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Lu

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(54) MICRO ELECTRO-KINETIC PUMP HAVING A NANO POROUS MEMBRANE

(75) Inventor: **Ming-Chang Lu**, Hsinchu (TW)

Correspondence Address:
BIRCH STEWART KOLASCH & BIRCH
PO BOX 747
FALLS CHURCH, VA 22040-0747 (US)

(73) Assignee: **Industrial Technology Research Institute**

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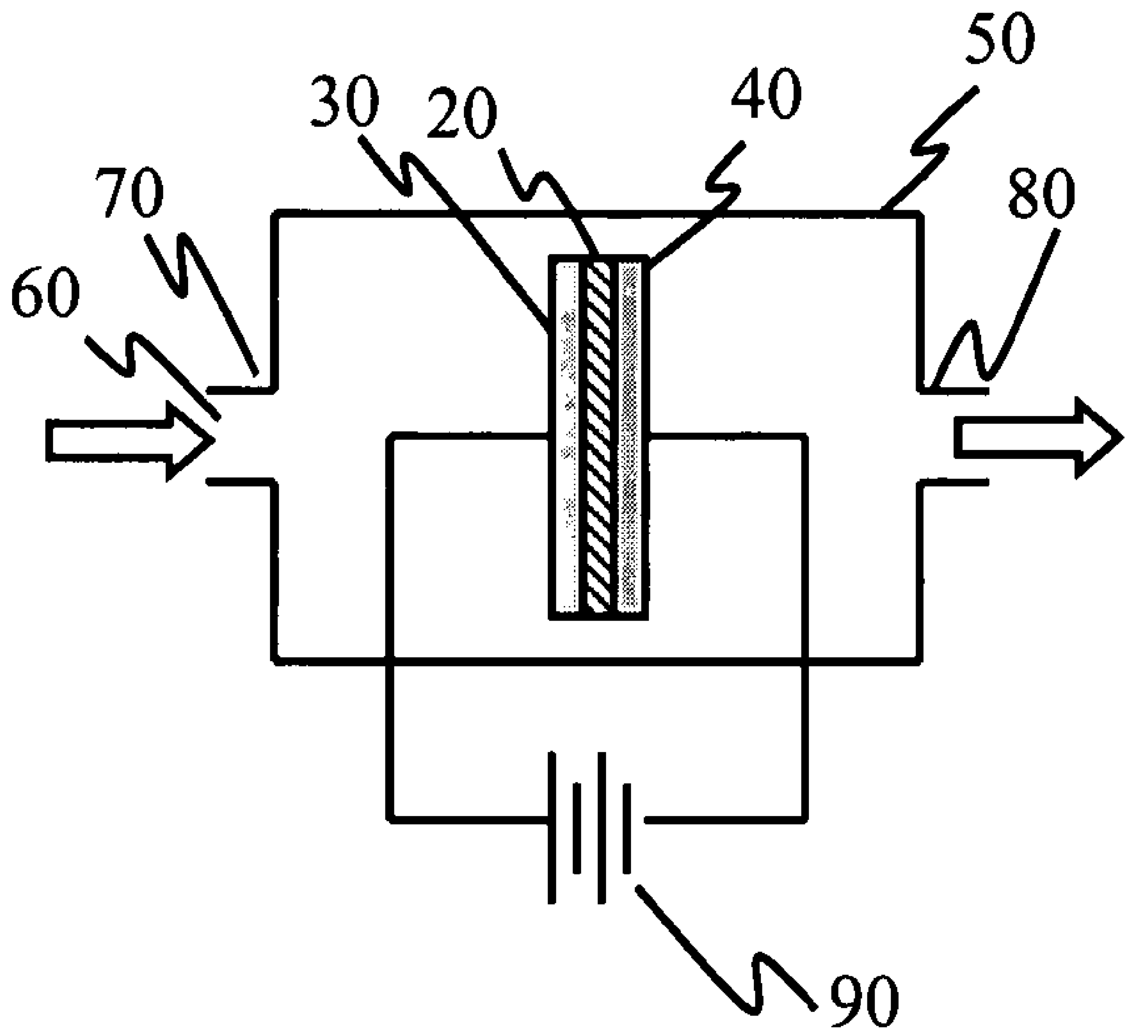
(57) **ABSTRACT**

An electro-kinetic micro pump having a nano porous membrane is introduced. When a voltage is applied to two opposing sides of the nano porous membrane, an electro-osmotic flow can be induced in each nano pore of the membrane. Since the pore diameter of the nano porous membrane is in the range of nano meters, the fluid inside the nano pore would be almost unipolar. As a result, by compared to a traditional micro electro-kinetic pump, the electro-kinetic micro pump having the nano porous membrane can produce a larger flow rate. Moreover, since the required driving voltage for the present micro pump is much smaller than that for the traditional micro pump, energy conversion efficiency of the present pump can be greatly improved.



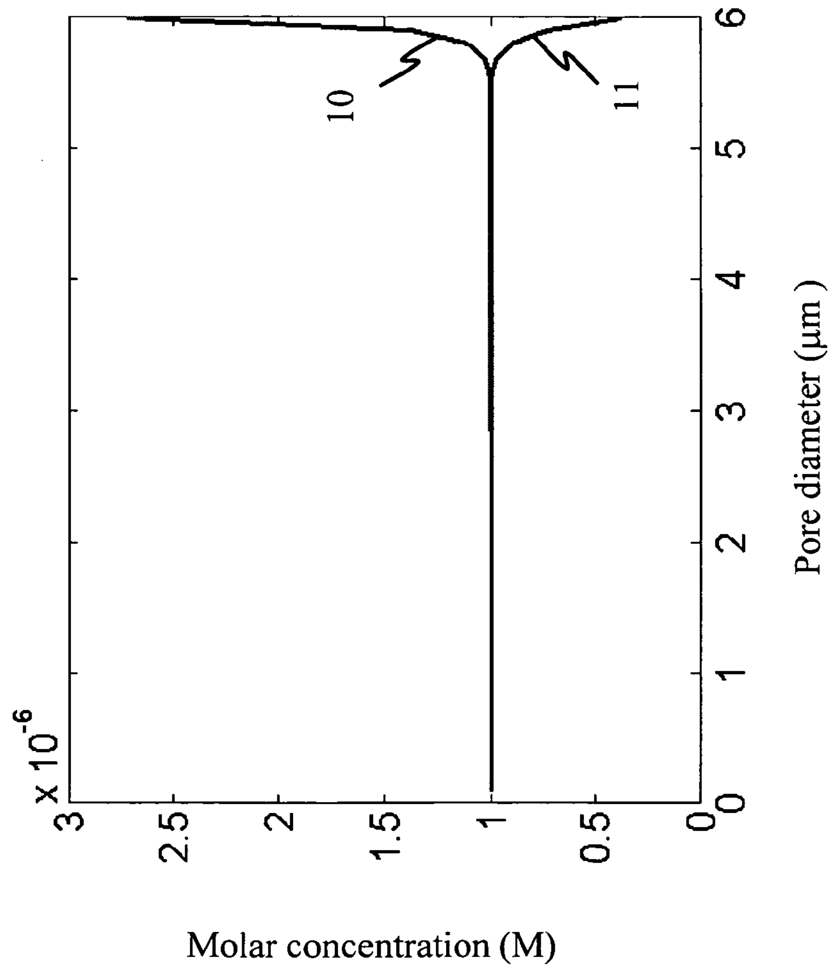


FIG. 1 (Prior Art)

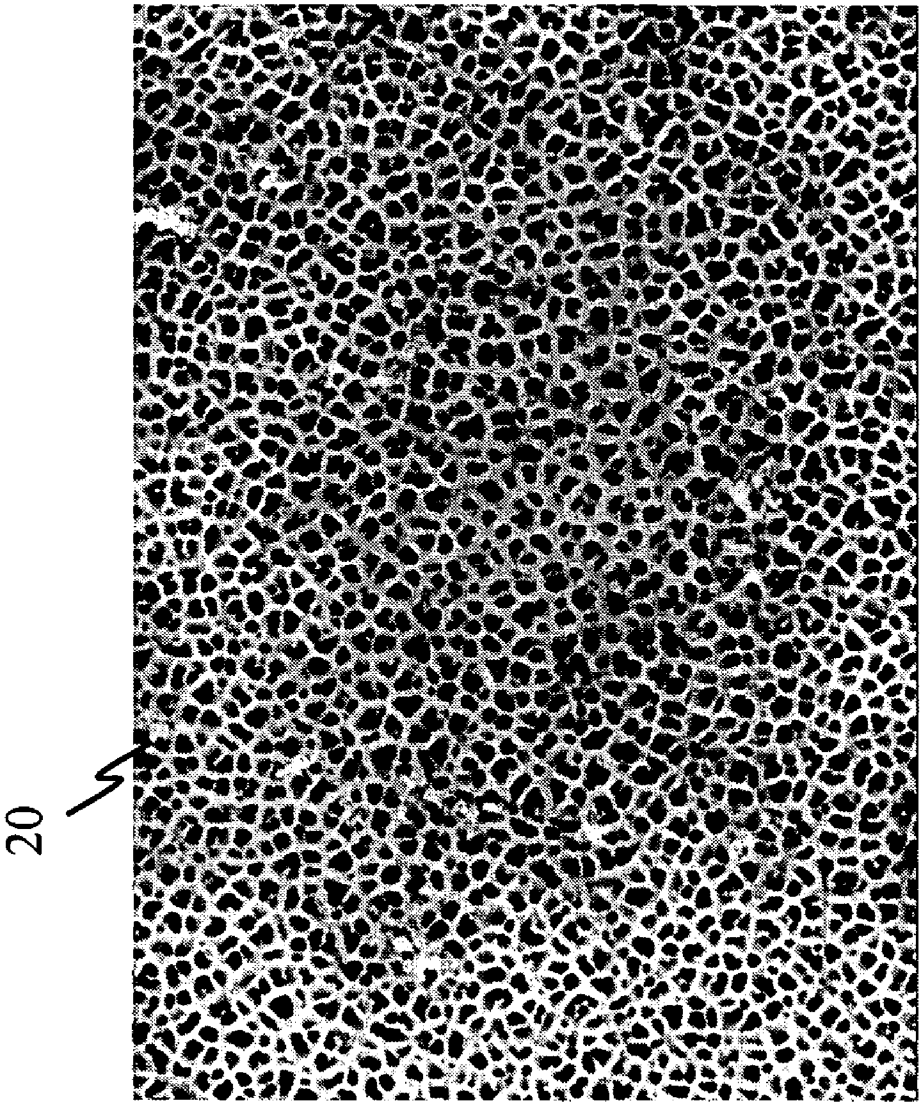


FIG. 2

30

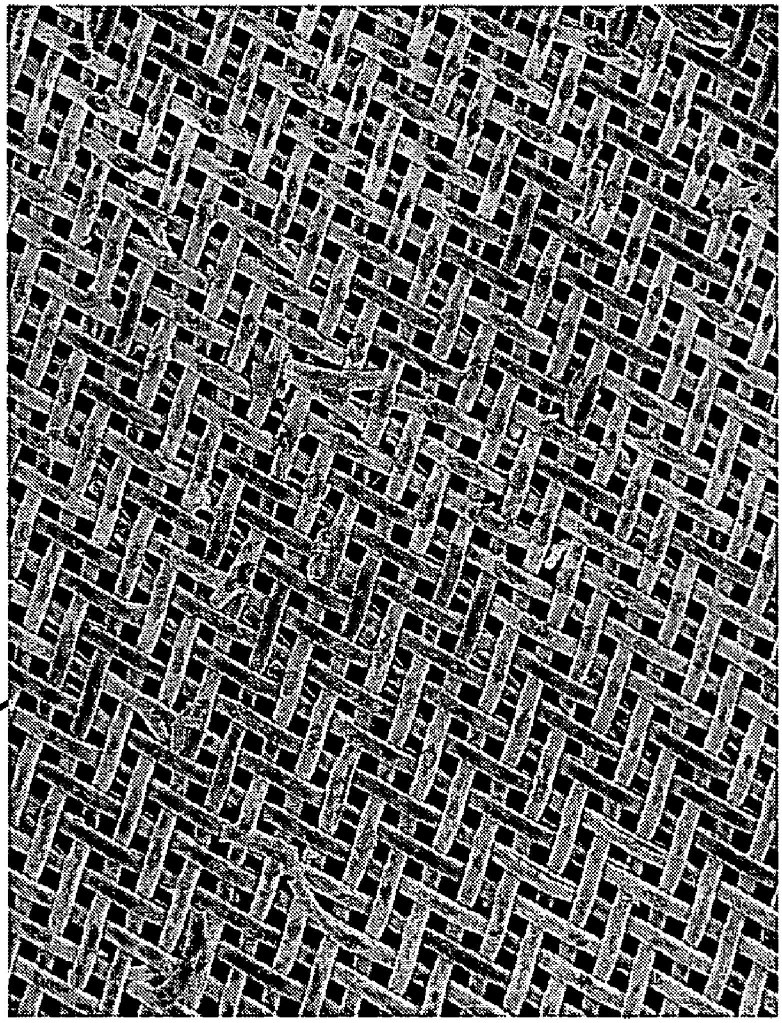


FIG. 3

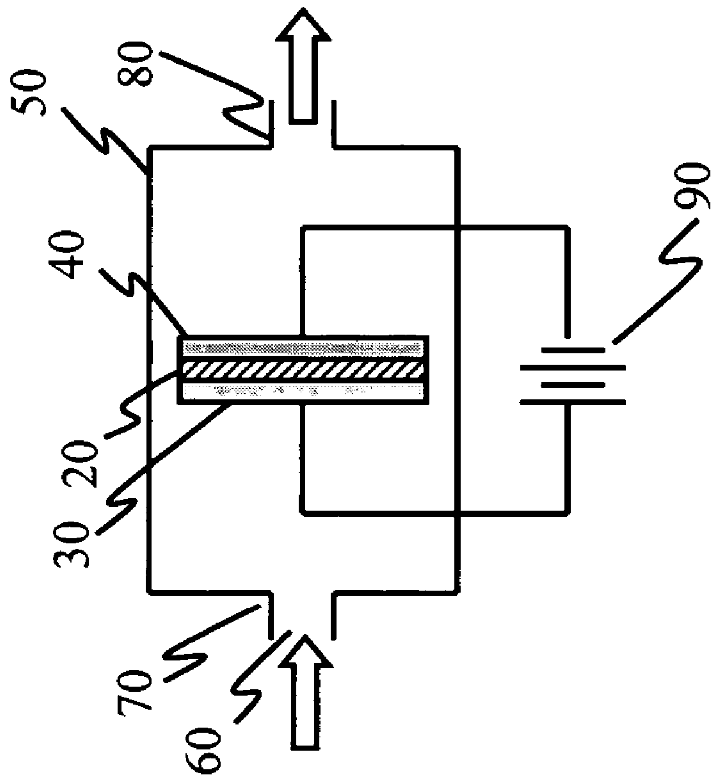


FIG. 4

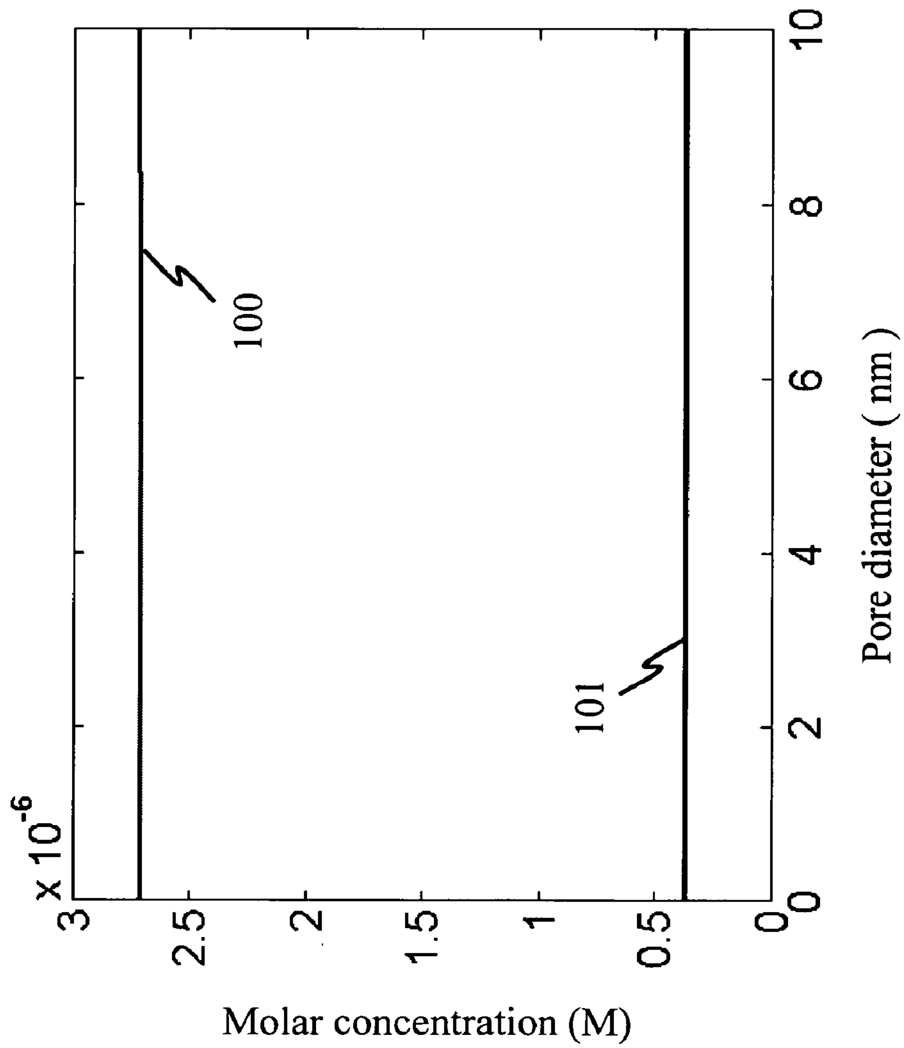

Molar concentration (M)
x 10^-6
3
2.5
2
1.5
1
0.5
0
Pore diameter (nm)
0
2
4
6
8
10
100
101

FIG. 5

MICRO ELECTRO-KINETIC PUMP HAVING A NANO POROUS MEMBRANE

BACKGROUND OF THE INVENTION

[0001] (1) Field of the Invention

[0002] The invention relates to an electro-kinetic (EK) pump applied to water-cool electronic devices or biomedical systems, and more particularly to an EK pump that has a nano porous membrane.

[0003] (2) Description of the Prior Art

[0004] It is well known that an EK pump is a particular pump having no reciprocal elements. Therefore, the simple-structured EK pump has a higher reliability than a conventional pump. The EK pump is also featured in its ability of generating a higher static pressure. However, the need of higher driving voltages and the less energy conversion efficiency are two usually-seen disadvantages of the EK pump.

[0005] In the art, a traditional EK pump usually adopts a micro meter-sized porous membrane. For the pore size (in diameter) of the traditional EK pump is in the range of micro meters, only a small portion of the pores is bipolar and thus the fluid inside the pore is almost electro-neutral. As shown in FIG. **1**, typical concentration distributions of positive ions (**10**) and negative ions (**11**) inside micro pores with negative surface charges of the micro meter-sized porous membrane for the EK pumps are demonstrated. Since most electrolyte in the pore is electro-neutral, the electro-osmotic flow induced by the applied voltage difference would be correspondingly small. In addition, when the EK pump is operated, a reverse potential difference would be formed in the pore due to accumulation of ions at the both ends of the pore; therefore, a reverse electro-osmotic flow would be easy to form in the electro-neutral middle of the pore and thereby the total output flow of the membrane would be substantially reduced.

SUMMARY OF THE INVENTION

[0006] Accordingly, it is a primary object of the present invention to provide a electro-kinetic (EK) pump having a nano porous membrane, which the nano porous membrane is used as an energy-conversion element for the EK pump. For the pore size of the nano porous membrane as well as the thickness of the diffusion double layer thereof are both in the range of nano meters (nm), the electrolyte inside each nano pore of the membrane would be almost unipolar. Thereby, a larger electro-osmotic flow to produce a larger flow rate can be formed in the nano porous membrane. Also, according to a theory proposed by Smoluchowski, the output pressure per unit voltage is inverse proportional to the diameter of the pore. Therefore, under nano diameters of the pores in the membrane, the required voltage for producing a substantial output pressure is lowered. It implies that the energy conversion efficiency of the EK pump would be substantially increased.

[0007] In the present invention, the pore diameter of the nano pore in the nano porous membrane is preferably ranged between 1 nm and 1,000 nm and the nano porous membrane has a pore distribution density could be as high as $10^{11}/cm^2$ in order to produce substantial flow rate. Two metal grid structures as electrodes for the EK pump are mounted to opposing sides of the nano porous membrane. When an external voltage is applied across the electrodes of the nano porous membrane, an electro-osmotic flow in each nano pore of the nano porous membrane can be induced.

[0008] All these objects are achieved by the micro EK pump having a nano porous membrane described below.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] The present invention will now be specified with reference to its preferred embodiment illustrated in the drawings, in which:

[0010] FIG. **1** shows typical concentration distributions of positive ions and negative ions inside micro pores with negative surface charges of a traditional micro meter-sized porous membrane for the EK pumps, in which the pore diameter of the membrane is about 12 micro meters;

[0011] FIG. **2** shows a micro view of the nano porous membrane having a 20-nm pore diameter in accordance with the present invention.

[0012] FIG. **3** shows another micro view of the stainless grid electrode with silver coating on its surface.

[0013] FIG. **4** is a schematic view of a system applying the micro EK pump of the present invention; and

[0014] FIG. **5** shows typical concentration distributions of positive ions and negative ions inside nano pores of the nano porous membrane in accordance with the present invention, in which the pore diameter of the membrane is about 20 nm.

DESCRIPTION OF THE PREFERRED EMBODIMENT

[0015] The invention disclosed herein is directed to a micro EK pump having a nano porous membrane. In the following description, numerous details are set forth in order to provide a thorough understanding of the present invention. It will be appreciated by one skilled in the art that variations of these specific details are possible while still achieving the results of the present invention. In other instance, well-known components are not described in detail in order not to unnecessarily obscure the present invention.

[0016] Referring to FIG. **2**, FIG. **3** and FIG. **4**, a schematic view of a preferred EK pump having a nano porous membrane in accordance with the present invention, a micro view of the nano porous membrane having a 20-nm pore diameter of FIG. **2** and a micro view of the stainless grid electrode of FIG. **3** (in which the stainless grid electrode is coated by a silver), and a schematic view of a system applying the micro EK pump of FIG. **4** are shown, respectively.

[0017] In the present invention, the micro EK pump can include a nano porous membrane **20** and two electrodes **30** and **40**. The nano porous membrane **20** used as the energy-conversion element of the EK pump is preferable to have a pore distribution density as high as $10^{11}/cm^2$. The nano porous membrane **20** permeable to water and electrolytes is preferably ranged between 1 nm and 1,000 nm. In particular, the nano porous membrane **20** can be a membrane made of an aluminum oxide and have a pore diameter of about 20 nm, as shown in FIG. **2**. As shown in FIG. **3**, the stainless-steel grid electrodes **30** and **40** coated by silver layers are mounted to two opposing sides of the nano porous membrane **20**. Preferably, the silver layer has a thickness of about 900 nm. As shown in FIG. **3**, the grid electrode **30** or **40** has a line thickness of about 20 μm and a line spacing of about 25 μm.

[**0018**] In the present invention, the material for the nano porous membrane is any material that can induce an electrical double layering effect. For example, the material for the nano porous membrane of the present invention can be the aluminum oxide as described above. The electrodes could be silver, gold, platinum, stainless steel, or any proper metal material. The line width of the grid electrode **30** or **40** can be ranged from 1 μm to 100 μm, and the line spacing thereof can be also ranged from 1 μm to 100 μm.

[**0019**] As shown in FIG. **4**, the system applying the EK pump having the nano porous membrane in accordance with the present invention is shown to install the EK pump (including the nano porous membrane **20** and the electrodes **30** and **40**) into a filter holder **50**. A fluid **60** is sent through the filter holder **50** as well as the EK pump. A proper voltage is applied to across the two stainless steel grid electrodes **30** and **40** so as to induce a corresponding electro-osmotic flow in the nano pores of the nano porous membrane **20**. While an external retarding force is applied to the exit side of the nano porous membrane **20**, an exit pressure would be formed at the exit side. As the retarding force increases, the flow rate at the exit side of the membrane **20** will decrease. When the flow rate at the exit side drops to zero, the exit pressure would achieve a maximum (i.e. the maximum output pressure). The input of the EK pump is the multiple of the voltage and the electoral current, while the output thereof is the flow rate and the exit pressure.

[**0020**] As shown in FIG. **5**, typical concentration distributions of negative ions (**100**) and positive ions (**101**) inside nano pores of the nano porous membrane **20** in accordance with the present invention is illustrated, in which the pore diameter of the membrane is about 20 nm. In the system of FIG. **4**, double of the debye length (L_D) of the fluid **60** is preferably greater than or in the same dimension with the pore diameter of the nano pore of the nano porous membrane **20**. Upon such an arrangement, every pore in the nano porous membrane **20** would be unipolar when a voltage is applied to across both sides of the nano porous membrane **20**, and thus the electro-osmotic flow in the nano pore as well as the flow rate of the nano porous membrane **20** would be maximized. Also, due to the pressure per unit voltage is inverse proportional to the pore diameter, a substantial output pressure (several atmosphere pressures for example) can be produced while the nano pore meets a low voltage (for example, 20 V). It is interesting to note that, in the prior art, thousands of voltages are needed so to produce an exit pressure of about 20 atm.

[**0021**] As described above, the EK pump having the nano porous membrane provided by the present invention utilizes the nano pores of the nano porous membrane to make the flow inside the nano pores be unipolar. Upon such an arrangement, the voltage to produce an expected flow rate can be lowered, and thus the energy conversion efficiency of the EK pump can be increased.

[**0022**] While the present invention has been particularly shown and described with reference to a preferred embodiment, it will be understood by those skilled in the art that various changes in form and detail may be without departing from the spirit and scope of the present invention.

I claim:

1. A micro electro-kinetic pump having a nano porous membrane, comprising:

a nano porous membrane for passing there through a fluid, having a plurality of nano pores, a pore diameter of each the nano pore being ranged between 1 nm and 1,000 nm; and

two electrodes mounted to two opposing sides of the nano porous membrane for accepting an across voltage so as to form an electro-osmotic flow inside each the nano pore.

2. The micro electro-kinetic pump according to claim 1, wherein said nano porous membrane is made of a material that makes the fluid presenting an electrical double layer effect.

3. The micro electro-kinetic pump according to claim 1, wherein said electrode is made of a metal grid material.

4. The micro electro-kinetic pump according to claim 3, wherein said metal grid material is selected from the group of silver, gold, platinum and stainless steel.

5. The micro electro-kinetic pump according to claim 3, wherein said metal grid material has a line width ranged from 1 nm to 100 μm.

6. The micro electro-kinetic pump according to claim 3, wherein said metal grid material has a line spacing and a line width, in which the line spacing is equal or on the same order to the line width.

7. The micro electro-kinetic pump according to claim 1, wherein said electrode is coated by a silver layer.

8. The micro electro-kinetic pump according to claim 7, wherein said silver layer has a thickness of 900 nm.

9. The micro electro-kinetic pump according to claim 1, wherein said fluid has a debye length that double of the debye length is greater than or on the same order to a pore diameter of said nano pore so as to make said nano pore being unipolar.

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