

## Supplementary Information

### **Evaporating Potential in Conical PTFE Membrane with Asymmetric Electrodes**

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## Simulation section

The velocity distribution for three type structures are numerically calculated using the finite-element software package COMSOL Multiphysics. For steady fluidic flow of porous material, it is determined by Brinkman equation:

$$-\nabla p + \nabla \cdot \left( \mu \frac{1}{\varepsilon_p} \nabla \mathbf{u} - \frac{2}{3} \mu \frac{1}{\varepsilon_p} (\nabla \cdot \mathbf{u}) \mathbf{I} \right) - \left( \mu \kappa^{-1} + \frac{Q_m}{\varepsilon_p^2} \right) \mathbf{u} = 0 \quad (1)$$

$$-\nabla \cdot \mathbf{u} = Q_m \quad (2)$$

where  $p$  is fluidic pressure,  $\mathbf{u}$  is flow velocity,  $\mu$  is fluidic viscosity,  $\varepsilon_p$  is porosity  $\kappa$  is permeability,  $Q_m$  is the mass source. For boundary conditions, the bottom is the fluid inlet and the top is the fluid outlet.

To simulate the energy conversion inside the channel, the electrostatic field, ions concentration and the velocity fields can be determined by coupled Poisson–Nernst–Planck (PNP) equations and Navier-Stocks (N-S) equation:

$$-\nabla \cdot (\varepsilon_0 \varepsilon_f \nabla \phi) = F \sum_{i=1}^2 z_i c_i \quad (3)$$

$$-\nabla \cdot (\varepsilon_0 \varepsilon_m \nabla \phi) = 0 \quad (4)$$

$$\mathbf{J}_i = c_i \mathbf{u} - D_i \nabla c_i - \frac{D_i z_i F c_i}{RT} \nabla \phi \quad (5)$$

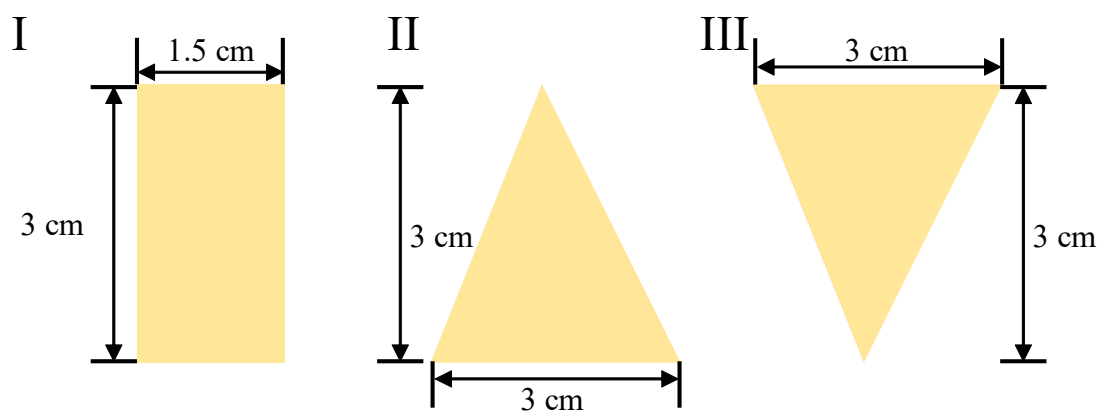
$$-\nabla \cdot \mathbf{J}_i = 0 \quad (6)$$

$$-\nabla p + \nabla \cdot (\mu \nabla \mathbf{u}) - F \sum_{i=1}^2 z_i c_i \nabla \phi = 0 \quad (7)$$

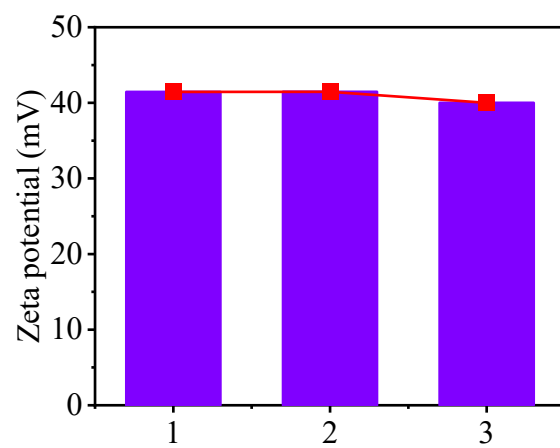
$$-\nabla \cdot \mathbf{u} = 0 \quad (8)$$

where  $\varepsilon_0$ ,  $\varepsilon_f$  and  $\varepsilon_m$  is the absolute permittivity of vacuum, fluid relative permittivity and membrane relative permittivity, respectively.  $F$ ,  $z$ ,  $D$ ,  $R$ ,  $T$ ,  $\mu$  is the Faraday constant, ions valence, diffusion coefficient, gas constant, temperature, fluid viscosity,

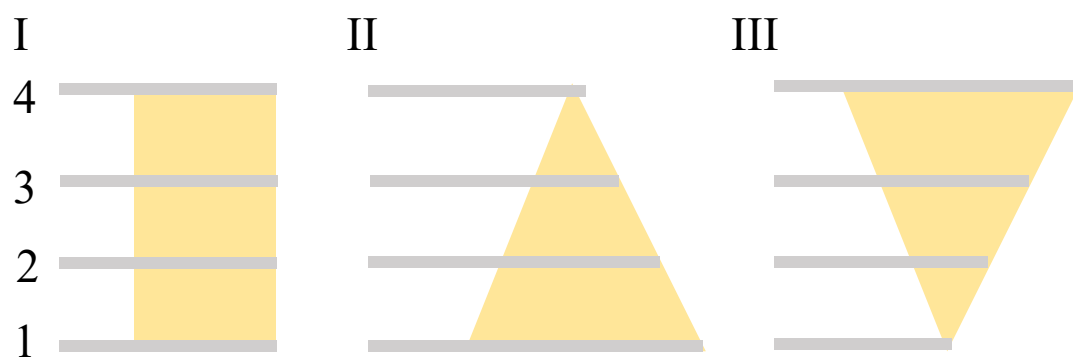
respectively. The  $\phi$ ,  $c_i$ ,  $\mathbf{u}$ ,  $p$  is the potential, ions concentration, fluid velocity and pressure, respectively. At the channel entrance, the velocity and ion concentration ( $1\text{e-}7$  mol/L for DI water) is specified. The wall surface charge is fixed at  $5\text{ mC/m}^2$ , impermeable to ions and no-slip condition. The channel outlet pressure is 0.



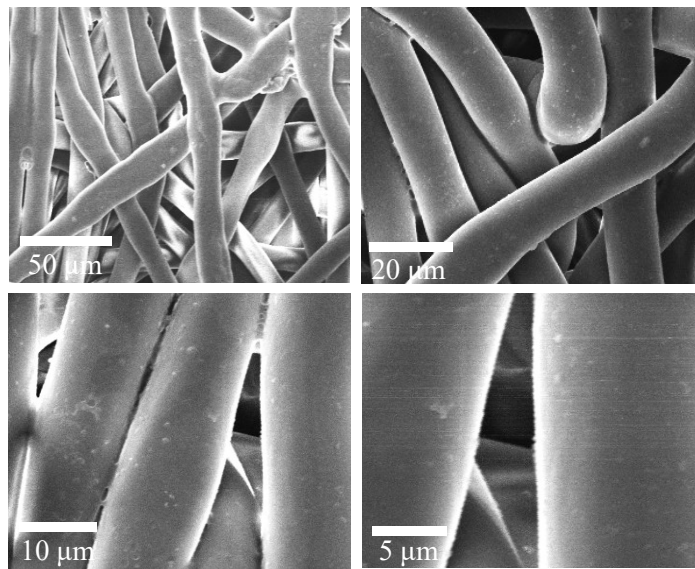
**Fig. S1** The geometric schematics of the three types of generators.



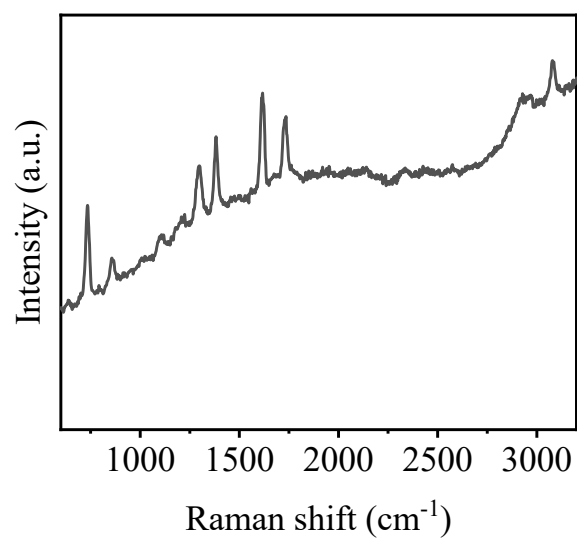
**Fig. S2.** The zeta potential under three measurements.



**Fig. S3.** The diagram of multi-electrode arrangement.

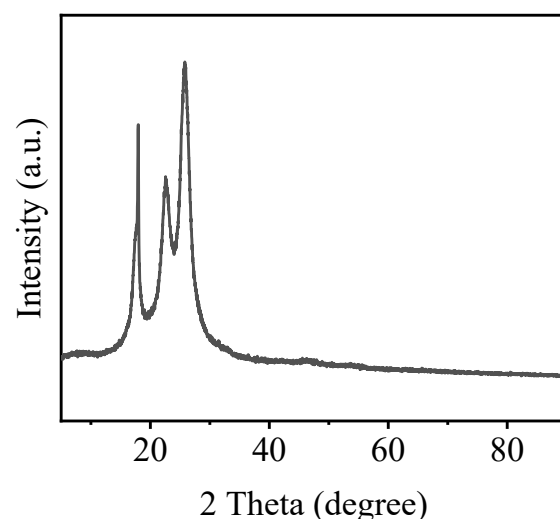


**Fig. S4** The SEM mages of PTFE membranes.

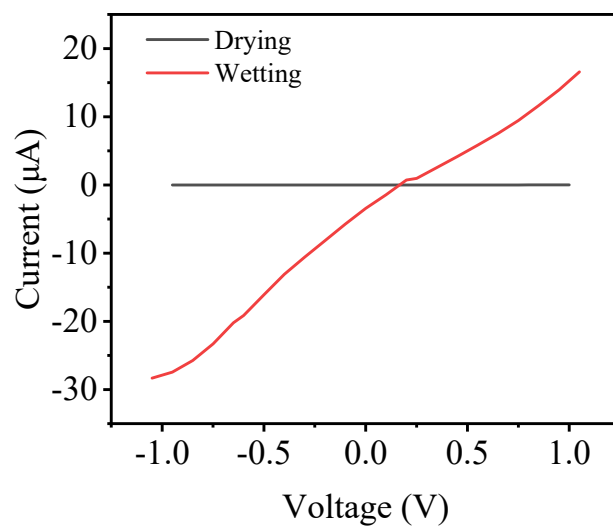


**Fig. S5** The Raman spectra of membrane.

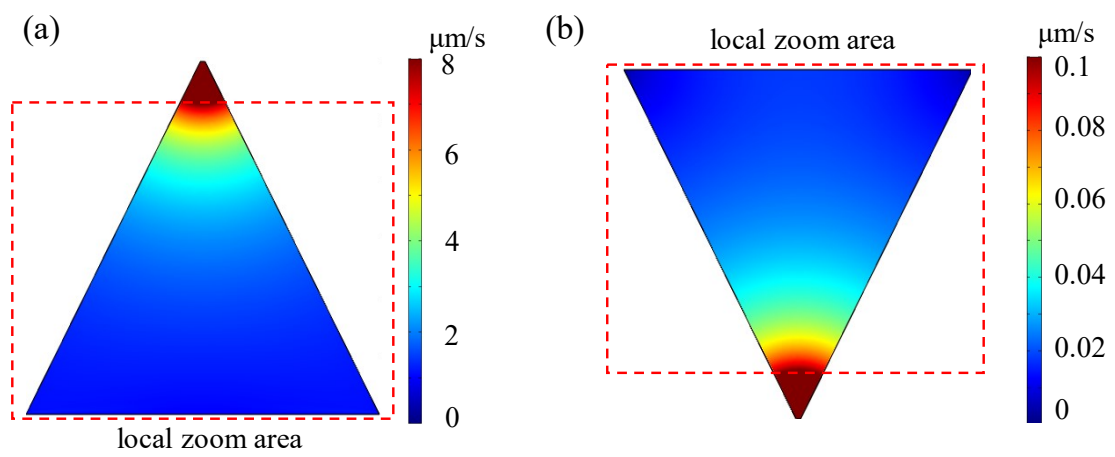




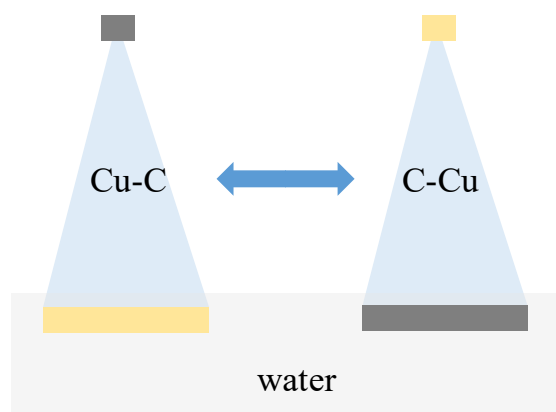
**Fig. S6** The XRD pattern of membrane.



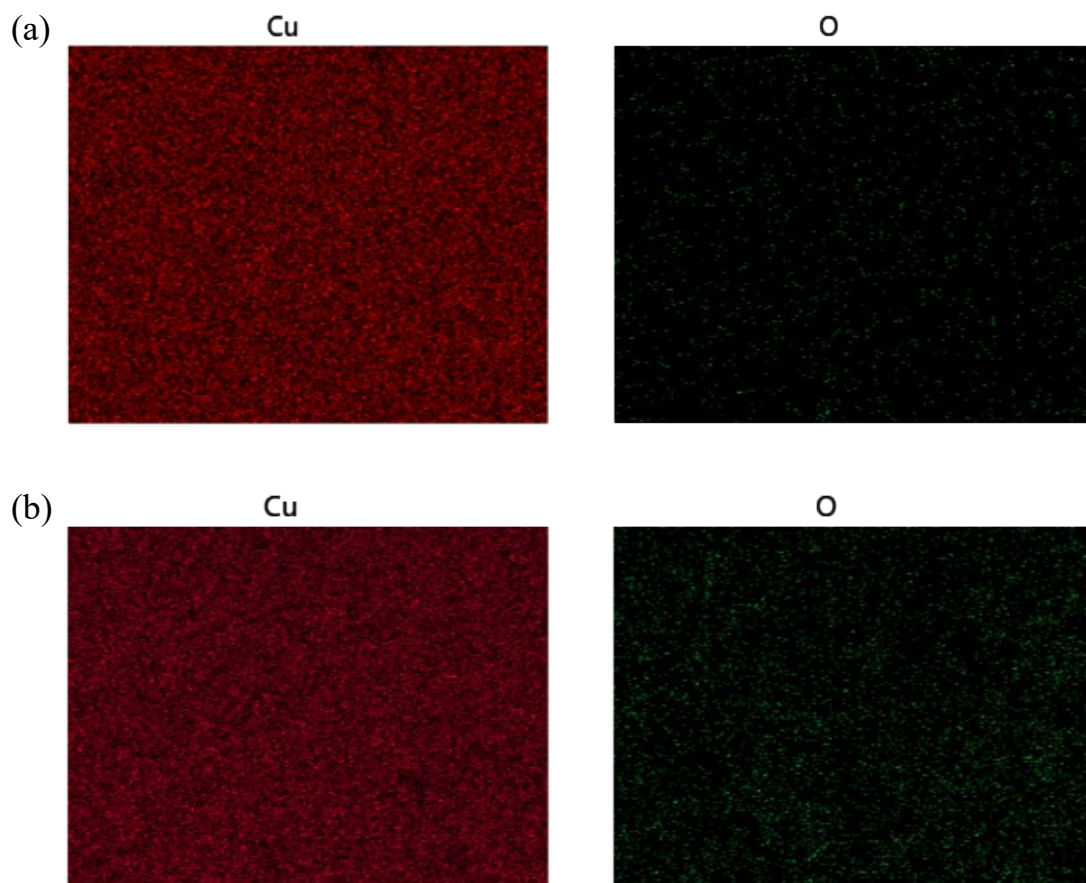
**Fig. S7** The IV curves of drying and wetting PTFE membranes.



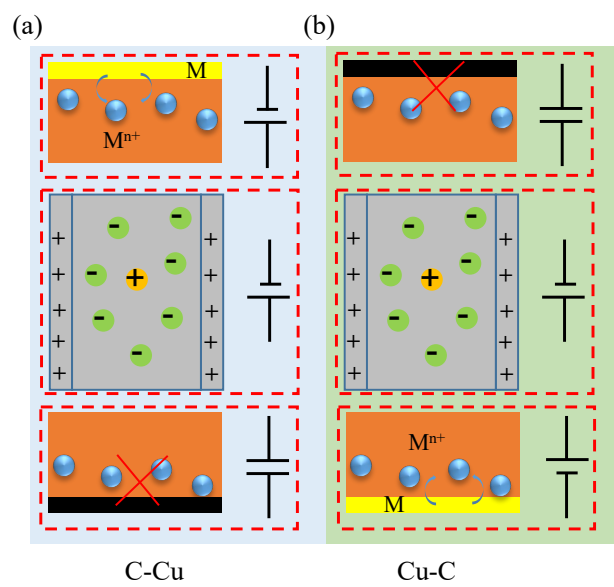
**Fig. S8** The local zoomed-in image of (a) FCS and (b) RCS.



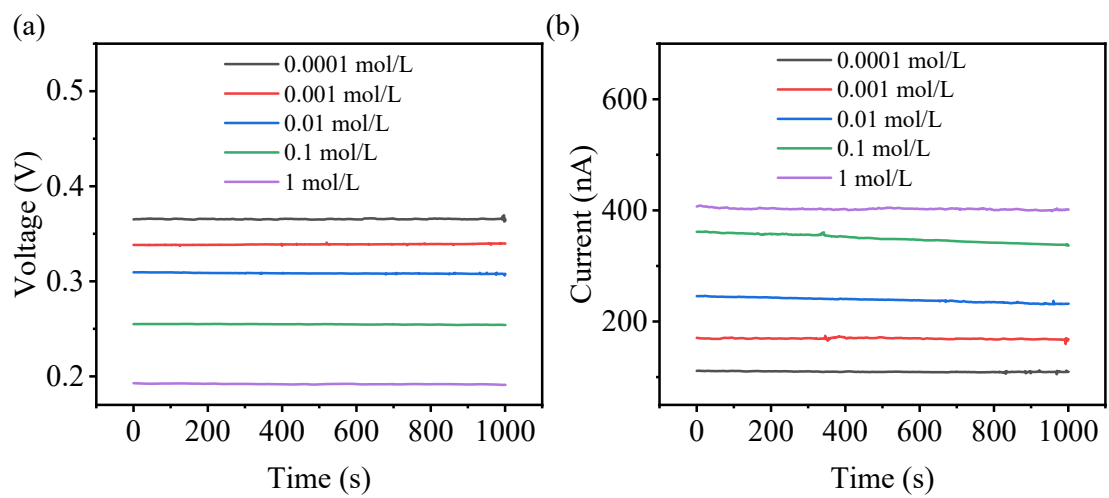
**Fig. S9** The diagram of generator upon Cu-C and C-Cu electrodes.



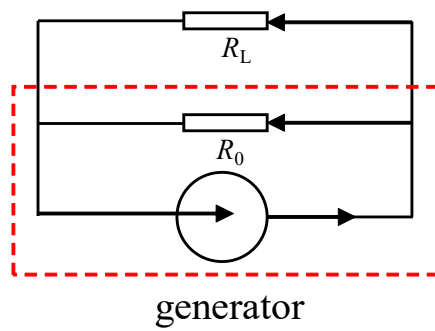
**Fig. S10** EDS images of Cu electrode before (a) and after (b) measurement in DI water.



**Fig. S11** The mechanism analysis for (a) asymmetric Cu-C electrodes (d) asymmetric C-Cu generator.



**Fig. S12** (a) The open circuit voltage and (b) short circuit current under different ion concentration. (c) The open circuit voltage and short circuit current as a function of ion concentration.



**Fig. S13** The equivalent circuit diagram of evaporating-hydrovoltaic generator.



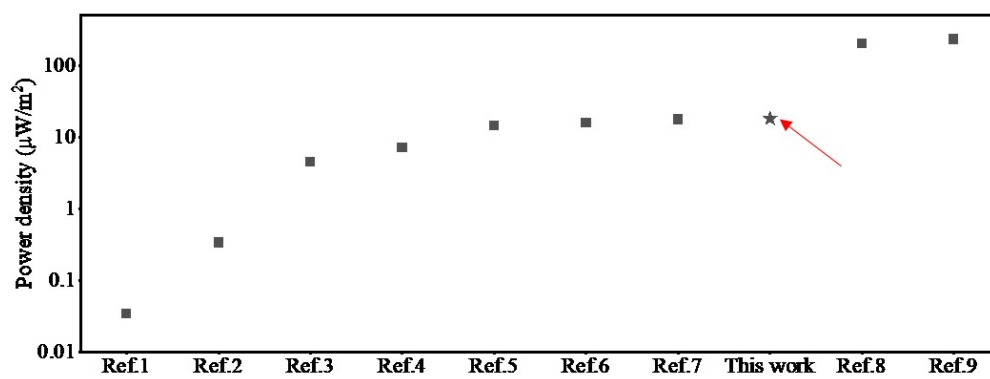
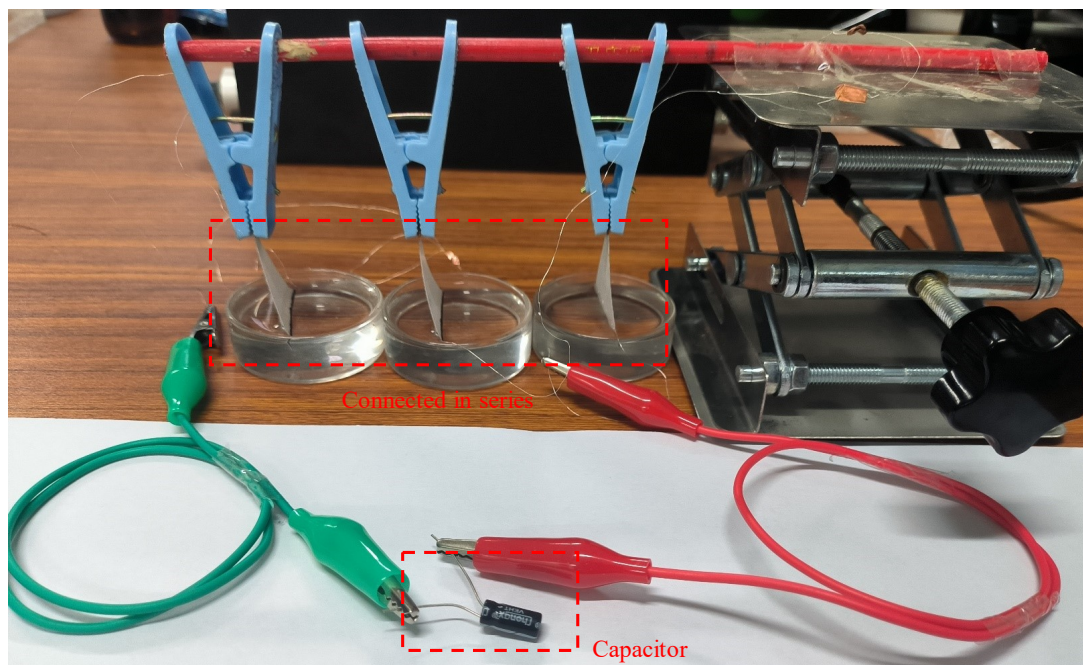
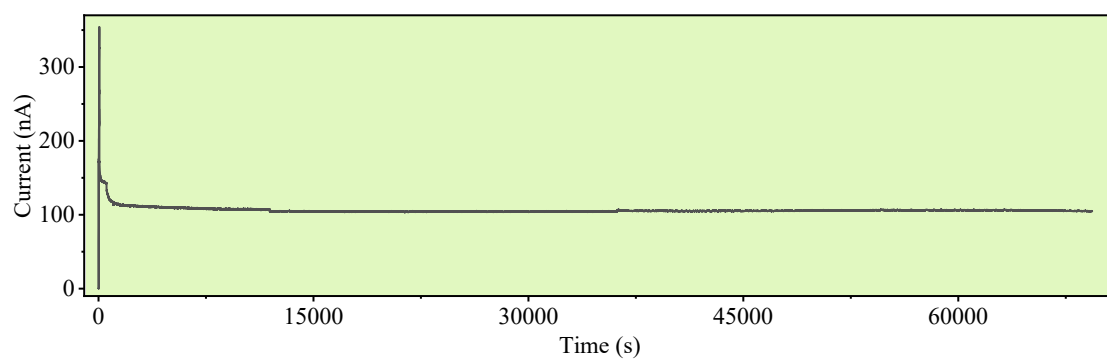


Fig. S14 The output power comparison of generator.



**Fig. S15** The real optical image of PTFE membrane charging capacitor.



**Fig. S16** The stability test of short circuit current.

## References

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