nature nanotechnology

SUPPLEMENTARY INFORMATION

DOI: 10.1038/NNANO.2014.56

Generating electricity by moving a droplet of ionic liquid along graphene

Jun Yin, Xuemei Li, Jin Yu, Zhuhua Zhang, Jianxin Zhou and Wanlin Guo [†]

[†]To whom correspondence should be addressed. E-mail: wlguo@nuaa.edu.cn

1, Figures S1 to S8

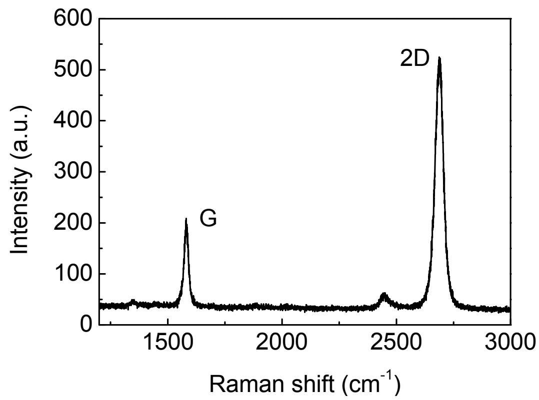

Figure S1. Raman spectra of monolayer graphene samples transferred onto SiO_2/Si substrate.

The Raman spectroscopy was performed at ambient with a Renishaw spectrometer with 514.5 nm wavelength excitation at intensity of 1 mW. The intensity ratio of the G and 2D modes of the Raman spectra is 0.35, indicating the monolayer of our sample. The nearly undetected D band of the Raman spectra suggests the high quality of our graphene sample.

DOI: 10.1038/NNANO.2014.56

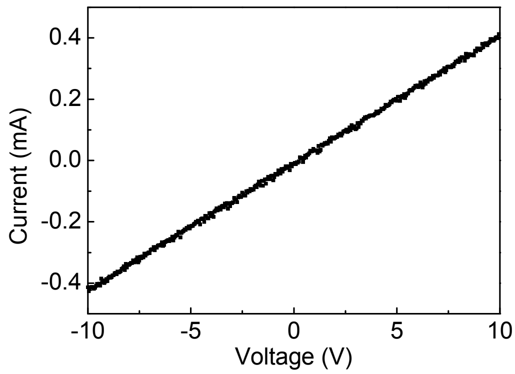

Figure S2. *I-V* curve of the graphene sample indicates the ohmic contact. The deduced square resistance is 1.09 kΩ/□.

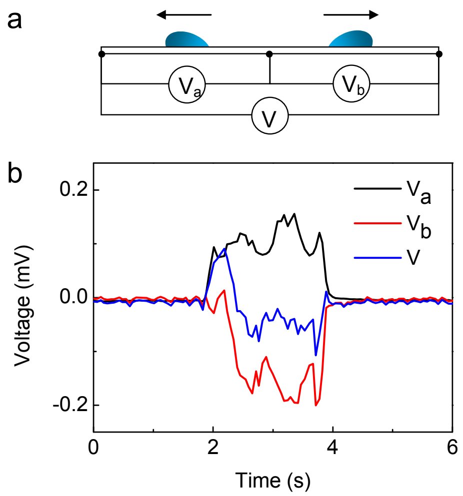

Figure S3. (a) Schematic illustration of the experimental setup. (b) The induced voltage by the left droplet (V_a), the right droplet (droplet V_b) at a moving velocity of 3.1 cm/s and the total induced voltage across the whole graphene sheet (V), respectively.

We patterned a middle electrode on the graphene strip, and measured the voltage across the left part, right part and the whole graphene strip when drawing two droplets to opposite directions, as schematic illustrated in Fig. S3a. As can be expected, the voltage generated by each individual droplet does offset each other (Fig. S3b).

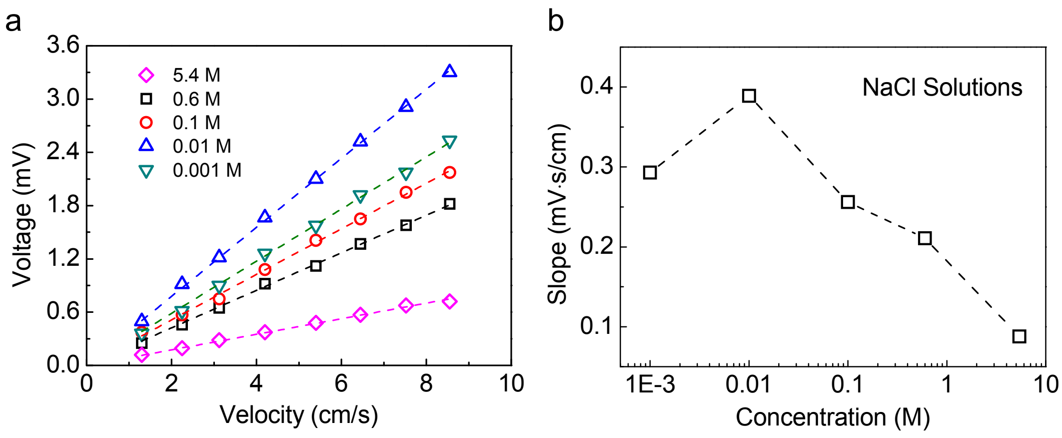

Figure S4. Dependence of the drawing potential on the concentration of the solution. **a,** The induced voltage as functions of velocity when dragging three droplets of NaCl solution with different concentrations at the surface of the graphene sample. **b,** Slopes of the *V*-*v* curves for three droplets of NaCl solution with various concentrations.

According to the mechanism in the text, the adsorption density of cation on graphene, which affect the magnitude of the pseudocapacitance, is expected to cause the induced voltage increases with the solution concentration. This is confirmed by the enhancement of induced voltage when the concentration of NaCl solution increases from 0.001 M to 0.1 M. However, then the induced voltage decreases for solutions with concentration increasing from 0.1 M to 5.4 M. We attribute this to that, in dense solution, the screening effect caused by the anion in the diffuse layer of the double layer is enhanced, as the Debye length is reciprocally proportional to the square root of the ion concentration.

DOI: 10.1038/NNANO.2014.56

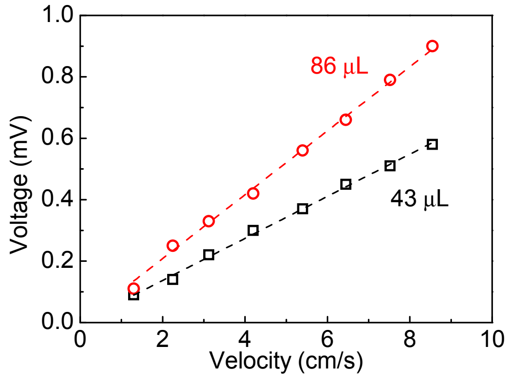

Figure S5. Dependence of the drawing potential on the volume of a droplet of 0.6M NaCl.

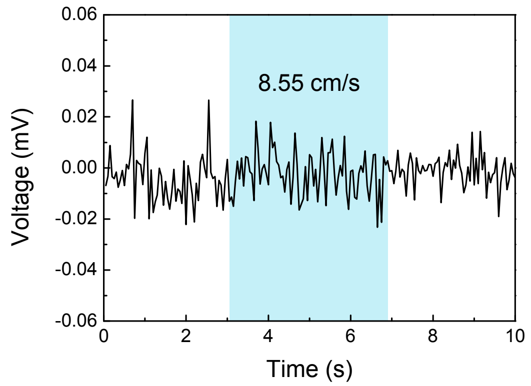

Figure S6. Response of the graphene sample for three droplets of deionzed water drawn at 8.55 cm/s on its surface. There is no noticeable change in the voltage signals.

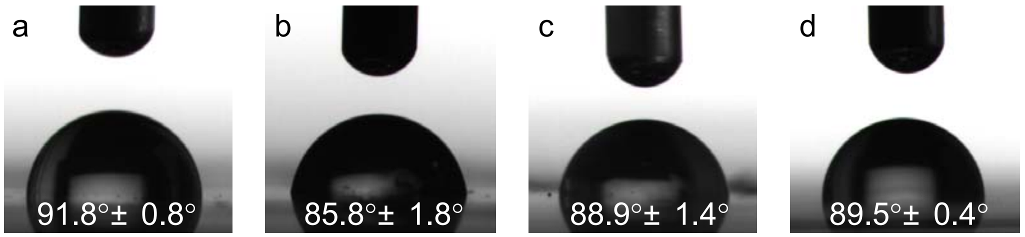

Figure S7. Contact angle of the graphene under different conditions. **a,** Deionized water on pristine graphene. **b,** 0.6 M HCl on graphene. **c,** Deionized water on graphene, which has been wetted by 0.6 M HCl. **d,** Deionized water on graphene, which has been rinsed by deionized water for 30 min after wetted by 0.6 M HCl for 2 min.

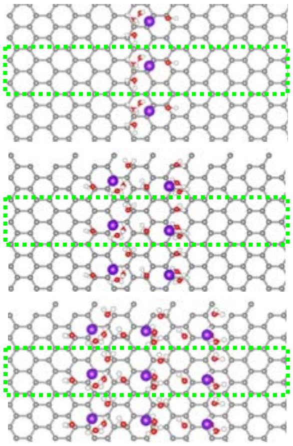

Figure S8. Models for DFT calculation of hydrated Na^+ ion(s) adsorbed on monolayer graphene. The green dashed line squares the unit cells performed in the simulation.

2, Efficiency of the energy harvesting

We estimate the efficiency based on the friction force applied to the flowing droplet $F_d = \frac{1}{2} c_d \rho \upsilon^2 A$, where F_d is the drag force, c_d is the drag coefficient (for our situation, $c_d = 1.328 / \sqrt{R_e} \approx 7.2 \times 10^{-3}$, R_e represents Reynolds number), ρ is the density of water, υ is the velocity of the droplet, and A is the area of the wetted surface. Taking the area of the wetted surface as $0.5 \times 2 cm^2$, the drag force is estimated to be $1.06 \times 10^{-6} N$, thus the consumed power should be around $1.8 \mu W$, and the efficiency is around 1%. We have made additional discussion in the text.