Electronic Supplementary Material (ESI) for Lab on a Chip.

Supplementary information

Paper based Energy Harvesting from Salinity Gradient

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S1. Microfluidic RED

The microfluidic RED device consists of Ag/AgCl electrode, ion selective membrane and external pump as shown in Figure S1. To compare with the net power density from the proposed device, we conduct experiment with same geometry and condition. The ion selective membrane sandwiched with double-coated tapes which has 2 mm × 10 mm opening area and it is placed in the microfluidic RED device. The concentration gradient (1000-fold) maintained with external pump at 100 μL/min and we obtain *I-V* curve as shown in Figure S2. The open circuit voltage similar with the proposed device. However, the output current is 6 times higher than the proposed device. Therefore, the total generated power of microfluidic RED device is measured to be 322.82 nW. The pump power of the microfluidic device given as follow:[1]

$$P_{pump} = \frac{16}{\pi}\frac{\mu L}{r^4}Q^2$$

Here, μ, L, r, and Q is dynamic viscosity of solution (1.002×10^{-3} N s/m^2), length of the tube (0.3 m), radius of the channel (0.5 mm) and flow rate (100 μL/min). The pump power could be estimated to be 136.08 nW. Therefore, the net power of microfluidic device could be estimated to be 186.74 nW which is 3.4 times higher than the power of the proposed device. In case of the proposed device, the effective opening area interfacing the ion selective membraneis reduced by cellulose networks in paper and the ion transportation is also hindered, which results in lower ionic current. Also, flow velocity induced by capillary force, is much lower than the flow velocity by hydraulic pump. Therefore, despite of the microfluidic RED device and the proposed device has similar open circuit voltage, the output current of microfluidic RED device higher than that of proposed device. Further investigation should be carried out to address this problem. However, by removing the external hydraulic pump, a truly portable and simple energy harvesting was realized.

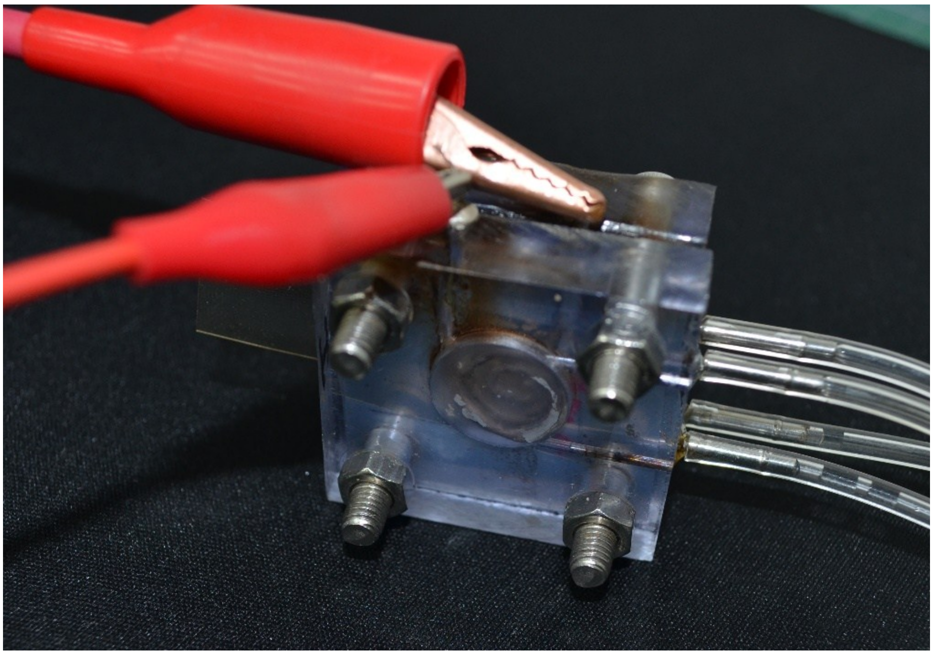

Figure S1 The picture view of microfluidic RED device.

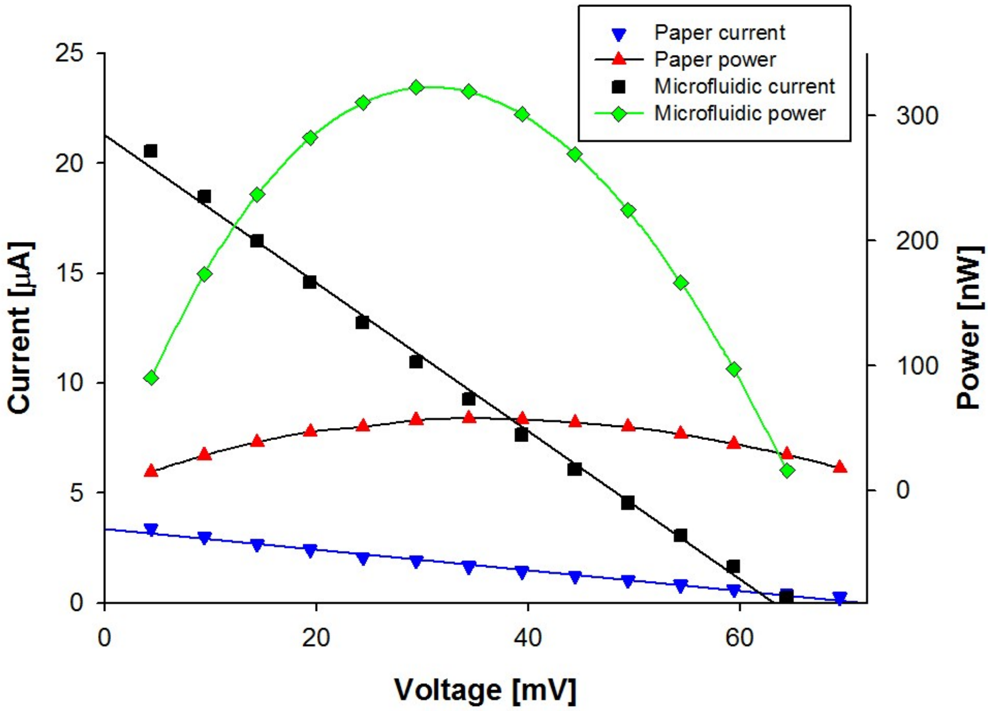

Figure S2 Current-potential curve from the proposed device and the microfluidic RED device: c_H= 100mM c_L= 0.1mM and KCL.

Reference

1. H. Bruus, *Theoretical microfluidics*, Oxford, New York, 2008.

S2. Life time

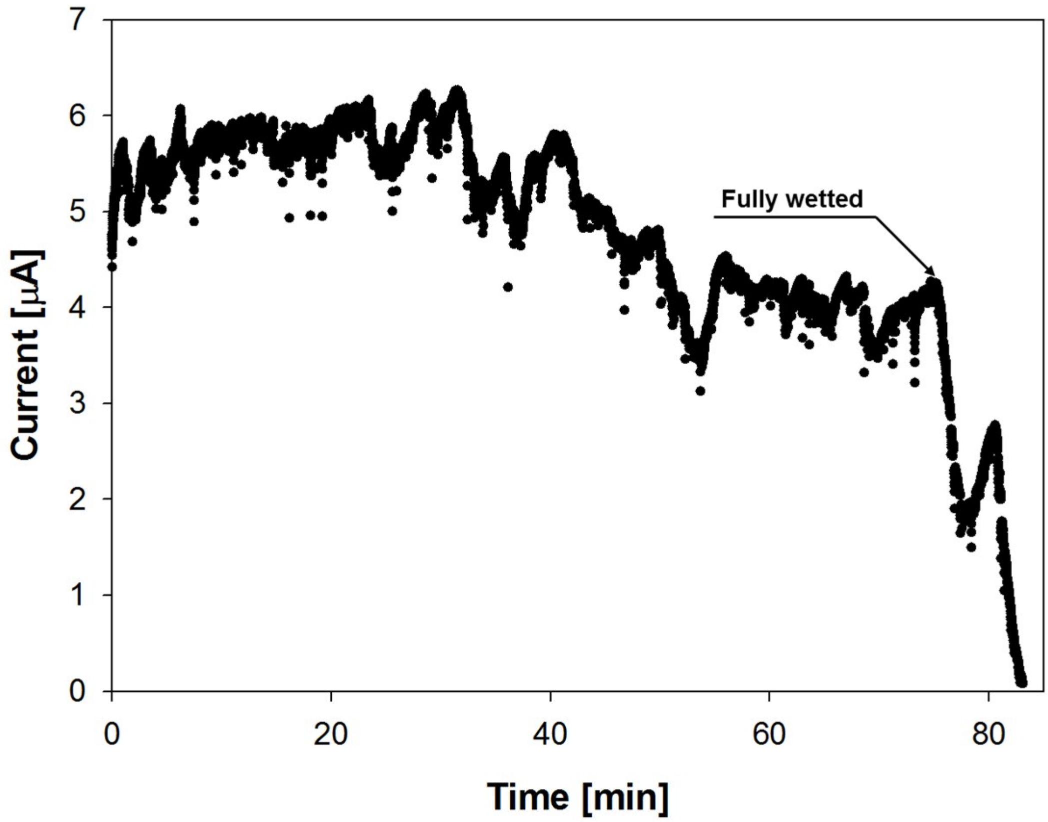

Figure S3. The output current measured from paper-based RED device

The operating time of the proposed device depend on flow rate in the paper. After the solution wets the entire buffer region, the flow velocity would be zero, resulting in dramatic decrease of power generation. To demonstrate life time of the proposed device, we obtain the output current using 2mm width channel at 1000-fold gradient condition. Figure S1 shows the output current from the proposed device. As we expected, the output current dramatically decrease when the buffer region fully wetted and it takes more than 1 hour.