Revised Supplementary Information

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High energy output nanogenerator based on reduced graphene oxide

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Fig. S1

A serial contrast experiments and related results have been provided to verify the effectiveness of the method and the authenticity of the data.

1) Tests with control devices (without graphene).

2) Change the relative positions between the working electrode and counter electrode.

3) The roles of all the (working, reference, counter) electrodes.

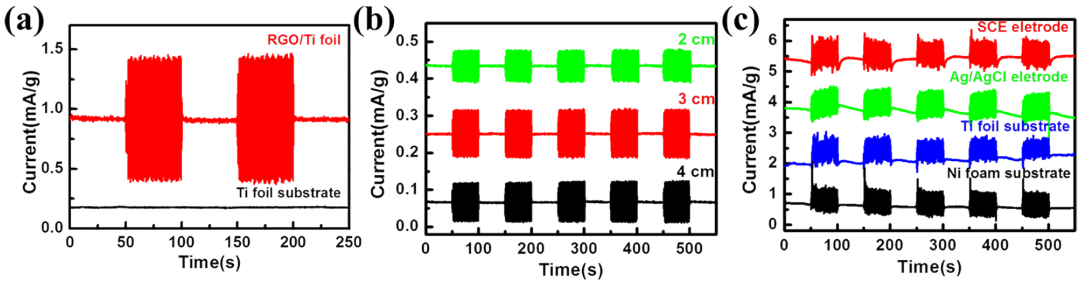

Fig. S1 (a) i-t curves with and without RGO sheets. (b) i-t curves as a function of the relative positions between the working and counter electrodes. (c) i-t curves with different working electrodes (Ni foam and Ti foil substrate) and different reference electrodes (Ag/AgCl electrode and SCE electrode)

The results revealed that: 1) The electric output could be generated from RGO, instead of blank substrate, which can rule out the underlying factors that contribute to the electromagnetic effect. 2) The distance between working electrode and counter electrode has the effect on current output but not prominently. 3) Different working electrodes (Ni foam and

Ti foil substrate) and different reference electrodes (Ag/AgCl electrode and SCE electrode) would not affect the experiment results.

Fig. S2

According to the FTIR spectra and the C 1s spectral region in XPS spectrum, the oxygen element was present in RGO as hydroxyl (C-OH), carboxyl (C=O, O=C-OH), and epoxide group (C-O-C).

Fig. S2 (a) FTIR spectra of the RGO. (b) C 1s spectral region in XPS spectra.

Fig. S3

In order to support the strain effect, we presented the integration of experimental setup in a microfluidic system, and used Raman spectroscopy to characterize the structure changes of RGO sheets in microfluidic system.

The microfluidic chips were fabricated by patterning channels in poly(dimethylsiloxane) (PDMS, Sylgard 184, Midland, MI, USA) using soft lithography. Briefly, SU8-2100 photoresist was spin-coated onto silicon wafers, patterned by UV exposure through a photolithography mask and then developed. A mixture of Sylgard 184 silicone elastomer and curing agent (10:1 w/w) was degassed under vacuum and then poured onto the silicon wafer to a depth of 2 mm and cured at 75 ºC for 1 hour. The PDMS was gently peeled from the master, then the input/output ports were punched out of the PDMS with a steel tube. The PDMS chip treated by oxygen plasma was bonded to the glass substrate, on which large area RGO films were spin-coated before.

When fluid (Na_2SO_4 solution) flows along the channel on the RGO sheets, the Raman spectrum of RGO changed weakly. The results revealed that the full width at half maximum (FWHM) of D and G band had the broad trend, and the value of I_D / I_G ratio changed from 0.76 to 0.88. The change of Raman spectrum could indicate the structural variation of RGO, which could prove that the strain effect could be achieved by friction between RGO sheet and electrolyte.

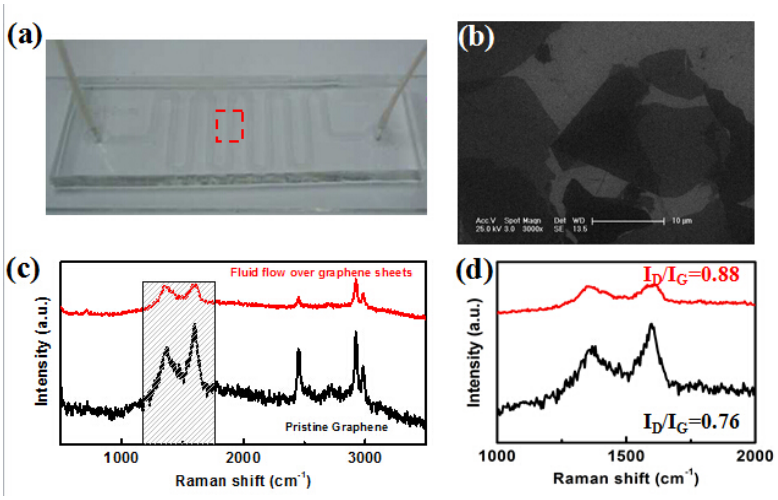

Fig. S3 (a) RGO based microfluidic system. (b) SEM images of RGO sheets on the glass substrate. (c) and (d) Raman spectrum of RGO sheets in the microfluidic system.

Fig. S4

Density functional theory (DFT) calculations were used to study the band structure of graphene. The calculations were performed using a Vienna Ab-initio Simulation Pack-age (VASP). Band structure of pristine sheet and the the sheet whose atoms shifted along one of vibration modes revealed that the band-gap opened about 160 meV wide. The result shows that the friction force between the electrolyte and RGO could disturb C-OH from their equilibrium sites, and caused the graphene vibration in its inherent frequencies.

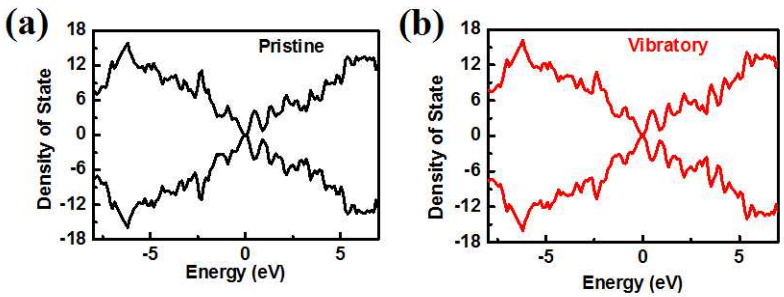

Fig. S4 (a) Band structure of pristine sheet. (b) Band structure of the sheet whose atoms shifted along one of vibration modes.

Fig. S5

Fig. S5 Electrochemical impedance spectra and equivalent circuit of the RGO/Ni electrode

Fig. S6

The voltage of RGO-based nanogenerator cannot be improved by adjusting the parameters. Therefore, we used a series connection for the voltage amplification, as shown in Fig. S6. The results showed that the voltage could be duplicated when two nanogenerators were connected.

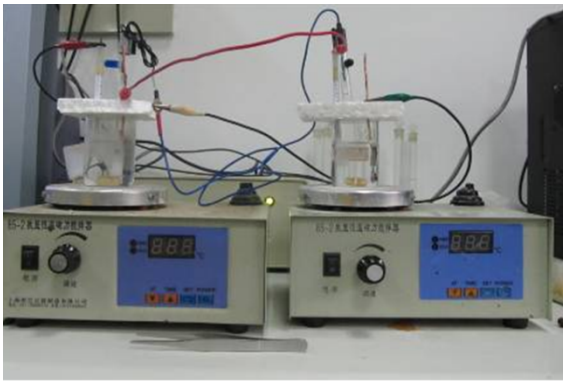

Fig. S6 Voltage amplification of nanogenerator by series connection.

Fig. S7

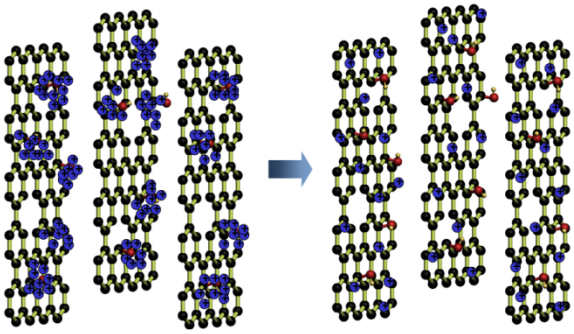

Fig. S7 Schematic model of the pulsed current generation

Fig. S8

We could realize the seawater power generator by using the RGO nanogenerator when we changed the electrolyte into seawater. The results revealed that the power output per unit area could improve 5 times, which is uplifting.

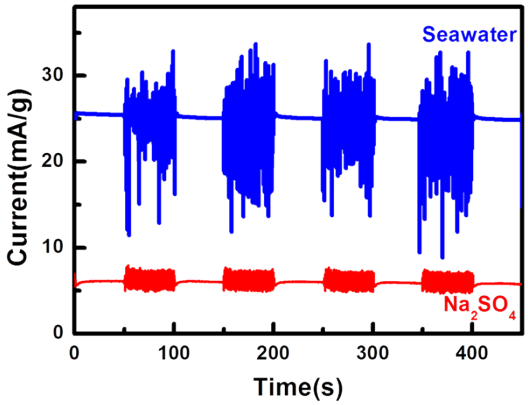

Fig. S8 The seawater power generator could be realized by using the RGO nanogenerator.