NANO DESALINATOR BY ELECTROSTATIC ION SIEVING FOR LOW-POWER WATER PURIFICATION

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ABSTRACT

This paper proposes to manipulate the thickness of the electro-double-layer (EDL) inside the anodic aluminum oxide (AAO) nanochannels as a virtual filter to select uni-ions for desalination through electrical static charges. Due to the electric static sieving effect at larger channel diameter (~100 nm), the power consumption is much less than those by tradition methods, such as reverse-osmosis (RO) and electrodialysis (ED) which need to function in much smaller nano pores or channels of 1 nm. This method has demonstrated the desalination rate at 55% and the pumping power consumption is estimated 0.2 kwh, which is decreased 1 order to that by RO method.

KEYWORDS

AAO, EDL, purification, seawater

INTRODUCTION

The Organization for Economic Co-operation and Development (OECD) has reported 0.35 billion people are currently suffering from water shortage [1][2]. And the U.S. Geological Survey [3] has found that 96.5% of water is in seas and oceans and 1.7% is in the ice caps, 1% in brackish water, and only 0.8% fresh water. So convert sea water to fresh water is important to solve the water shortage issue worldwide. There are about 26 countries that do not have sufficient pure water to agricultural irrigation and economic development. And about one billion people do not have safe water to drink [4].Tradition methods of desalination consume much power, such as RO and ED [5]. The RO process requires a large pressure to feedwater, forcing water through a membrane that restricting the salt ions. The ED process use electric current to attract the ions through perm-selective membranes. The other method is ion concentration polarization (ICP) [6]. It is an electrochemical transport phenomenon. In this work we purpose to manipulate EDL overlap as virtual filter to remove cations or anions inside nanochannals. Because the channel's pores are in hundreds nm range, thus the water flow resistance can be 4 orders of magnitudes smaller, so the power consumption for pumping water through the filters is much lower. The experiment results demonstrated a 55% reduction on solution concentration at 1.0V driving voltage for filters and and the pumping power consumption is estimated 0.2 kwh, which is decreased 1 order to that by RO method.

EXPERIMENT

The operation principle is shown in Fig.1. The surface of the nanochannel array of the nano desalinator was coated with a conductive metal layer and an insulation layer. When high enough voltages applied on the nano channel wall, the thickness of the EDL will increase to overlap owning to the increment of the charge density on the channel wall [4]. Co-ion can thus be rejected from the nano desalinator due to electrostatic expelling while the counter-ion and water can go through. Fig.2 (a) shows the two chamber system for diffusion testing of the nano desalinator. 1M NaCl solution and pure water were loaded into the upper and lower chamber, respectively. Fig.2 (b) shows the setup of the water purification system by pumping salt water from the first chamber into second one through the nano desalinator. The generation-rate is about 3 c.c/min.

The fabrication process of the nano desalinator is shown in Fig.3. First 50 nm Alumina by sputtering and then 10 nm HfO_2 by atomic-layer-deposition (ALD) were deposited into AAO inner surface to construct uniform thin films inside the nanochannals without defects.

The result of the diffusion test on the EDL nano desalinator for NaCl solution by the two chamber system is shown Fig.4. After 12 hours, the concentration of the lower chamber with 10nm and 20nm HfO2 raised to 25.25 mM and 22.23 mM, respectively, without voltage application. After the applications of +0.1V, +0.3V and +0.5V onto the desalinator membrane, the concentrations were reduced to 14.96 mM, 12.12 mM, and 8.98 mM, respectively. Due to the EDL overlap, the desalination rate reached 50%, which is close to the maximum desalination ability of this system for taking away all the co-ions.

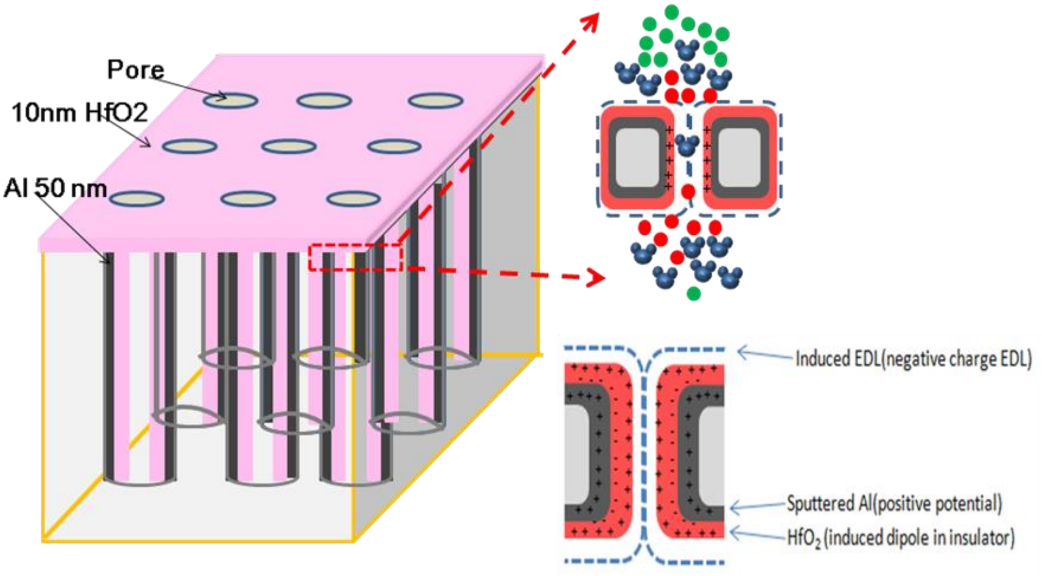

Figure 1: The working principle for AAO ion filter. When adding positive voltage the on the electrodes, positive charge is induced on the surface and negative EDL will occur. By controlling the density of the induced charges, the EDL thickness can be further controlled for manipulating nanochannels

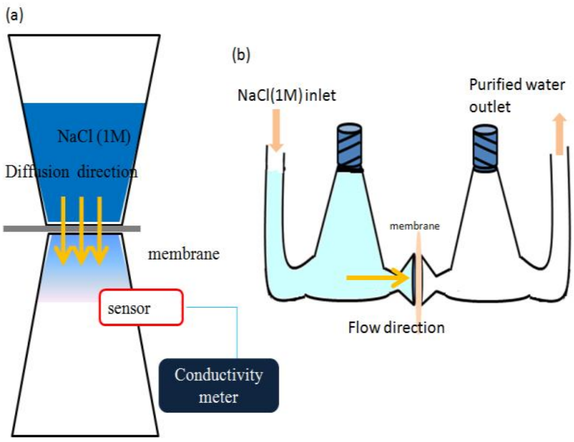

Figure 2: (a) The Sea water purification testing system with a membrane pore size about 200nm and operated in. (b) the pumping system of purification test through the desalination membrane.

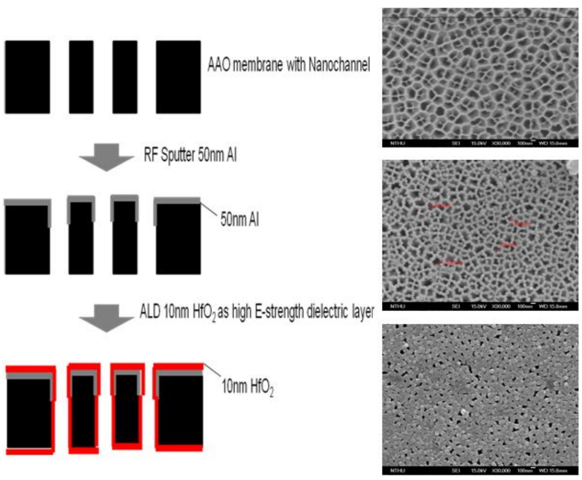

Figure 3. The fabrication process of the desalination membrane which combines sputtering 50nm Al on AAO membrane with 200nm pore size and then followed by coating 10nm HfO_2 by ALD technology.

When pump is employed for pumping salt water through the desalinator, higher voltage provide better desalination result, as shown in Fig.5, +0.5 v gives a best desalination result with a 36% desalination rate. Table 1 compares the power consumption by the nano desalinator and RO method, the results demonstrate a 6 times lower power consumption.

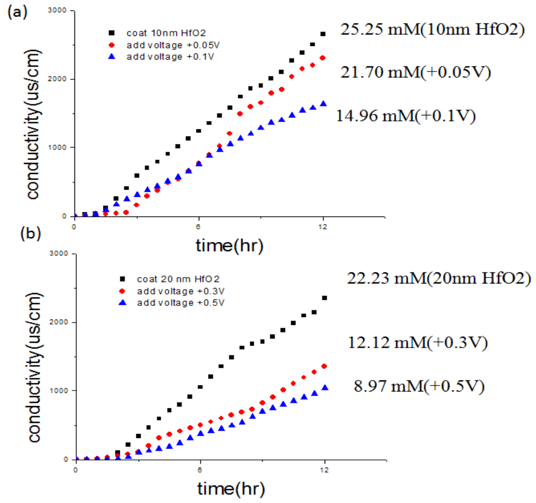

Figure 4: (a) When adding +0.1V on the membrane surface, the surface will induce negative charge to form EDL overlap and the concentration is down from 25.25 mM to 14.96 mM.(b) When adding +0.5V on the membrane surface to form EDL overlap, the concentration is down from 22.23 mM to 8.97 mM. The desalination rate is about 55%.

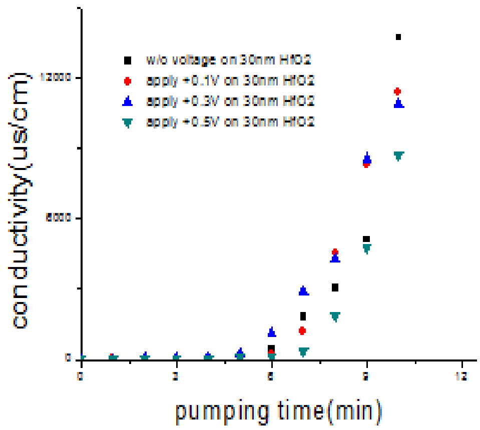

figure 5: The 1M NaCl was pumped through 30nm HfO_2 coated AAO membrane. The conductivity drops is due to the potential applied on the membrane to form EDL overlap. The desalination rate is about 36%.

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