Selective ion migration in polyelectrolyte driving high-performance flexible moisture-electric generator

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† Electronic supplementary information (ESI) available.

Experimental section

Materials

Poly(4-styrene sulfonic acid) solution (PSS, Mw ~75000, 30 wt% in water), Phytic acid (PA, 50 wt% in water), and Poly(vinyl alcohol) (PVA 1788) were purchased from Shanghai Aladdin Biochemical Technology Co., Ltd. Carbon paste (CH-8) was supplied by Jujo Printing Supplies & Technology (PingHu) Co., Ltd. Polyester Film was received from Dongguan Jubang Plastic Materials Co., Ltd. All reagents were used as received without further purification. Deionized (DI) water was used in all experiments.

Preparation of PSS-PA@PVA

Heat and stir 5g of PVA with 50 mL of DI water at 90℃ for 4 hours. Then take out 1.2 mL of PA and mix it with the above solution (6 mL) at 100 ℃, stir and ultrasonicate for 2 hours separately, then add 20 mL of PSS and continue stirring for 4 hours. Finally, ultrasonicate the solution for 30 minutes, blow with nitrogen for 5 minutes, and centrifugate at 4000 rpm for 10 minutes. The obtained solution has a ratio of PSS: PA@PVA (mass ratio of 5:1). Solutions with other ratios are obtained using the same method described above.

Preparation of MEG

Trim the PET film to 8 cm x 4 cm. Apply carbon paste to a PET film through screen printing, and dry it at 50°C. Once again, spread the solution of PSS-PA@PVA (1 mL) onto the dried PET film to form MEG. The area (4 cm^2) of PSS-PA@PVA can be customized according to requirements. Finally, dry it for 8 hours at 50°C. After applying PET tape, we can test it in any humid environment. The film thickness was controlled by changing the number of printings. Carbon electrodes were used for all electrodes in this test.

Measurements

Clip the testing Device directly onto both ends of MEG for testing. The data for voltage and current were measured using a Voltmeter (Fluke 289C) and Picoammeter (Model 6485, Keithley). Different humidity controls were achieved through a constant

temperature and humidity chamber.

Characterizations

Fourier transform infrared (FTIR) spectra were obtained by using a Nicolet iS50 FT-IR in attenuated total reflection (ATR) mode, with a resolution of 1 cm^{-1} and 64 scans. The morphologies of the film were characterized by scanning electron microscopy (SEM, HITACHI 8020). The element contents were carried out by EDS spectrograms (EDS). The zeta potentials of the surface of MEG were measured by Electrokinetic Analyzer (Sur PASS 3). X-ray photoelectron spectroscopy (XPS, ESCALAB 250Xi, Thermo Fisher Scientific) was performed to identify the change in element composition.

Supporting Figures

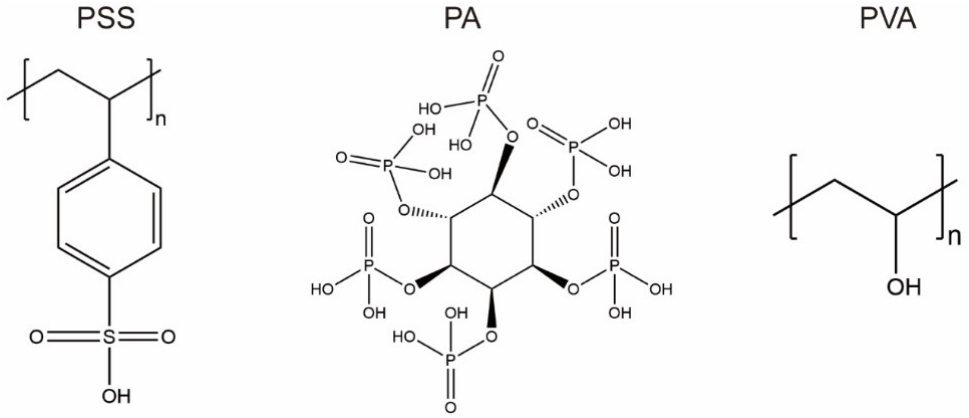


Figure S1. Chemical structures of PSS, PA, and PVA.

Figure S2. Temperature and humidity monitoring equipment photo and diagram. The overall size of the box is 70 cm × 50 cm × 40 cm, the main principle is to fill the ultrapure water into the internal container, and then through the ultrasonic sprayer will be atomized and dispersed liquid water, and then through the top of the small fan blowing to the top of the box. The box is configured with the corresponding temperature and humidity sensing probe, the humidity value can be monitored in real-time. In addition, the exterior is also designed with an air pump solenoid valve and dehumidifying materials, low humidity is obtained by inhaling the internal gas into the dehumidifying materials to dry them and then circulating them through the box. The range of controlled humidity is 10%-90% RH, and the control return is within ±1.5% RH.

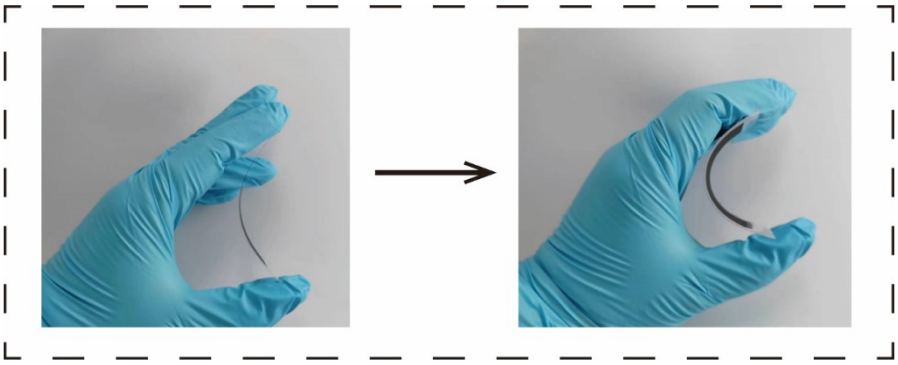


Figure S3. Bent MEG photo.

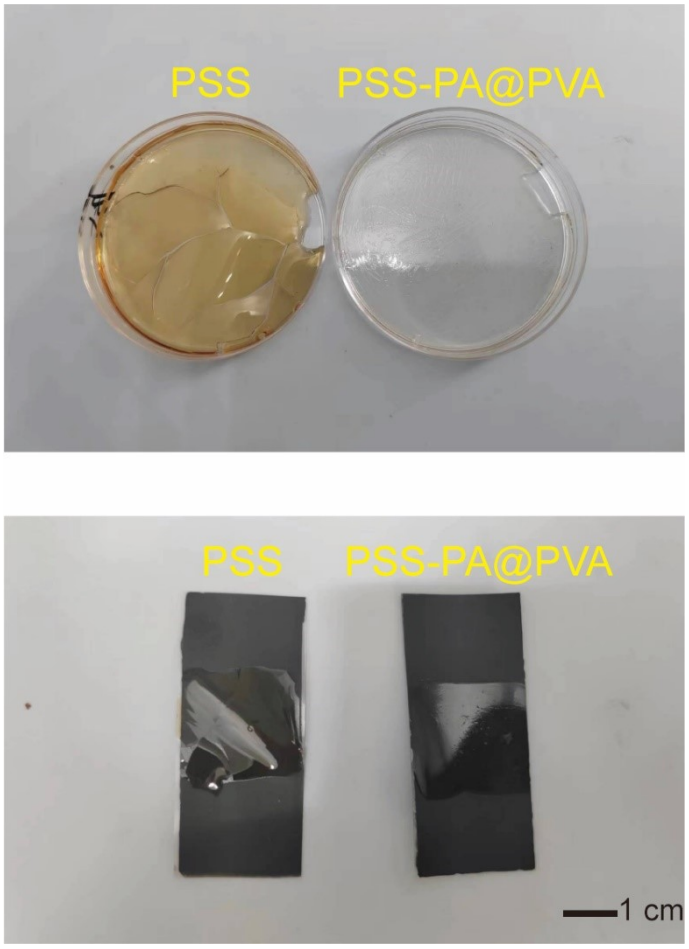


Figure S4. Comparison photo of PSS and PSS-PA@PVA.

Figure S5. Comparison photo of MEG attached directly to the arm and MEG worn as a bracelet.

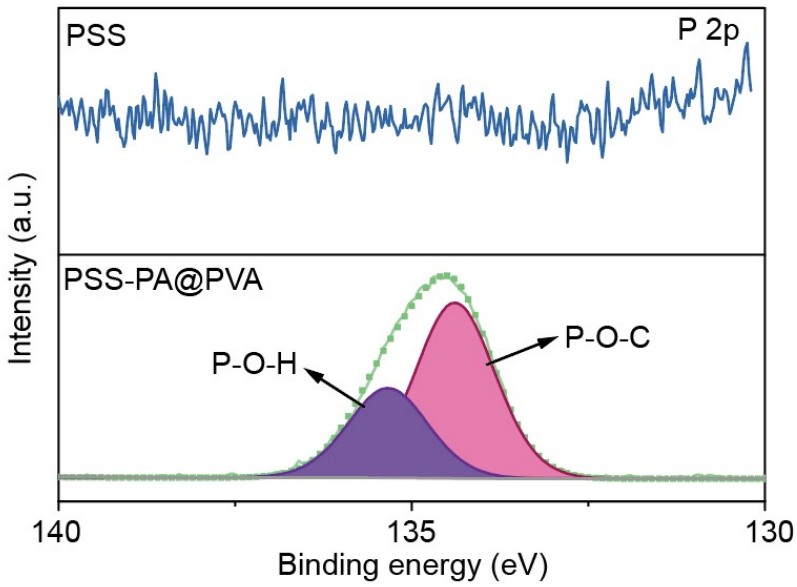


Figure S6. P 2p XPS spectra of PSS and PSS-PA@PVA.

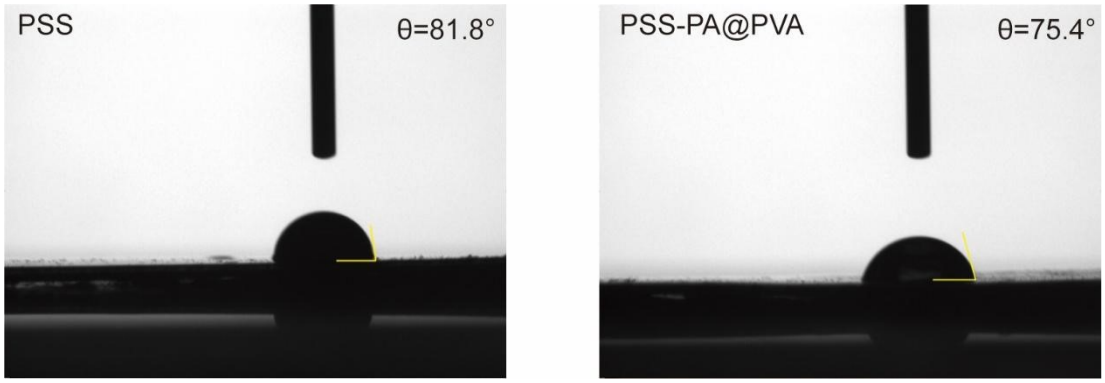
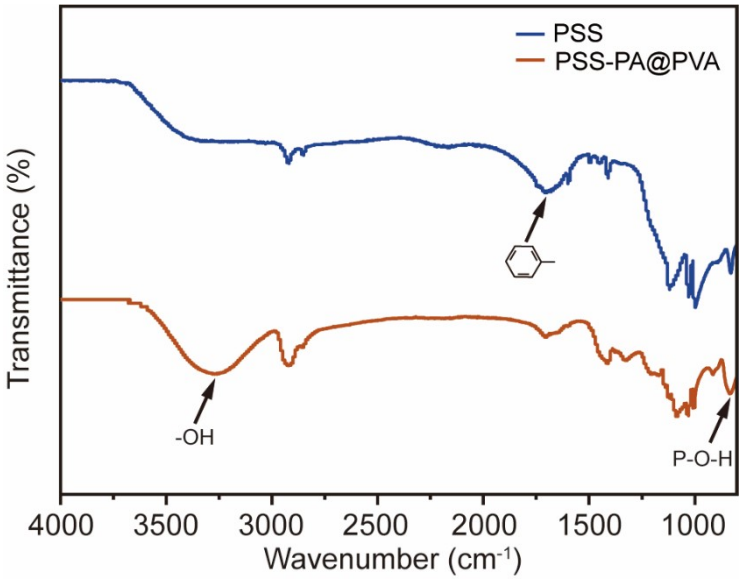


Figure S7. Water contact angles of PSS and PSS-PA@PVA.



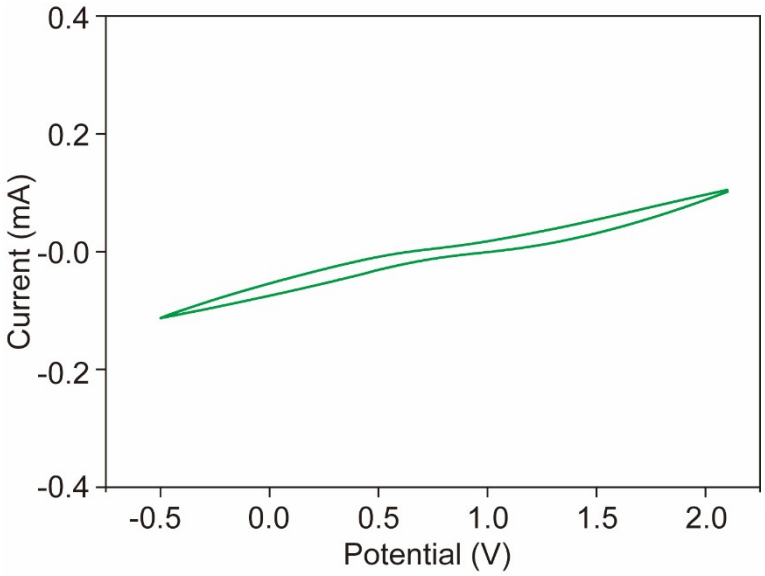


Figure S8. FTIR spectra of PSS and PSS-PA@PVA.

Figure S9. CV test for PSS-PA@PVA between Carbon electrodes.

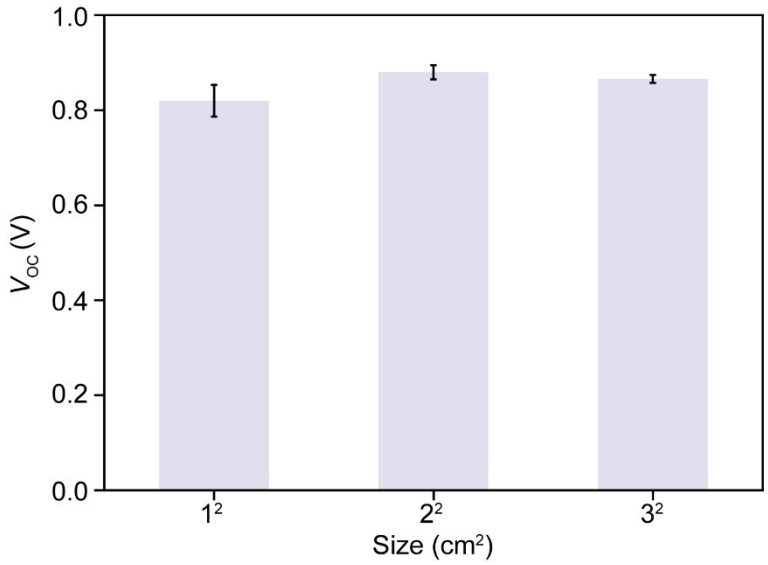


Figure S10. The V_{OC} in different areas.

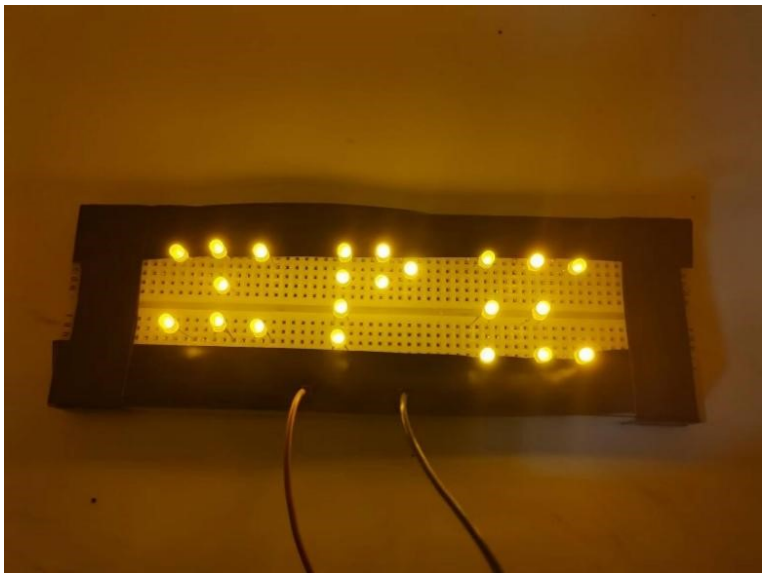


Figure S11. After MEG charges the capacitors, the series-connected LED lights forming letters can be lit directly.

Figure S12. The V_{OC} is generated by the moisture produced from breathing when MEG is attached to a mask.

Supporting Tables

Table S1. Summary of the performance of previously reported MEGs.

Material	Voltage(V)	Power density(μW cm $^{-2}$)	Ref.
PAN-PVP	0.8	0.61	1
CDs+PSS+PVA	0.83	0.6	2
Biofilm	0.45	1	3
Polypyrrole	0.069	0.69	4
Hydrogel	0.65	0.67	5
Textile-PSS	1	0.1	6
Nanofiber film	0.7	0.15	7
Cellulon	0.78	0.7	8
Ionic aerogels	0.12	0.04	9
Nanofiber	0.28	0.08	10
MoS_2	0.8	0.0185	11
Cornstalk	0.56	0.18	12
Geobacter	0.65	1.087	13
PSS-PA@PVA	0.88	1.36	**This work**

Supporting References

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