Electronic Supplementary Information for

Simple and sustainable electric power generation by free evaporation of liquids from the surface of a conventional thermoelectric generator

Pengfei Cheng,* *Dong Wang*,* *Peter Schaaf*

Chair Materials for Electrical Engineering and Electronics, Institute of Materials Science and Engineering and Institute of Micro and Nanotechnologies MacroNano, TU Ilmenau, Gustav-Kirchhoff-Str. 5, 98693 Ilmenau, Germany

* Corresponding author: dong.wang@tu-ilmenau.de; pengfei.cheng@tu-ilmenau.de

Methods

Materials and regents

De-ion (DI) water (18.2 MΩ·cm) was obtained from a laboratory ultrapure water machine. Ethanal and acetone were purchased from Sigma-Aldrich company. Thermoelectric generator modules (p/n type, Bi2Te3, TEC1-12706) were bought from Shenzhen Zhiquchuang Technology Co., Ltd.

Characterization

The real-time surface temperature of the thermoelectric generators was measured by an infrared camera (FLIR SYSTEM, Thermovision A40). The evaporated masses of different liquids were tested by an analytic balance (KERN, precision: 0.1 mg). Contact angle of thermoelectric generator was measured by Krüss DSA 10 Mk2 system. Open circuit voltage and short circuit current were measured by a multimeter. The wind velocity was measured by an anemometer (DA02 Wind Gauge).

Temperature and performance measurements of liquid evaporation generators at the room temperature

About 2 mL DI water, ethanol and acetone were spread on the surface (4 × 4 cm^2) of the thermoelectric modules, respectively. Then, IR camera was used to record the real-time surface temperatures of different samples at room temperature of 21.1 °C and relative humidity (RH) of 46%±5%. At the same time, the multimeter was used to measure the open-circuit voltage and short-circuit current.

Open-circuit volage (V_{OC}) measurement

$$V_{OC} = n \times (S_p\text{-}S_n) \times \Delta T$$

where n, S_p, S_n and ΔT stand for the number of the pairs of thermoelectric elements, Seebeck coefficients of p-type and n-type thermoelectric materials, and ΔT between the hot side and cold side of thermoelectric elements, respectively. In our work, commercially available TEGs have the same n, and (S_p-S_n). Therefore, the V_{oc} depends on the ΔT, namely the temperature differences between the both sides of the TEG. By adjusting the temperature of upper and lower surface of TEG, various V_{OC} are achieved. For free evaporation at room temperature, we measured the V_{OC} with/without wind at the same RH environment to ensure the reliability of experiments.

Performance measurements of w-LEG, e-LEG, a-LEG and five tandem w-LEGs

The open-circuit voltage and short-circuit current of a single LEG were initially measured at room temperature without wind. Approximately 2 mL each of DI water, ethanol, and acetone were spread on the surface of the thermoelectric modules. The voltage and current were then recorded during the process of free evaporation. For a single w-LEG, the voltage and current were recorded under different wind velocities, controlled by adjusting the power of the fan and the distance between the device and the fan. When testing on the hot stage, temperature sensor 1 (TS1 in Fig. 4b) was used to regulate the temperature, while TS2 was employed to calibrate the actual temperature. The performance of the five tandem w-LEGs was measured similarly to the single w-LEG. No voltage amplifier was used when powering the LED array, electronic device, and colorful lights. However, a voltage amplifier was utilized to maintain a 5V voltage for charging a mobile phone.

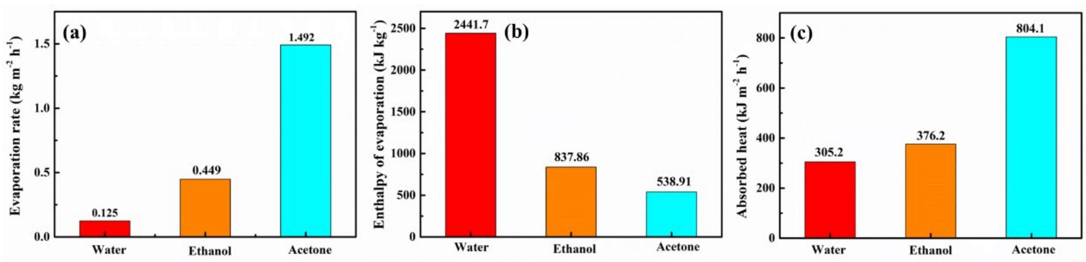

Fig. S1 Mass and energy transfer. The evaporation rates (a), evaporation enthalpies at room temperature 20 °C, (b) and absorbed heat from the surroundings for evaporation (c) of water, ethanol and acetone, respectively.

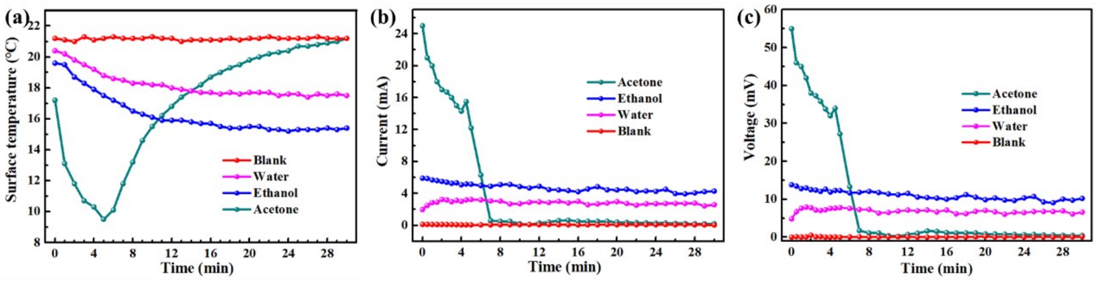

Fig. S2 (a) The surface temperature of blank TE module, TE module covered with water, TE module covered with ethanol and TE module covered with acetone. The surface temperature rise from t = 5 min is because the rapid evaporation of acetone and reduction of the area covered by acetone. (b) The corresponding evaporation cooling generated current in a. (c) The corresponding evaporation cooling generated voltage in a.

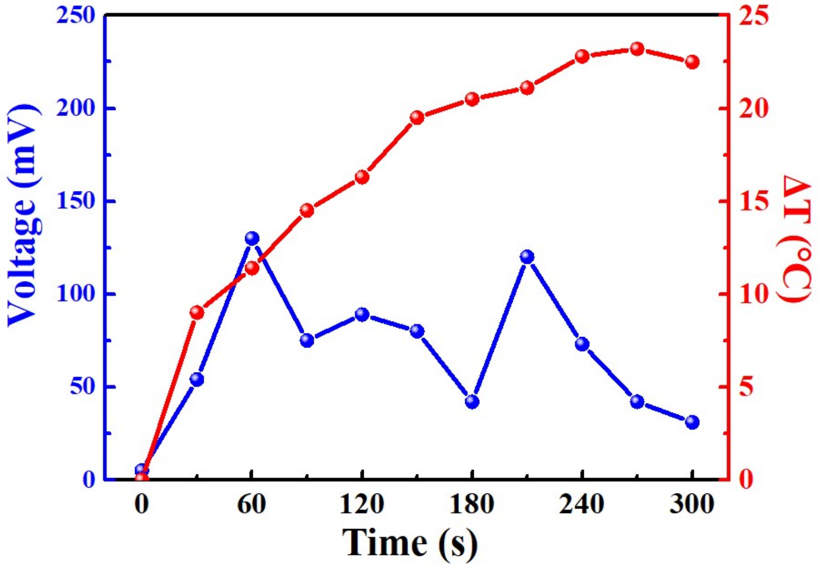

Fig. S3 The voltage output performance of a bare TE module is measured under a rising ΔT temperature at a wind velocity of 2 m/s.

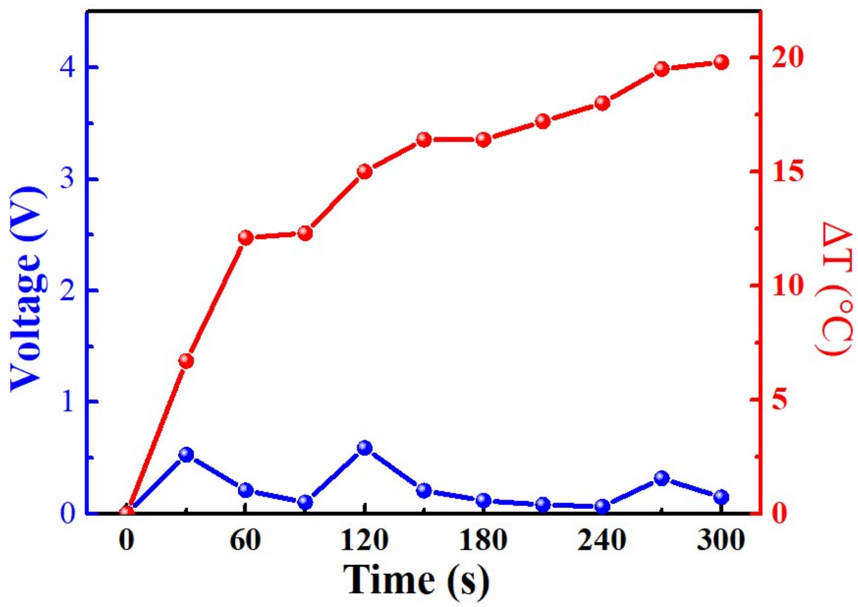

Fig. S4 The voltage output performance of five tandem TE modules is measured under a rising ΔT temperature at a wind velocity of 2 m/s.

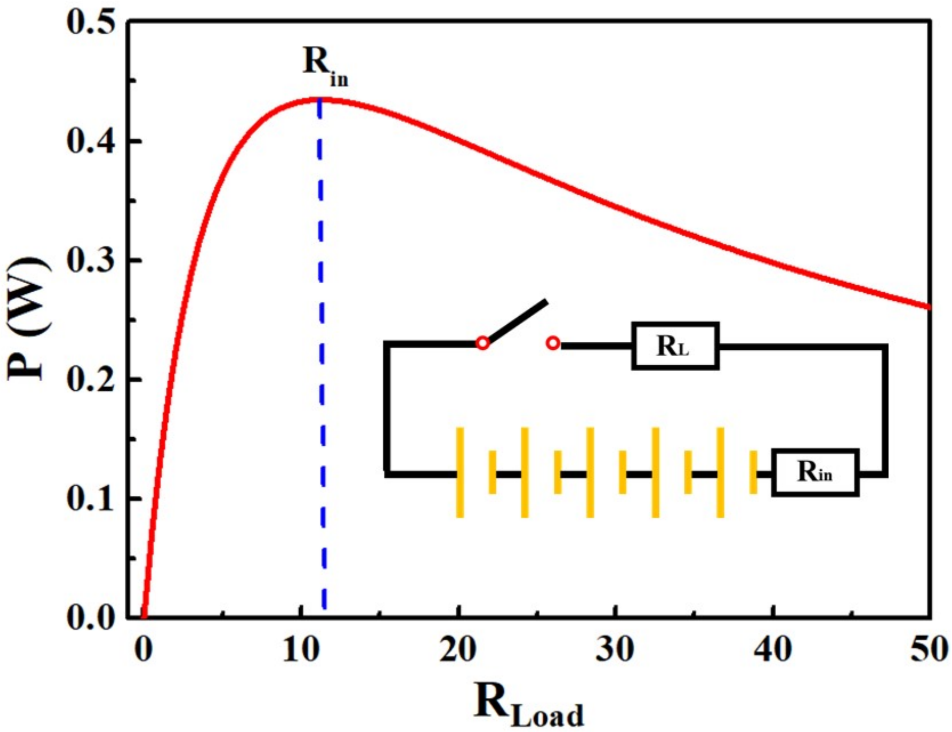

Fig. S5 The output power of 5 tandem WEGs changes with the load resistance. The inset is the equivalent circuit diagram.

The power (P) is calculated by the following equation: P = I2 RL = [U/(Rin+RL)]2×RL, where U is the open-circuit voltage, Rin is the inner resistance of 5 WEGs and RL stands for the load resistance.

Supplementary Movie

Video S1 Five tandem w-LEGs can continuously supply power for a string of LED lights.