferably be in form of a plate made of a metallic material or of silicon, comprising roughness elements (22) on one side thereof.

[0014] Fluid contact surfaces of the flow restrictive elements are preferably at least partly coated with a material different than that of the flow restrictive elements, such that the hydrophilicity of said surfaces are different near two distal ends of each flow restrictive element in accordance with the fluid flow direction (F). Preferably, the fluid inlet (upstream side distal end) of a flow restrictive element is the most hydrophobic location, while the outlet (i.e. downstream side distal end) corresponds to the most hydrophilic location.

[0015] The flow restrictive elements may be in form of venturi or orifice, having lengths along fluid flow direction within a range between 1 micrometer and 10000 micrometers; and having a mean value for their hydraulic diameters ranging between 100 nanometers and 250 micrometers.

[0016] Preferably, at least a part of the roughness elements are located at a distance from downstream side opening of at least a flow restrictive element, such that the ratio of said distance to the mean value of hydraulic diameters of flow restrictive elements is within a range between 10 and 1000.

[0017] The device preferably comprises a flow aligner section (11) including a plurality of flow aligners (12) located at the upstream side, in form of protrusions mainly perpendicular to the fluid flow direction.

[0018] The device can be adaptable (or adapted) to a tap (not shown) for harvesting energy from e.g. flowing means water. Alternatively, a tap (not shown) provided with the device according to the present invention can be considered as replacement or alternative of a tap for additional energy harvesting function. Accordingly, the present invention further proposes a tap provided with the device.

[0019] The present invention further proposes a method for energy harvesting from flowing liquid streams. The method comprises the following steps:

- passing the liquid through at least one flow restrictive element of a device, in such conditions where cavitation bubbles arise in the liquid upon passing the flow restrictive element,
- letting the cavitation bubbles collapse at a portion of the device located at a downstream side with respect to the flow restrictive elements, by roughness elements provided on said portion for contacting the liquid flowing through the device and facilitating said collapse,
- harvesting the heat generated around collapsing bubbles with a thermoelectric generator or a thermophotovoltaic cell in thermal connection with said portion.

[0020] Said harvesting may be considered as heating of the liquid by heat generation around collapsing bubbles. Yet, the thermal energy generated around the collapsing bubbles can also be utilized for electric energy generation as an energy harvesting fashion. To this end, the method comprises that the collapse of the cavitation bubbles occurs near a surface in thermal connection with a thermoelectric generator or a thermophotovoltaic cell.

EXAMPLE

[0021] Schematic view of an exemplary energy harvesting device is shown in Fig. 1. A liquid can be guided to a plurality of micro scale flow restrictive elements with preferably functional (i.e. variable hydrophilicity) surfaces, the flow restrictive elements being arranged mainly parallel to each other.

[0022] In this case, the surfaces are prepared in such a way that the wettability varies along the flow restrictive element. Accordingly, the fluid inlet of a flow restrictive element (inlet) is the most hydrophobic location, while the fluid outlet of the flow restrictive element (outlet) corresponds to the most hydrophilic location. Thus, cavitation would incept toward the inlet of the flow restrictive element due to potential low pressure zones and more pronounced surface effects in small scale as well as more hydrophobic behavior, which promotes bubble nucleation. As a result, surface nuclei would be the key parameter for the inception of hydrodynamic cavitation. The conditions for obtaining cavitation in a fluid stream can be predicted using related knowledge on fluids dynamics and physical chemistry.

[0023] The existence of wettability gradient (i.e. variable hydrophilicity) mitigates bubble motion near the surface thereby enhancing transport of bubbles to the downstream distal end of the flow restrictive element. Thus, cavitation bubbles head towards the downstream side, and are targeted to the downstream side of the device, to a plate with a surface having roughness elements which can be out-of-plane protrusions in form of micro pillars, or a rough surface with indentations. The bubbles either collapse near the surface due to the pressure recovery or blast due to collision with the roughness elements and micro pillars, which releases energy and causes a rise in the temperature. Since many flow restrictive elements exist and bubble release is expected from each element due to functional surfaces, the rise in the temperature on the surface will be uniform. As a result, the downstream side (or preferably the plate located there) will act as the heat source for a thermoelectric generator. The temperature difference between the plate and cold side of the thermoelectric generator causes generation of electrical power. The amount of power in such case can easily meet personal energy need. Necessary power for daily devices such as cell phones, laptops, and devices in offices could be provided using this approach. The only required input is a simple flow of a fluid, which could be well provided from a tap in a household. Thus in such scale, this approach has the potential for solving personal energy needs in a cheap and environmentally friendly fashion and can trigger a paradigm shift in energy harvesting.

[0024] The proposed device can be connected to a water supply, which could be a pressurized tank as well as a tap in a household via appropriate fittings. Also, the device can be provided in form of taps each being adaptable to a certain size of standard tubing for connecting to the main water system. The flow rate can be controlled by a fine control valve and measured with sensitive commercial flow meters capable of measuring low flow rates as well as intermediate flow rates. Upstream side of the device (even when it includes an inlet section and a flow aligner section) can be fabricated with standard IC fabrication methods (e.g. lithography, sputtering, deep reactive ion etching), micromachining and laser machining tools. The flow aligner section serves for an enhanced homogeneity in flow rate distribution to each flow restrictive element. The plate with small flow restrictive elements such as venturis and orifices (hydraulic diameters of 100 nm-250 μm) (lengths of 1-10000 μm) can be fabricated using the same microfabrication techniques as the inlet and flow aligner section. For the fabrication of the flow restrictive elements, E-Beam Lithography and Focused Ion Beam methods can be implemented.

[0025] Surfaces of flow restrictive elements to be contacted with fluid can be prepared with deposition methods such as the iCVD method. The surfaces can be modified in such a way that the wettability changes along the flow restrictive element. These functional surfaces mitigate both nucleation from the surface and motion of the formed bubbles to the exit thereby ensuring cavitating flows in each flow restrictive element and intensifying cavitation.

[0026] The fluid stream is guided through the flow restrictive elements so that local static pressure of the fluid inside flow restrictive elements decreases in consistency with the Bernoulli equation and there will be a local minimum pressure due to the Vena Contracta effect. If the pressure decreases to a certain critical value under appropriate conditions, phase change takes place and bubbles form inside each flow restrictive element due to the inception of cavitation and move toward the exit upon passing through the downstream side, with the help of the (functionalized) surfaces of flow restrictive elements.

[0027] The emerging bubbles are targeted to the downstream side (preferably provided with a metallic plate or a plate made of Silicon) at different distances from the fluid releasing distal ends of the flow restrictive elements. Preferably, here, the distance to hydraulic diameter ratio is within a range between 10 and 1000. One side of the thin plate preferably has micro roughness elements and micro pillars, which will serve for enhanced blasting of incoming bubbles. Sanding, chemical vapor deposition and deep reactive ion etching methods can be implemented for the introduction of micro roughness elements and micro pillars.

[0028] Erosion on the thin plate due to bubble collapse seems at the first glance to badly influence energy harvesting. However, roughness elements and micro pillars will be first exposed to bubble collapse so that pits and sharp locations could form on the surfaces, which will further facilitate bubble blasting on the surface and contribute to temperature rise.

[0029] The thin plate to be exposed to small bubbles is used as the heat source and is joined to the generators via bonding or high quality thermal grease. Daily used electronic appliances can be powered using the experimental setup.

[0030] (Micro-) thermophotovoltaic cell can be developed using standard IC microfabrication techniques. For this, the downstream side (preferably the plate) can be used as the heat source. The emitter (52) of the thermophotovoltaic cell (50) may be deposited (using low-pressure and plasma-enhanced chemical vapor deposition) on the back surface of the thin plate and can be for example polycrystalline Si and SiO_2 structure. This combined structure can be fitted to a commercially available stepper motor and piezo controlled micromanipulator assembly so that the vacuum gap (51) between the emitter (52) and the thermophotovoltaic cell (50) can be fine controlled with a resolution below 1 μm (Fig. 1). Commercial miniature photovoltaic cells are already available in the microelectronics market and can be utilized in the proposed concept.

[0031] The photovoltaic cell can be bonded to an available thermal management system, which can be based on microchannel cooling. The fluid passing through the system can be recycled and directed to this thermal management system. An anomalous increase in radiative transfer between surfaces at small separation is expected to occur, which potentially increases the performance of thermophotovoltaic cells. Surface phonon polaritons related to thermal vibration of lattices (transverse optical phonons) may improve the radiative energy transfer between two surfaces at small gaps. These phenomena can be also exploited to enhance the performance and efforts can be made to attain the smallest possible vacuum gap between the emitter and thermophotovoltaic cell.

[0032] The proposed technique does not require any external power and moving parts in contrast to common energy-harvesting devices, such as the ones involving piezoelectric material and micro-engines. It has the potential for providing high power density and the necessary power to run many daily used electronic devices and fulfilling personal energy demands in daily life; in addition to heating of fluids.

[0033] In the proposed technique, high temperatures on the surfaces near collapsing small bubbles are exploited in energy harvesting in small scale so that miniature cheap and environmentally friendly energy-harvesting devices (with a price of only few hundred Euros) can be developed. Necessary power for daily devices such as cell phones, laptops, and devices in offices could be provided using this novel approach. The only required input is a simple flow of a fluid, which could be well provided from a tap in a household. Thus, this approach has the potential for solving personal energy needs in a cheap and environmentally friendly fashion and can trigger a paradigm shift in energy harvesting.

[0034] As illustrated in the Fig.3, the use of the device according to the present invention can be directing a liquid stream from a supply tank (60) passing through the device (100) to one or more target tank(s) (61), which can thus be filled with heated liquid.

[0035] The proposed concept could find applications in underwater usages requiring electricity, such as wildlife observation and military and security applications. In such applications, the aim is to generate power on the locations, which are not easily accessible because of depth, flow and unreachable coordinates. Besides, the output power from the proposed approach could be utilized as a power source for both lighting and GPS location devices installed on buoys in open sea.

Reference numerals	**Related features**
10	Upstream side
11	Flow aligner section
12	Flow aligner
20	Downstream side
21	Portion
22	Roughness element
30	Flow restrictive element
31	Collapsing bubble
40	Thermoelectric generator
41	Hot side (of the thermoelectric generator)
42	Cold side (of the thermoelectric generator)
50	Thermophotovoltaic cell
51	Vacuum gap
52	Emitter
60, 61	Supply tank and vacuum tank, respectively
100	Device according to the present invention

[0036] Thus the following objects are achieved by the present invention:

- overcoming the abovementioned shortcomings of the prior art,
- provision of a device and method for sustainable energy generation with low investment and operational costs.

Claims

1. A device (100) comprising a liquid's flow path having an upstream side (10) and a downstream side (20), a plurality of flow restrictive elements (30) providing material communication between the upstream side (10) and the down-

stream side (20), and configured to generate cavitation bubbles in the liquid upon passing the flow restrictive elements, further comprising a thermoelectric generator (40) or a thermophotovoltaic cell (50) in thermal connection with a portion (21) of the device (100) located at the downstream side (20) with respect to the flow restrictive elements (30) **wherein** the portion (21) is provided with roughness elements (22) for, in use, contacting a fluid flowing through the device and facilitating collapse of any cavitation bubbles, so that heat generated around collapsing bubbles is harvested by the thermoelectric generator (40) or the thermophotovoltaic cell (50).

2. Device according to the claim 1, wherein fluid contact surfaces of the flow restrictive elements (30) are at least partly coated with a material different than that of the flow restrictive elements (30), such that the hydrophilicity of said surfaces are different near two distal ends of each flow restrictive element (30) in accordance with the fluid flow direction.

3. Device according to the claim 2, wherein an upstream side distal end of each flow restrictive element (30) is more hydrophobic relative to a downstream side distal end of said flow restrictive element (30).

4. Device according to any of the claims 1 to 3, wherein said portion (21) is in form of a plate made of a metallic material or of silicon, comprising roughness elements (22) on one side thereof.

5. Device according to any of the claims 1 to 4, wherein the flow restrictive elements (30) are in form of venturi or orifice, having lengths along fluid flow direction within a range between 1 micrometer and 10000 micrometers; and having a mean value for their hydraulic diameters ranging between 100 nanometers and 250 micrometers.

6. Device according to the claim 5, wherein at least a part of the roughness elements are located at a distance from downstream side opening of at least one of the flow restrictive elements (30), such that the ratio of said distance to the mean value of hydraulic diameters of flow restrictive elements (30) is within a range between 10 and 1000.

7. Device according to any of the claims 1 to 6, comprising a plurality of flow aligners (12) located at the upstream side (10), in form of protrusions mainly perpendicular to the fluid flow direction.

8. Device according to any of the claims 1 to 7, wherein the cold side (42) of the thermoelectric generator (40) is provided with a heat sink, when the device comprises a thermoelectric generator (40).

9. A tap provided with a device according to any of the claims 1 to 7.

10. A method for energy harvesting from flowing liquid streams, comprising the following:

- passing the liquid through at least one flow restrictive element of a device, in such conditions where cavitation bubbles arise in the liquid upon passing the flow restrictive element,
- letting the cavitation bubbles collapse at a portion of the device located at a downstream side with respect to the flow restrictive elements, by roughness elements provided on said portion for contacting the liquid flowing through the device and facilitating said collapse,
- harvesting the heat generated around collapsing bubbles with a thermoelectric generator or a thermophotovoltaic cell in thermal connection with said portion.

Patentansprüche

1. Vorrichtung (100), umfassend einen Flüssigkeitsströmungsweg mit einer stromaufwärtigen Seite (10) und einer stromabwärtigen Seite (20), einer Vielzahl von strömungsbegrenzenden Elementen (30), die eine Materialkommunikation zwischen der stromaufwärtigen Seite (10) und der stromabwärtigen Seite (20) bereitstellen, und so konfiguriert, um Kavitationsblasen in der Flüssigkeit beim Passieren der strömungsbegrenzenden Elemente zu erzeugen, ferner umfassend einen thermoelektrischen Generator (40) oder eine Thermophotovoltaikzelle (50) in thermischer Verbindung mit einem Teil (21) der Vorrichtung (100), angeordnet an der stromabwärtigen Seite (20) in Bezug auf die strömungsbegrenzenden Elemente (30),
wobei der Teil (21) mit Unebenheitselementen (22) zur, bei Verwendung, Kontaktierung eines Fluids, das durch die Vorrichtung strömt, und zum Ermöglichen eines Kollaps irgendwelcher Kavitationsblasen bereitgestellt ist, so dass Wärme, die um kollabierende Blasen erzeugt wird, durch den thermoelektrischen Generator (40) oder die Thermophotovoltaikzelle (50) gewonnen wird.

2. Vorrichtung nach Anspruch 1, wobei Fluidkontaktoberflächen der strömungsbegrenzenden Elemente (30) wenigstens teilweise mit einem Material beschichtet sind, das unterschiedlich ist von demjenigen der strömungsbegrenzenden Elemente (30), so dass die Hydrophilizität der Oberflächen verschieden ist nahe zweier distaler Enden jedes strömungsbegrenzenden Elements (30) gemäß der Fluidströmungsrichtung.

3. Vorrichtung nach Anspruch 2, wobei ein stromaufwärtsseitiges distales Ende jedes strömungsbegrenzenden Elements (30) hydrophober ist relativ zu einem stromabwärtsseitigen distalen Ende besagten strömungsbegrenzenden Elements (30).

4. Vorrichtung nach einem der Ansprüche 1 bis 3, wobei besagter Teil (21) in Form einer Platte ist, hergestellt aus einem metallischen Material oder aus Silizium, umfassend Unebenheitselemente (22) auf einer Seite derselben.

5. Vorrichtung nach einem der Ansprüche 1 bis 4, wobei die strömungsbegrenzenden Elemente (30) in Form von Venturi oder einer Düse sind, mit Längen entlang der Fluidströmungsrichtung innerhalb eines Bereichs zwischen 1 Mikrometer und 10000 Mikrometern; und mit einem Mittelwert für deren hydraulische Durchmesser im Bereich von zwischen 100 Nanometern und 250 Mikrometern.

6. Vorrichtung nach Anspruch 5, wobei wenigstens ein Teil der Unebenheitselemente in einem Abstand von einer stromabwärtsseitigen Öffnung von wenigstens einem der strömungsbegrenzenden Elemente (30) angeordnet sind, so dass das Verhältnis besagten Abstands zu dem Mittelwert von hydraulischen Durchmessern der strömungsbegrenzenden Elementen (30) innerhalb eines Bereichs zwischen 10 und 1000 ist.

7. Vorrichtung nach einem der Ansprüche 1 bis 6, umfassend eine Vielzahl von Strömungsausrichtern (12), die an der stromaufwärtigen Seite (10) angeordnet sind, in der Form von Vorsprüngen hauptsächlich senkrecht zu der Fluidströmungsrichtung.

8. Vorrichtung nach einem der Ansprüche 1 bis 7, wobei die Kaltseite (42) des thermoelektrischen Generators (40) mit einer Wärmesenke bereitgestellt ist, wenn die Vorrichtung einen thermoelektrischen Generator (40) umfasst.

9. Hahn, der mit einer Vorrichtung nach einem der Ansprüche 1 bis 7 bereitgestellt ist.

10. Verfahren zur Energiegewinnung aus fließenden Flüssigkeitsströmen, umfassend das Folgende:

- Führen der Flüssigkeit durch wenigstens ein strömungsbegrenzendes Element einer Vorrichtung, unter solchen Bedingungen, wo Kavitationsblasen in der Flüssigkeit beim Passieren des strömungsbegrenzenden Elements entstehen,
- Kollabierenlassen der Kavitationsblasen an einem Teil der Vorrichtung, angeordnet an einer stromabwärtigen Seite in Bezug auf die strömungsbegrenzenden Elemente, durch Unebenheitselemente, die an besagtem Teil zum Kontaktieren der durch die Vorrichtung strömenden Flüssigkeit und zum Ermöglichen besagten Kollaps bereitgestellt sind,
- Gewinnen der um kollabierende Blasen erzeugten Wärme mit einem thermoelektrischen Generator oder einer Thermophotovoltaiczelle in thermischer Verbindung mit besagtem Teil.

Revendications

1. Dispositif (100) comprenant un trajet d'écoulement d'un liquide ayant un côté amont (10) et un côté aval (20), une pluralité d'éléments de restriction d'écoulement (30) assurant une communication matérielle entre le côté amont (10) et le côté aval (20), et configurés pour générer des bulles de cavitation dans le liquide au moment du passage des éléments de restriction d'écoulement,
comprenant en outre un générateur thermoélectrique (40) ou une cellule thermophotovoltaïque (50) en relation thermique avec une partie (21) du dispositif (100) située au niveau du côté aval (20) par rapport aux éléments de restriction d'écoulement (30)
dans lequel la partie (21) comporte des éléments de rugosité (22) pour, en utilisation, entrer en contact avec un liquide s'écoulant à travers le dispositif et faciliter un effondrement de toutes les bulles de cavitation, de telle sorte que de la chaleur générée autour des bulles qui s'effondrent est collectée par le générateur thermoélectrique (40) ou la cellule thermophotovoltaïque (50).

2. Dispositif selon la revendication 1, dans lequel des surfaces de contact de fluide des éléments de restriction d'écoulement (30) sont au moins en partie revêtues d'un matériau différent de celui des éléments de restriction d'écoulement (30), de telle sorte que le caractère hydrophile desdites surfaces est différent près de deux extrémités distales de chaque élément de restriction d'écoulement (30) selon la direction d'écoulement de fluide.

3. Dispositif selon la revendication 2, dans lequel une extrémité distale côté amont de chaque élément de restriction d'écoulement (30) est davantage hydrophobe par comparaison à une extrémité distale côté aval dudit élément de restriction d'écoulement (30).

4. Dispositif selon l'une quelconque des revendications 1 à 3, dans lequel ladite partie (21) se présente sous la forme d'une plaque faite d'un matériau métallique ou de silicium, comprenant des éléments de rugosité (22) sur un côté de celle-ci.

5. Dispositif selon l'une quelconque des revendications 1 à 4, dans lequel les éléments de restriction d'écoulement (30) se présentent sous la forme d'un venturi ou d'un orifice, ayant des longueurs le long d'une direction d'écoulement de fluide à l'intérieur d'une plage entre 1 micromètre et 10 000 micromètres ; et ayant une valeur moyenne pour leurs diamètres hydrauliques située dans une plage entre 100 nanomètres et 250 micromètres.

6. Dispositif selon la revendication 5, dans lequel au moins une partie des éléments de rugosité sont situés à une distance à partir d'une ouverture côté aval d'au moins un des éléments de restriction d'écoulement (30), telle que le rapport de ladite distance à la valeur moyenne des diamètres hydrauliques d'éléments de restriction d'écoulement (30) se situe à l'intérieur d'une plage entre 10 et 1000.

7. Dispositif selon l'une quelconque des revendications 1 à 6, comprenant une pluralité d'aligneurs d'écoulement (12) situés au niveau du côté amont (10), sous la forme de saillies principalement perpendiculaires à la direction d'écoulement de fluide.

8. Dispositif selon l'une quelconque des revendications 1 à 7, dans lequel le côté froid (42) du générateur thermoélectrique (40) comporte un dissipateur thermique, lorsque le dispositif comprend un générateur thermoélectrique (40).

9. Robinet comportant un dispositif selon l'une quelconque des revendications 1 à 7.

10. Procédé de collecte d'énergie à partir de courants de liquide en écoulement, comprenant ce qui suit :

- faire passer le liquide à travers au moins un élément de restriction d'écoulement d'un dispositif, dans des conditions telles que des bulles de cavitation apparaissent dans le liquide au moment du passage de l'élément de restriction d'écoulement,
- laisser les bulles de cavitation s'effondrer au niveau d'une partie du dispositif située au niveau d'un côté aval par rapport aux éléments de restriction d'écoulement, par des éléments de rugosité prévus sur ladite partie pour entrer en contact avec le fluide s'écoulant à travers le dispositif et faciliter ledit effondrement,
- collecter la chaleur générée autour des bulles qui s'effondrent avec un générateur thermoélectrique ou une cellule thermophotovoltaïque en relation thermique avec ladite partie.

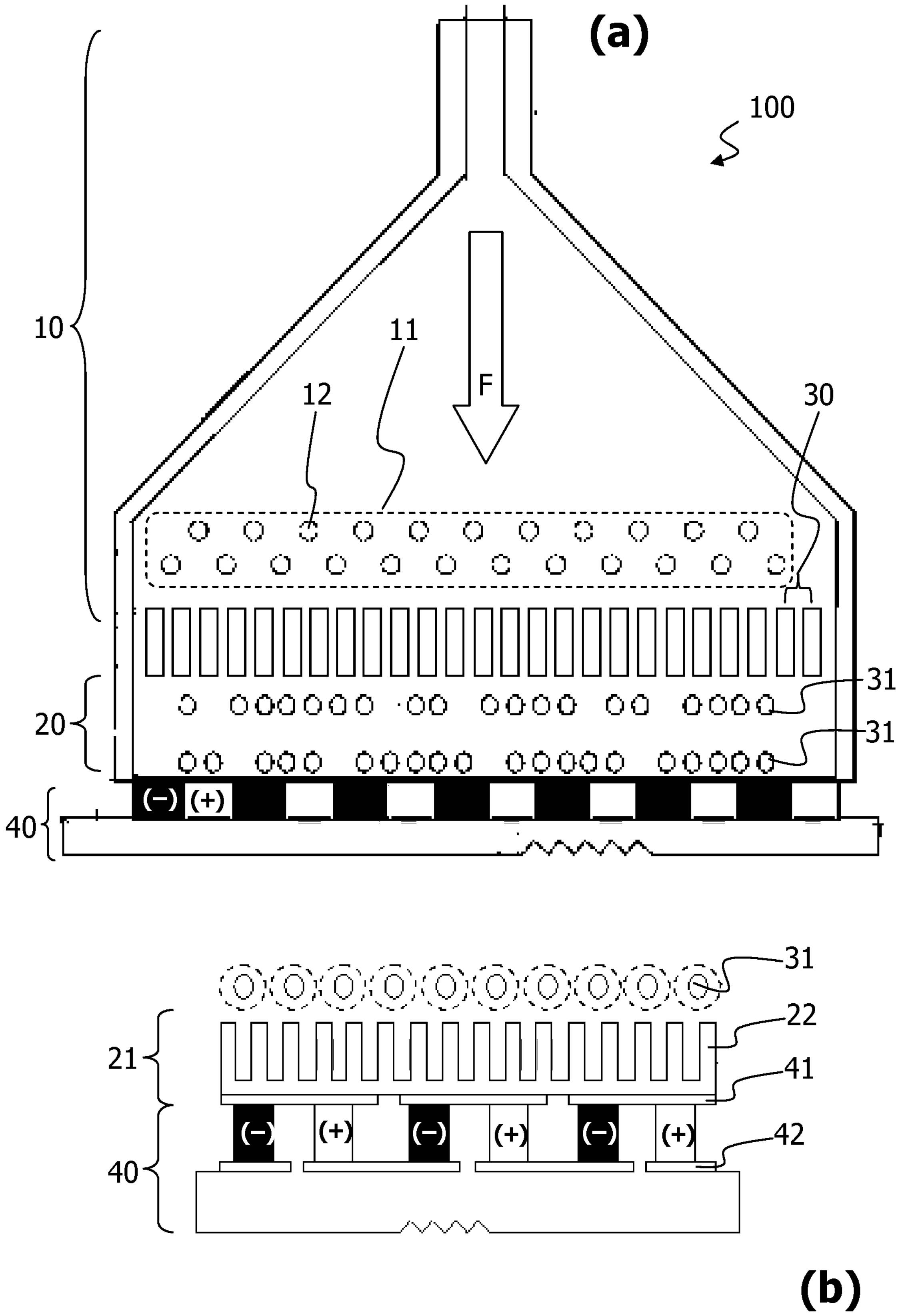

FIGURE 1

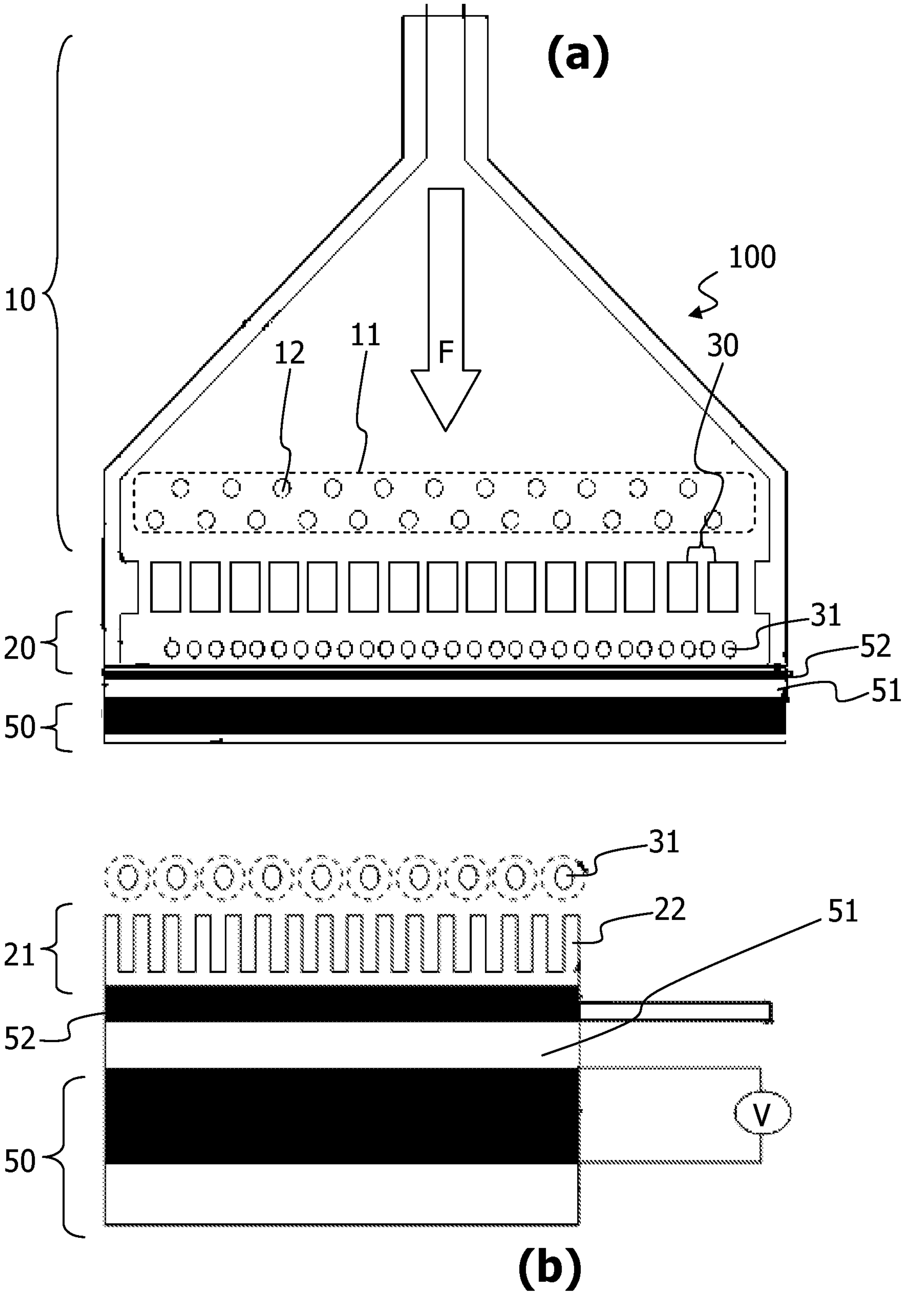

FIGURE 2

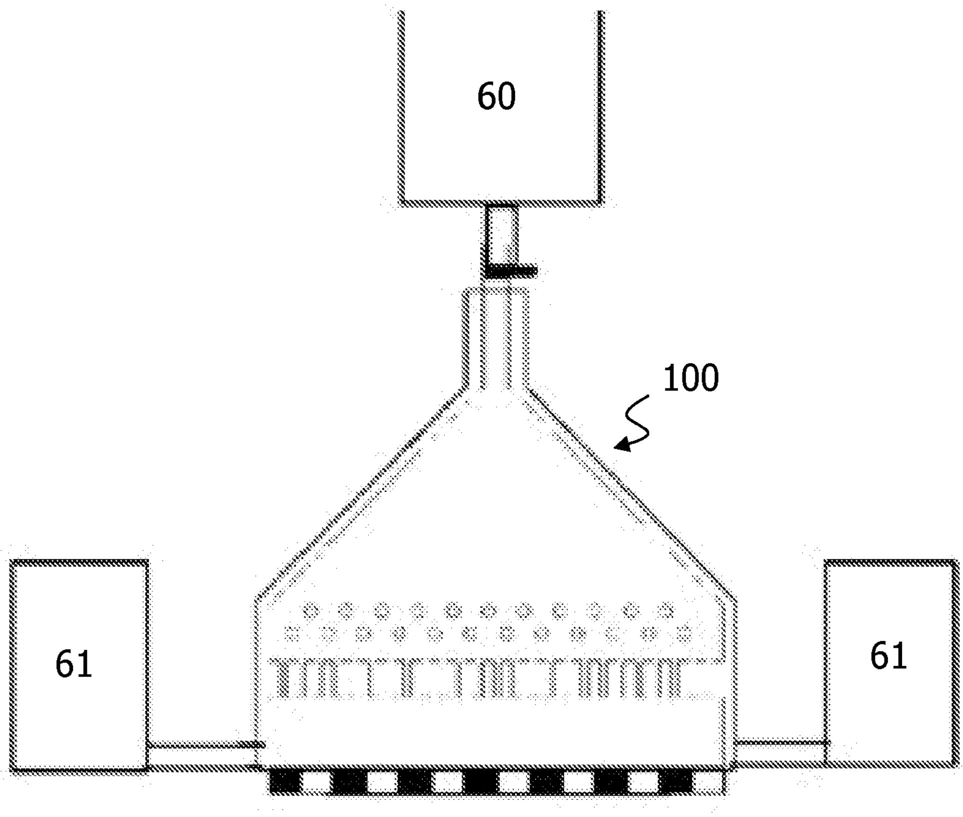

FIGURE 3

REFERENCES CITED IN THE DESCRIPTION

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