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Supplementary Information

Photo-Induced Charge Boosting of Liquid-Solid Electrokinetic Generators for Efficient Wave Energy Harvesting

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Table S1. Electrical data produced by waving seawater onto *L*-SEKGs with different film content at seawater temperature of 25 °C and wave frequency of 0.9 Hz.

Film composition	Variable	Values	Voltage (mV)	Current (μA)	Power (μW)
GO-CB	GO-CB ratio	0/1	49.56 ± 5.51	0.57 ± 0.05	0.03 ± 0.01
		1/6	68.70 ± 11.51	7.35 ± 0.81	0.50 ± 0.15
		2/5	76.63 ± 7.36	35.93 ± 8.04	2.75 ± 0.94
		3/4	78.82 ± 12.43	9.10 ± 0.71	0.72 ± 0.18
		4/3	62.33 ± 6.19	4.25 ± 0.61	0.26 ± 0.07
		5/2	38.33 ± 3.33	0.57 ± 0.17	0.02 ± 0.01
GO-CB	GO reduction time	0	75.20±5.89	7.33±1.25	0.55±0.14
		3	72.73±6.88	9.05±1.02	0.66±0.14
		5	71.11±15.14	18.90±4.28	1.34±0.65
		10	58.46±8.15	1.74±0.16	0.1±0.02
GO-CB-MWCNT	MWCNT dosage	0 wt%	78.82±12.43	9.10 ± 0.71	0.72 ± 0.18
		5 wt%	104.07±17.06	14.45 ± 1.91	1.50 ± 0.48
		10 wt%	89.62±11.78	77.51 ± 16.43	6.95 ± 2.65
		17 wt%	81.12 ± 17.48	111.72 ± 16.68	9.06 ± 3.59
		25 wt%	64.10 ± 11.41	98.55 ± 16.85	6.32 ± 1.64
GO-CB-MWCNT/CQDs	CQD dosage In the dark	0 mL	77.72 ± 9.26	134.29 ± 9.66	10.44 ± 2.08
		10 mL	79.75 ± 9.89	144.94 ± 6.27	11.56 ± 1.99
		20 mL	79.27 ± 5.20	135.56 ± 11.18	10.75 ± 1.65
		30 mL	71.54 ± 8.32	132.01 ± 8.42	9.43 ± 1.78
	CQD dosage Illumination (AM 1.5, 100 mWncm^{-2})	0 mL	78.72 ± 15.08	113.62 ± 10.09	8.94 ± 2.66
		10 mL	95.22 ± 17.62	292.75 ± 63.85	27.88 ± 12.37
		20 mL	101.26 ± 6.63	394.70 ± 39.40	39.97 ± 6.87
		30 mL	91.42 ± 11.29	275.62 ± 64.02	25.20 ± 9.68

Table S2. Influences of wave frequency, seawater temperature and illumination intensity on the output performance of optimum *L*-SEKGs with GO/CB ratio of 3/4, GO reduction time of 5min, MWCNT dosage of 17 wt% and CQDs dosage of 20mL.

Film content	**Test parameters**		**Voltage (mV)**	**Current (μA)**	**Power (μW)**
GO-CB-MWCNT	**Wave frequency (Hz)**	0.17	115.24 ± 15.46	160.22 ± 8.6	18.46 ± 3.60
		0.3	96.09 ± 11.65	155.71 ± 9.06	14.96 ± 2.79
		0.9	78.31 ± 13.67	109.13 ± 11.67	8.55 ± 2.56
	Seawater temperature (℃)	0	96.76 ± 3.40	175.36 ± 3.8	16.97 ± 0.97
		10	89.51 ± 5.67	149.73 ± 6.5	13.40 ± 1.47
		20	78.03 ± 7.09	143.10 ± 5.40	11.17 ± 1.47
		30	69.36 ± 11.23	127.27 ± 7.06	8.83 ± 2.00
		40	46.11 ± 4.06	113.62 ± 11.60	5.24 ± 1.04
GO-CB-MWCNT/ CQDs	**Illumination intensity (mW cm^{-2})**	0	80.35 ± 9.77	116.98 ± 11.45	9.40 ± 2.17
		40	83.83 ± 8.54	197.07 ± 14.67	16.52 ± 3.04
		70	88.74 ± 6.63	231.67 ± 24.23	20.56 ± 3.84
		100	101.26 ± 6.63	394.70 ± 39.40	39.97 ± 6.87

Raman spectra characterization

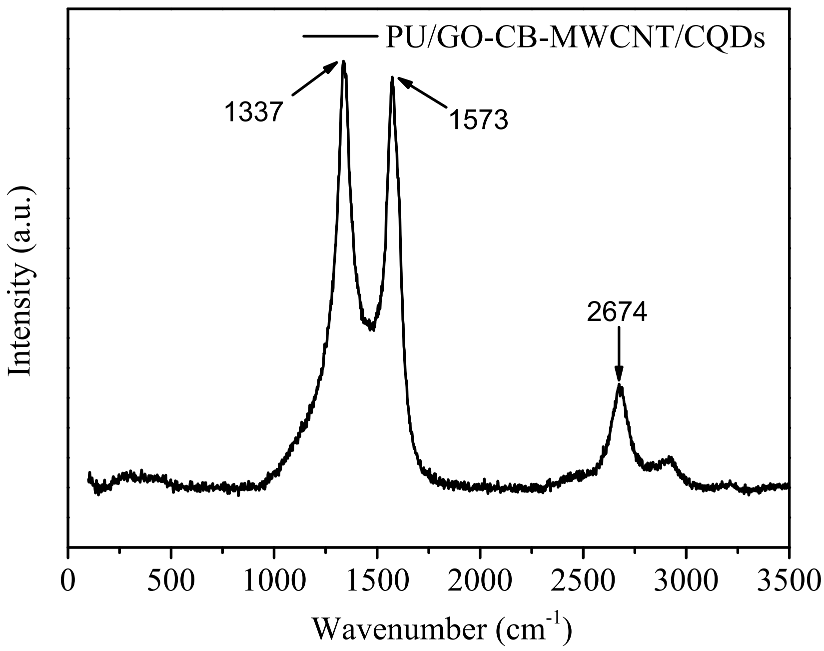


Figure S1. Raman spectra of PU/GO-CB-MWCNT/CQDs composite film using 532 nm wavelength laser.

For pristine PU/GO-CB-MWCNT/CQDs composite film, the D, G, and 2D peaks are detected at 1337, 1573, and 2674 cm^{-1}, respectively. There are no peak deviations compared to the typical Raman spectrum of graphene oxide and multiwalled carbon nanotubes, indicating the existing of graphene and multiwalled carbon nanotubes in the PU/GO-CB-MWCNT/CQDs composite film. The high intensity ratio of the D peak to the G peak (I_D/I_G) of 1.04 shows the presence of defects and oxygen-containing funtional groups in GO and multiwalled carbon nanotubes.

X-ray photoelectron spectroscopy (XPS) characterization

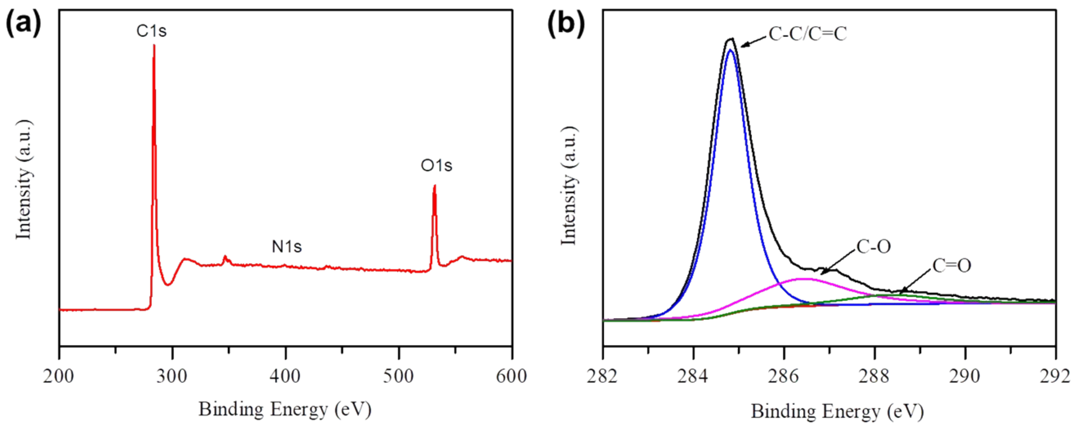


Figure S2. Survey scan (a) and C 1s (b) XPS spectra of the PU/GO-CB-MWCNT/CQDs composite film.

X-ray photoelectron spectroscopy (XPS) measurements were also performed on the PU/GO-CB-MWCNT/CQDs composite film after grinding. Three kind of elements of C, N and O are detected to exist as well as C derives from carbon nanomaterials in the film including graphene oxid, multiwalled carbon nanotubes, carbon black and carbon quantum dots, O and N mainly comes from the funtional groups linked to graphene oxid and multiwalled carbon nanotubes. The C1s XPS spectrum of PU/GO-CB-MWCNT/CQDs composite film clearly shows considerable carbon content (C-C/C=C, 284.6 eV) and oxygen content with two components that correspond to carbon atoms in different functional groups: the carbon in C-O bonds (hydroxyl and epoxy, 286.4 eV), and the carbonyl carbon (C=O, 288.5 eV). The results prove the massive content of carbon materials and the presence of oxygen-containing fountional groups in the film.

There are no signal generation by waving deionized water onto *L*-SEKG based on GO-CB composite film as shown in Figure S1.

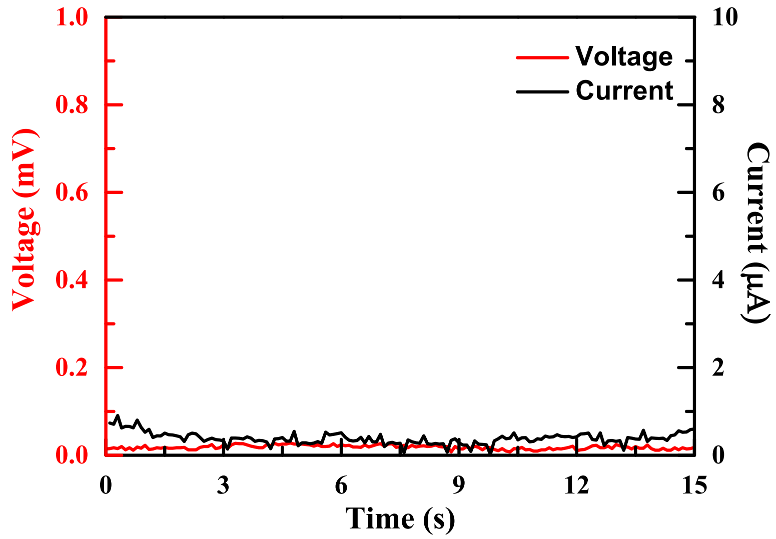


Figure S3. Voltage and current signals yielded by waving room-temperature deionized water onto PU/GO-CB/Cu *L*-SEKG at a frequency of 0.9 Hz.

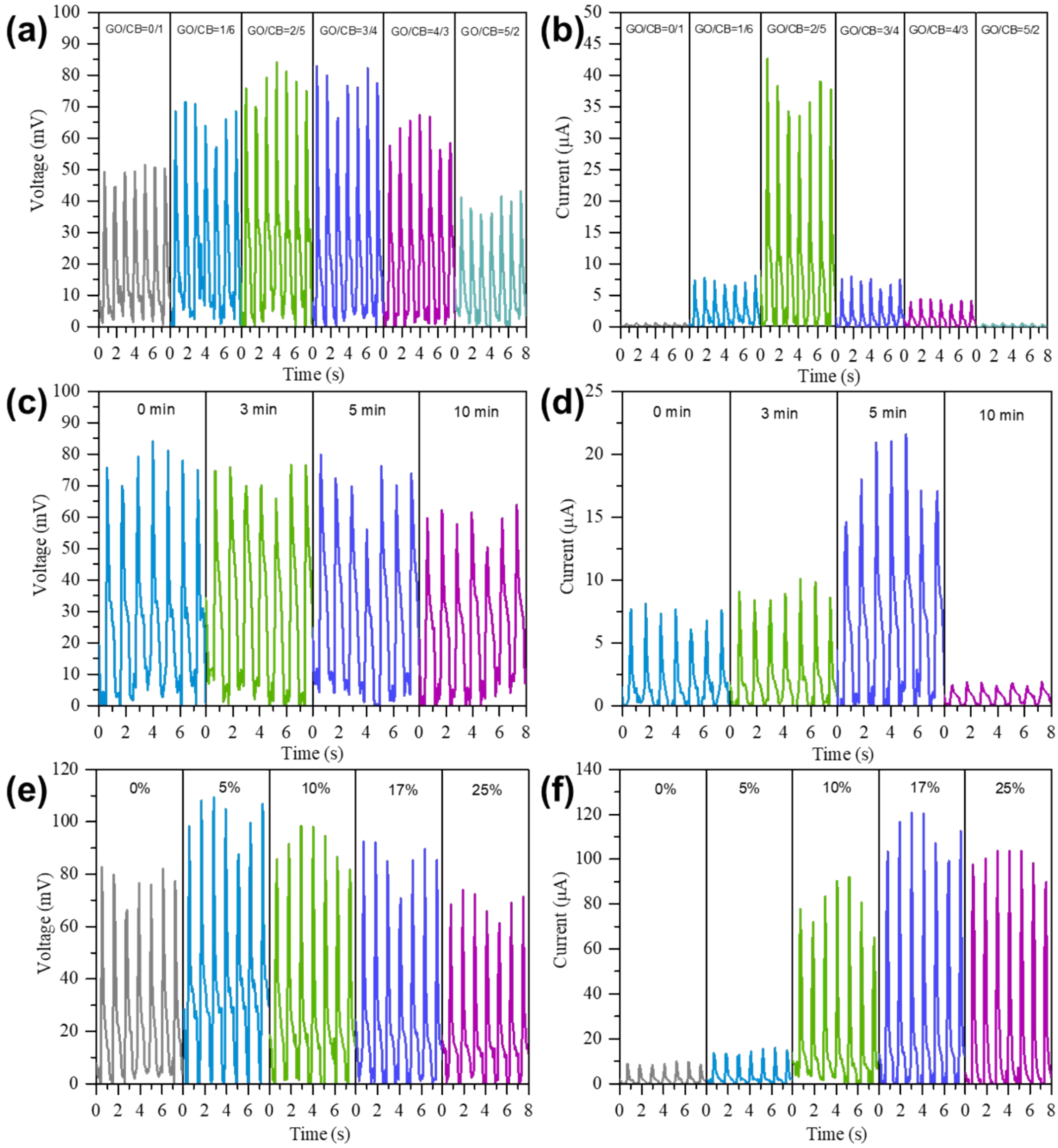


Figure S4. Periodic voltage and current output signals of GO-CB composite film based L-SEKG impacted by various (a, b) GO/CB ratio and (c, d) Reduction time of GO at wave frequency of 0.9Hz at 25^{o}C. (e, f) Voltage and current output signals of GO-CB-MWCNT composite film based L-SEKG with different MWCNT dosage at 25^{o}C and frequency of 0.9Hz.

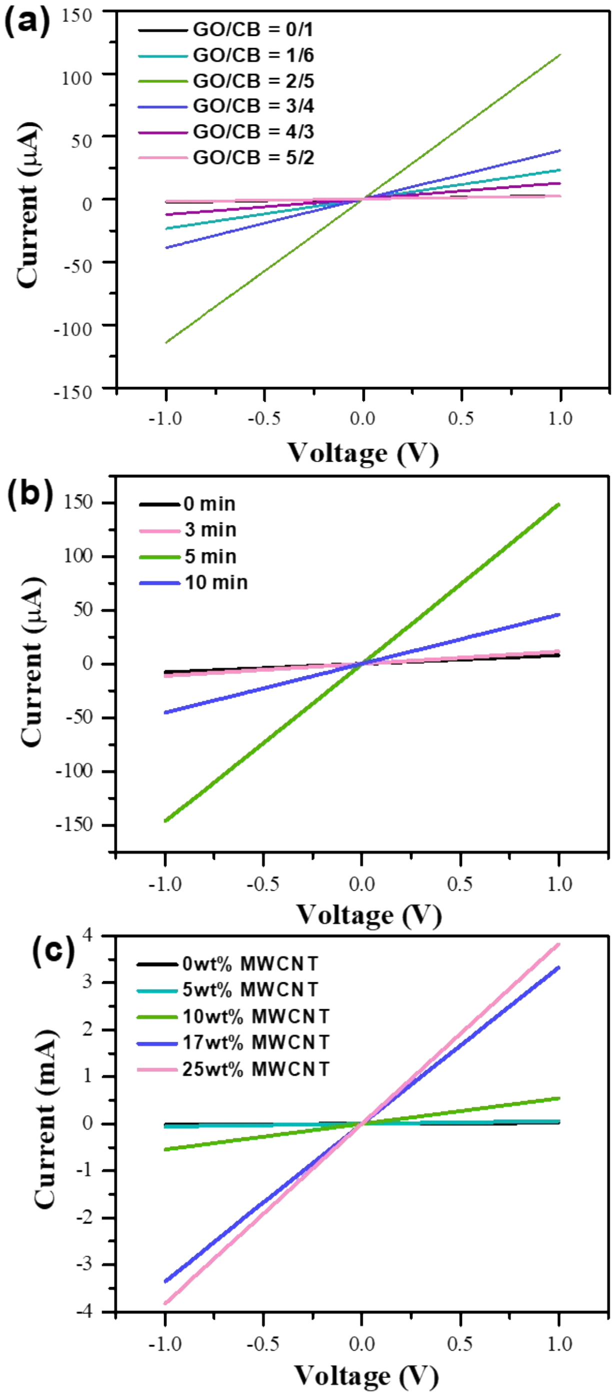


Figure S5. The Ohmic resistances recorded on GO-CB composite films with (a) Different GO/CB ratio and (b) Various GO reduction time. (c) The ohmic resistances recorded on GO-CB-MWCNT with different MWCNT dosages.

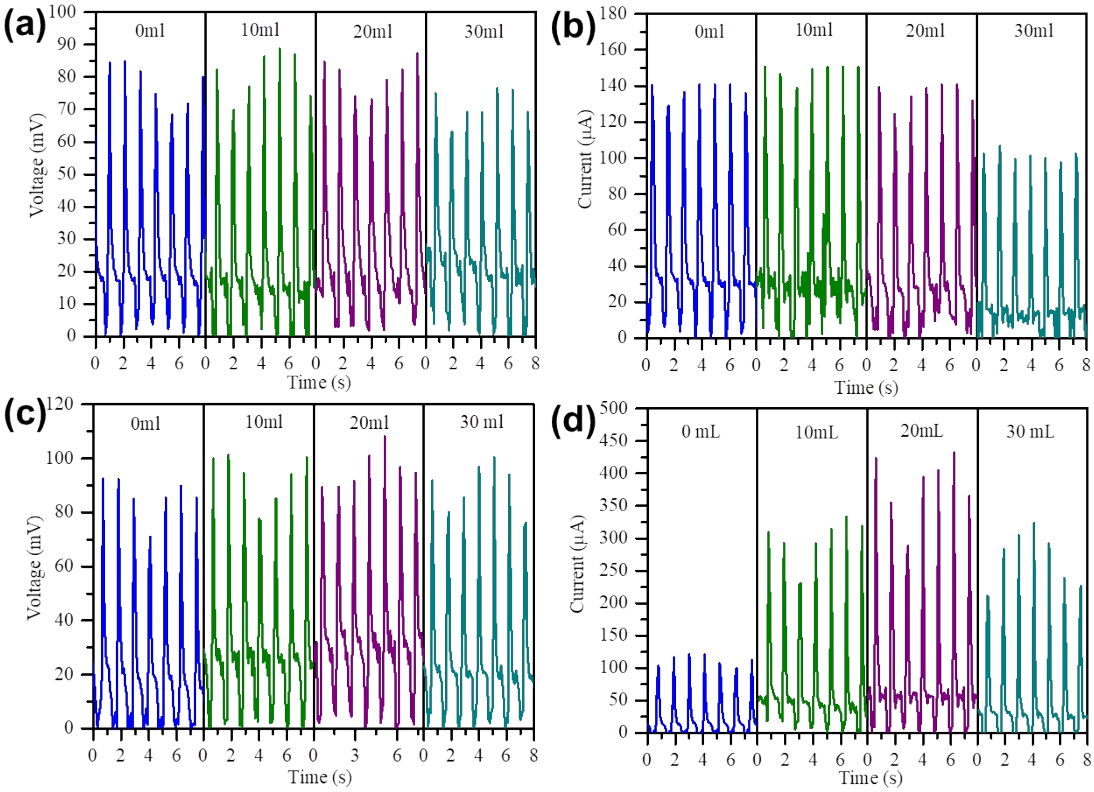
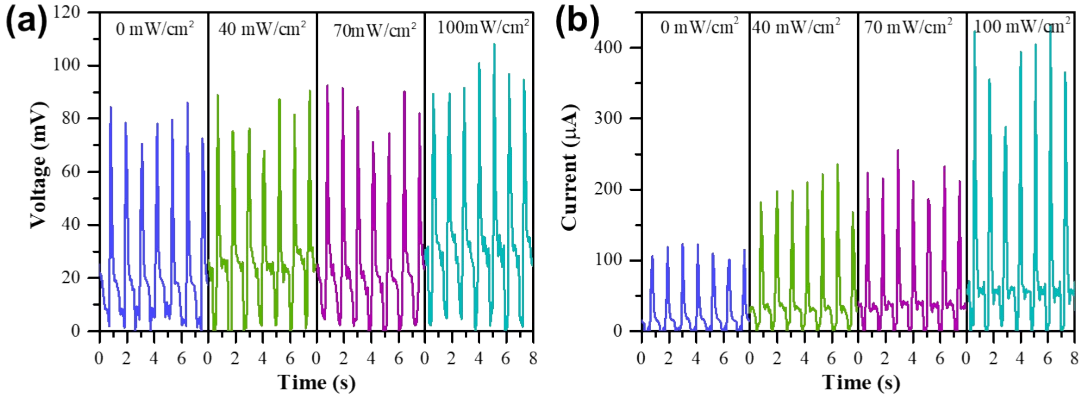


Figure S6. The voltage and current signals by waving room-temperature seawater onto PU/GO-CB-MWCNT/GQDs/Cu *L*-SEKGs with various CQDs dosage at wave frequency of 0.9 Hz under (a, b) Dark condition and (c, d) Illumination intensity of 100 mW cm^{-2}.



Figre S7. The (a) voltage and (b) current signals by waving room-temperature seawater onto PU/GO-CB-MWCNT/CQDs/Cu *L*-SEKGs with illumination intensity increased from 0 to 100 mW cm^{-2} with CQD dosage of 20mL at wave frequency of 0.9 Hz.