Supporting Information

Fabrication of Pressure Responsive Energy Device from Nanofluidic Vanadium Pentoxide and Polymeric Hydrogel

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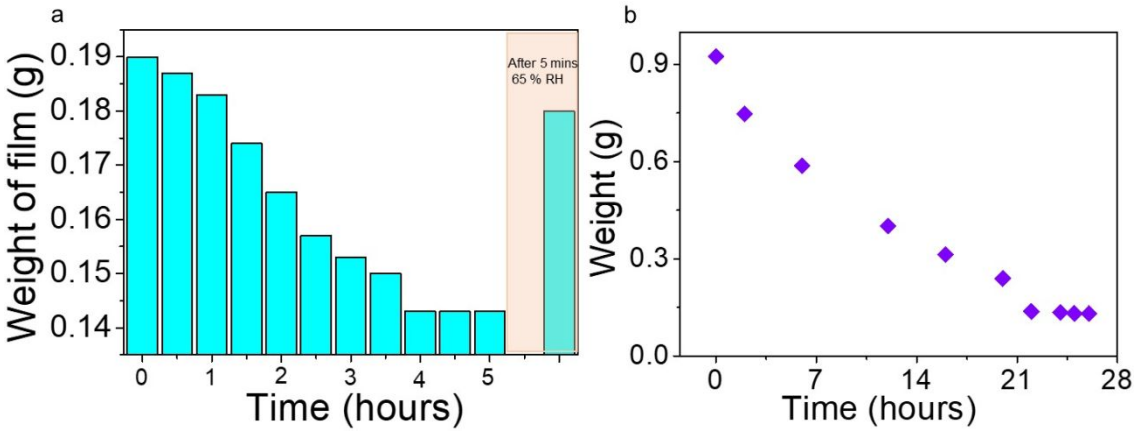

Figure S1: (a) Weight loss of agar membrane at a low humidity of 12 % RH as a function of time followed by recovery at environmental humidity of RH 65 %, (b) Weight loss of agar membrane wrapped in V_2O_5 membrane and Al foil at a low humidity of 12 % RH as a function of time.

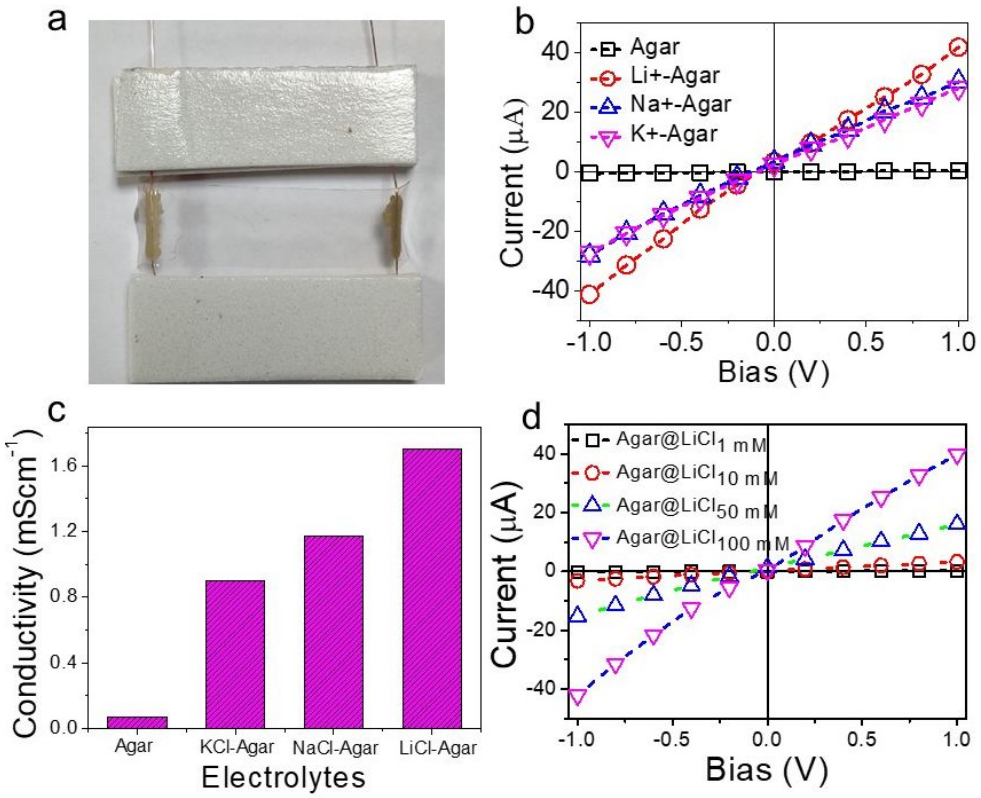

Figure S2: Ionic conductivity of agar gel membranes: (a) Digital photograph of device fabricated to measure the ionic conductivity of agar gel membranes, (b) characteristics I-V curves of agar gel membranes intercalated with different electrolytes, (c) bar diagram showing conductivity of different agar gel electrolytic membranes, and (d) characteristics I-V curves of agar gel membranes intercalated with electrolytes of different concentration.

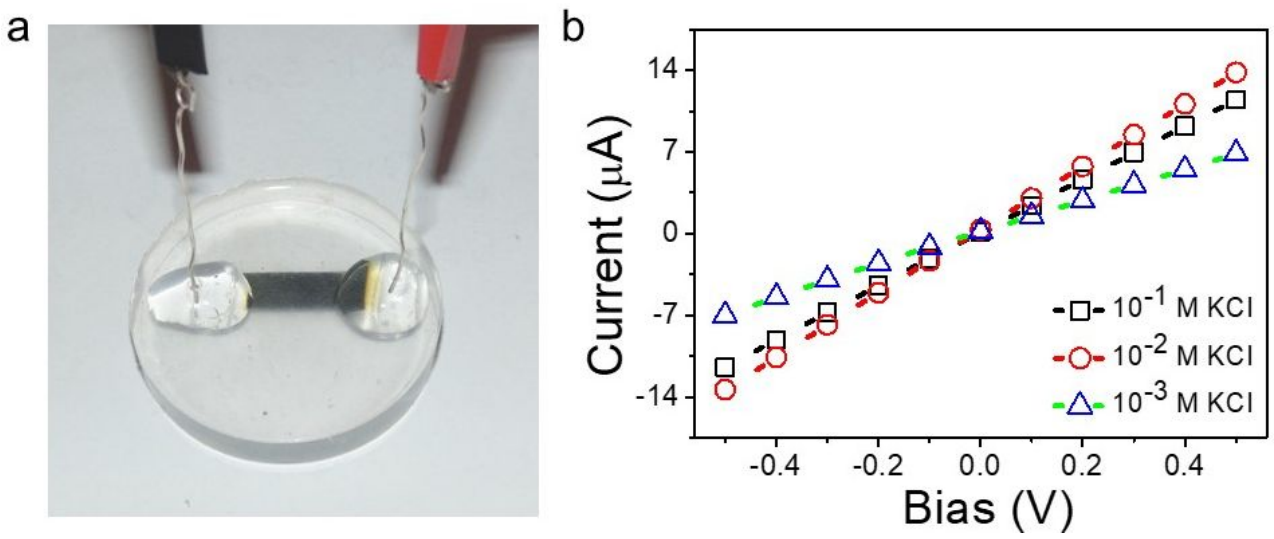

Figure S3: Surface charge governed ionic conductivity: (a) Digital photograph of device, (b) Representative I-V curves recorded with nanofluidic V_2O_5 at different electrolyte concentration.

Nanofluidic device was prepared by encapsulating a rectangular strip of V_2O_5 film into a PDMS (polydimethylsiloxane) elastomer and carving out the edges to form electrolyte chambers. The linear I-V curves recorded for different electrolytes confirm the formation of percolated nanofluidic channels of V_2O_5. Conductivity values at different electrolyte concentration was determined by multiplying the slope of the I-V curves with respective cell constant of the device.

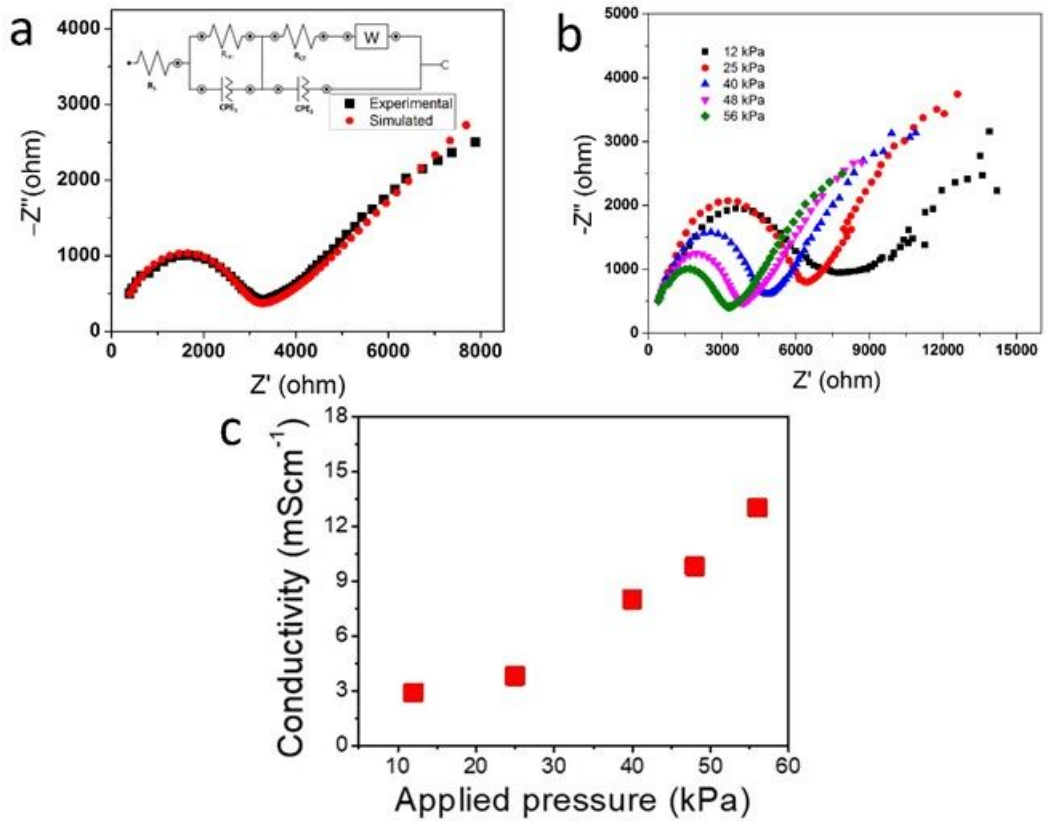

Figure S4: (a) Experimental and simulated EIS of Al-gel@Li+-VO device with the equivalent circuit (inset), (b) Nyquist plot for Al-gel@Li^+-VO device recorded at different applied pressure (c) Conductivity of Al-gel@Li^+-VO device as a function of applied pressure.

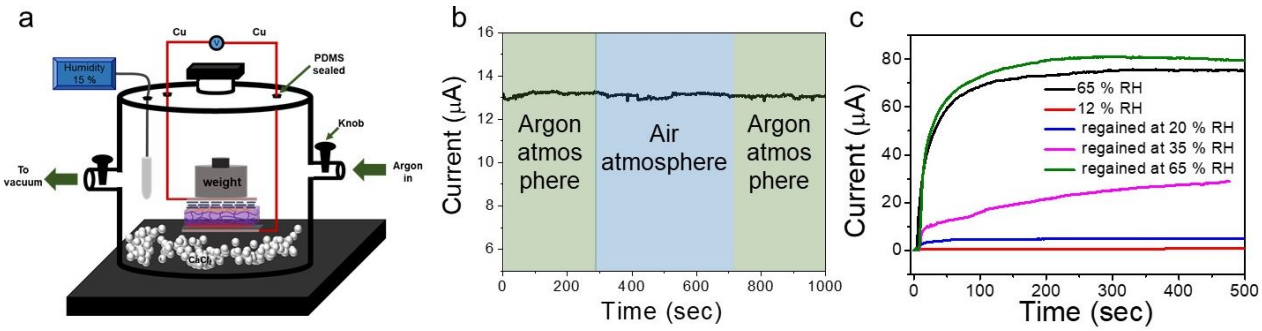

Figure S5: (a) Schematic representation of controlled humidity chamber, (b) Output-current of an Al-gel-VO device in alternating argon and air atmosphere at 15 % relative humidity, and (c) A plot comparing the output-current of an Al-gel-VO devices recorded at different humidity levels.

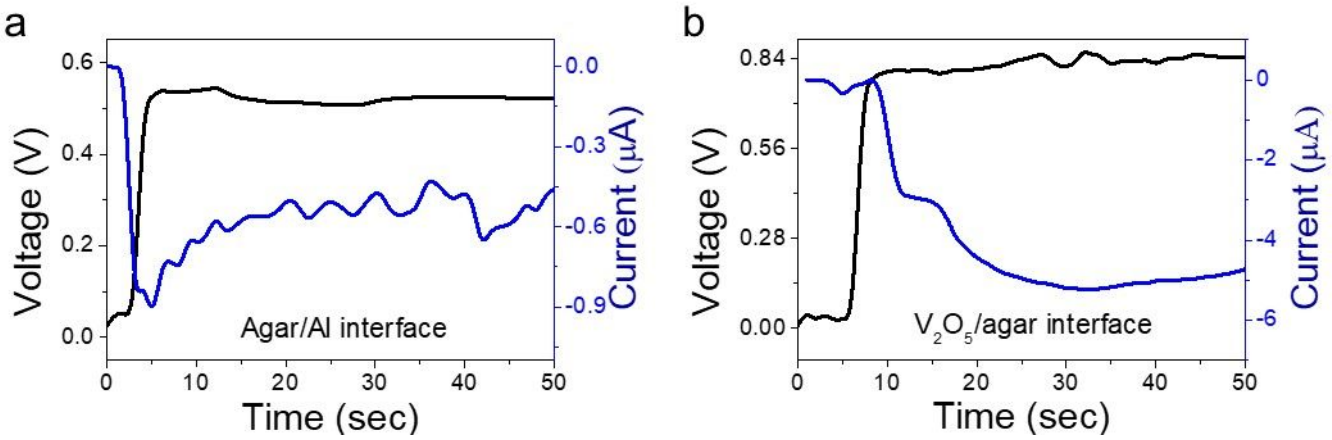

Figure S6: Open circuit voltage and short circuit current generated at the interface of (a) agar and aluminium and (b) V_2O_5 and agar.

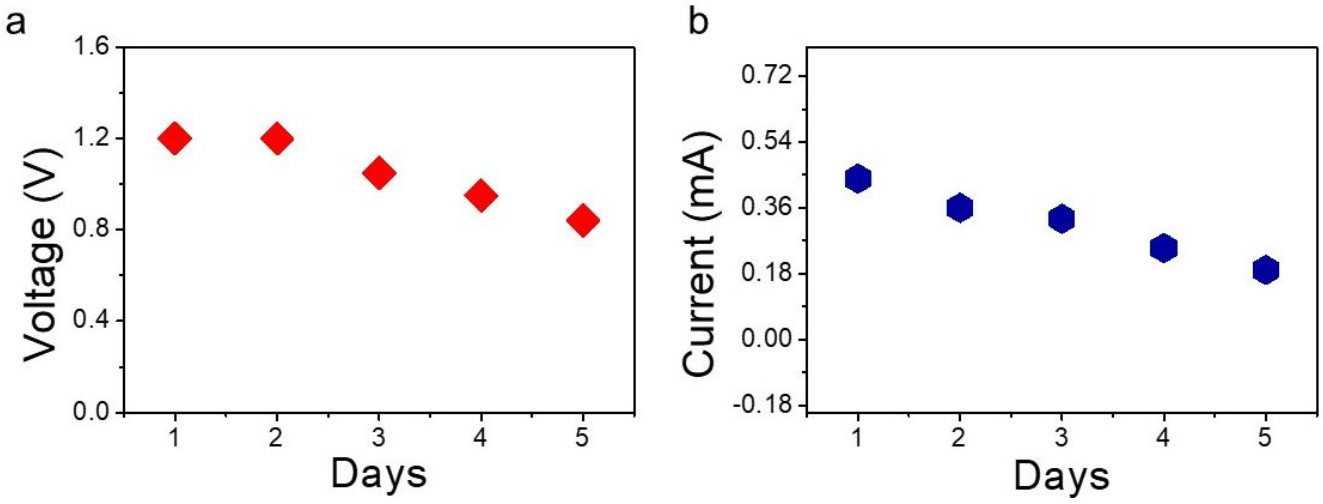

Figure S7: Device stability: (a) Open circuit voltage and (b) short circuit current of Al-agar@Li+-VO device recorded for 5 continuous days in contact mode.

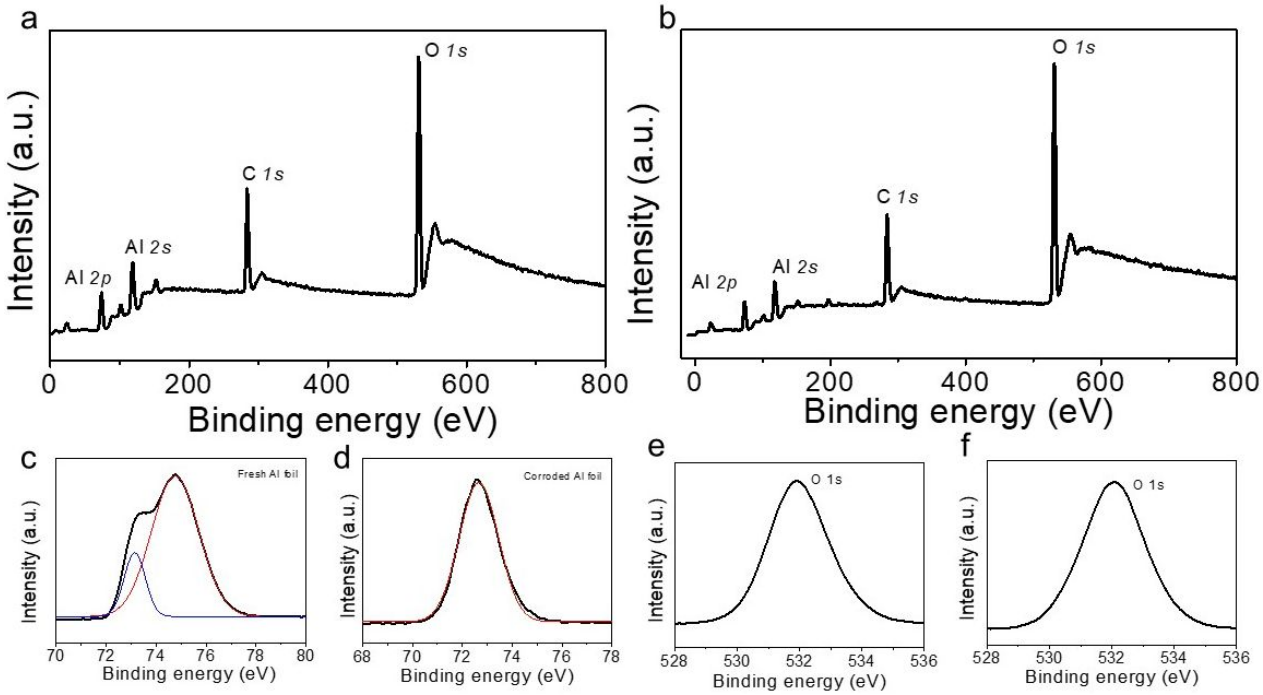

Figure S8: XPS survey scan of Al electrode recorded (a) before and (b) after 5 days of continuous power generation, the presence of carbon along with Al and O is attributed to the absorption of carbon dioxide on the surface. Moreover, the sample was attached the XPS stub with the help of a conductive carbon tape. XPS Al 2p peaks of (c) fresh Al foil and (d) corroded Al foil, XPS peaks of O1s of (e) fresh Al foil and (f) corroded Al foil.

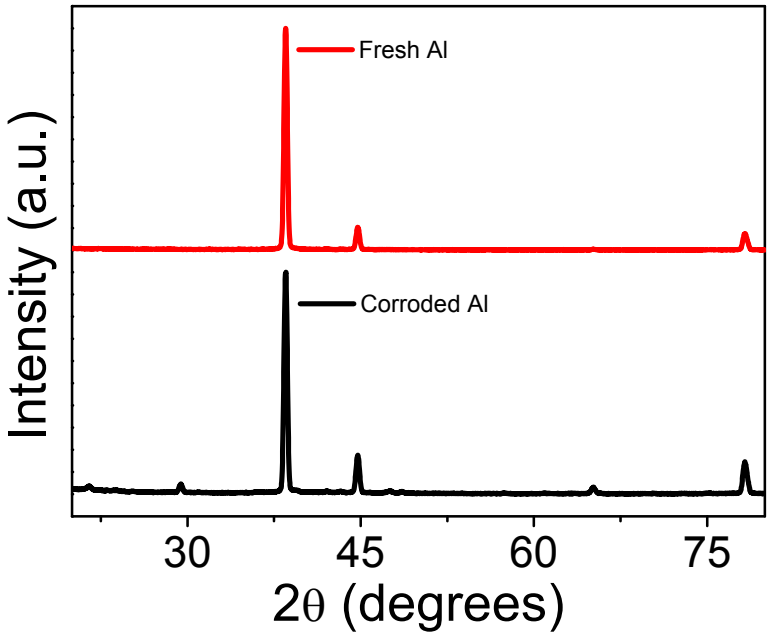

Figure S9: pXRD pattern of the Al foil before and after discharge process.

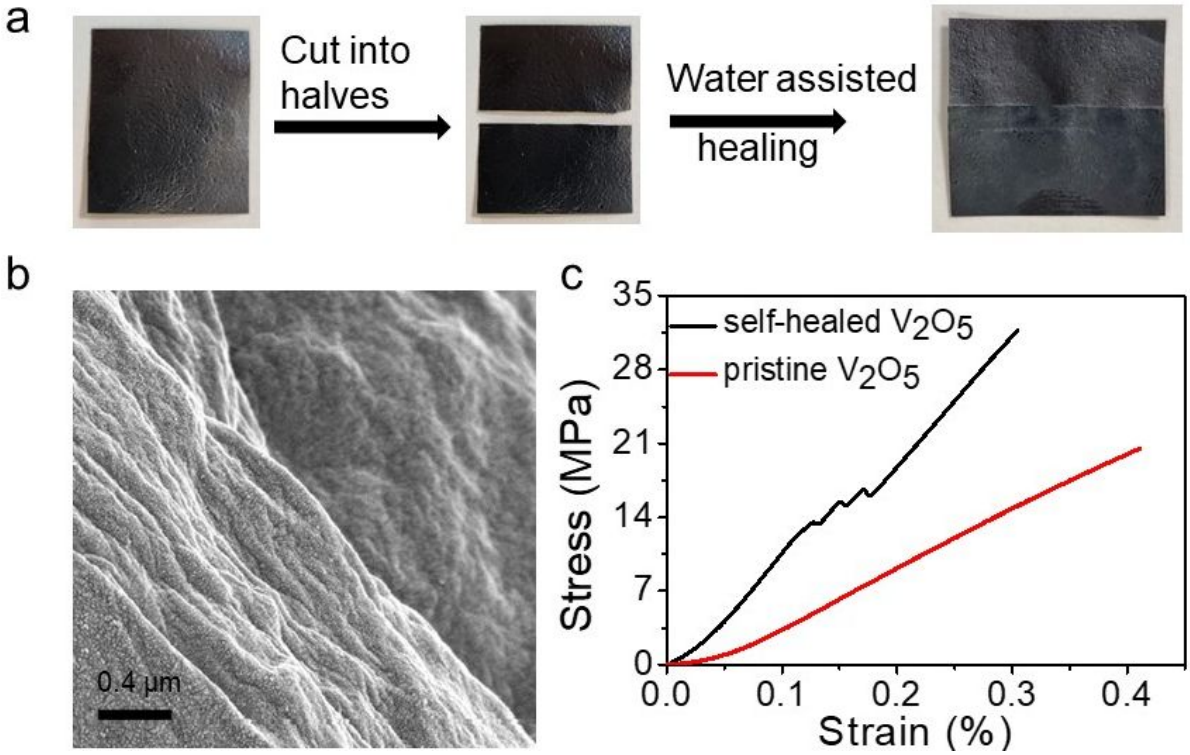

Figure S10: Regeneration energy harvesting devices: (a) Photographs showing water assisted healing of V_2O_5 membrane, (b) Surface FESEM image of self-healed V_2O_5 membrane, (c) comparison of stress-strain curve of self-healed and pristine V_2O_5 membrane.

Self-healing of vanadium pentoxide membranes: A V_2O_5 strip of 1.5 cm × 1.5 cm was cut into two halves with the help of scissors and gently placed upon one another with edges overlapping each other. A water droplet of 20 µL is spread over the overlapping edges and was allowed to dry under ambient conditions. The water droplet evaporates from the surface within 2 hours, thereby assisting water-induced self-repairing of the V_2O_5 strips into a single strip.

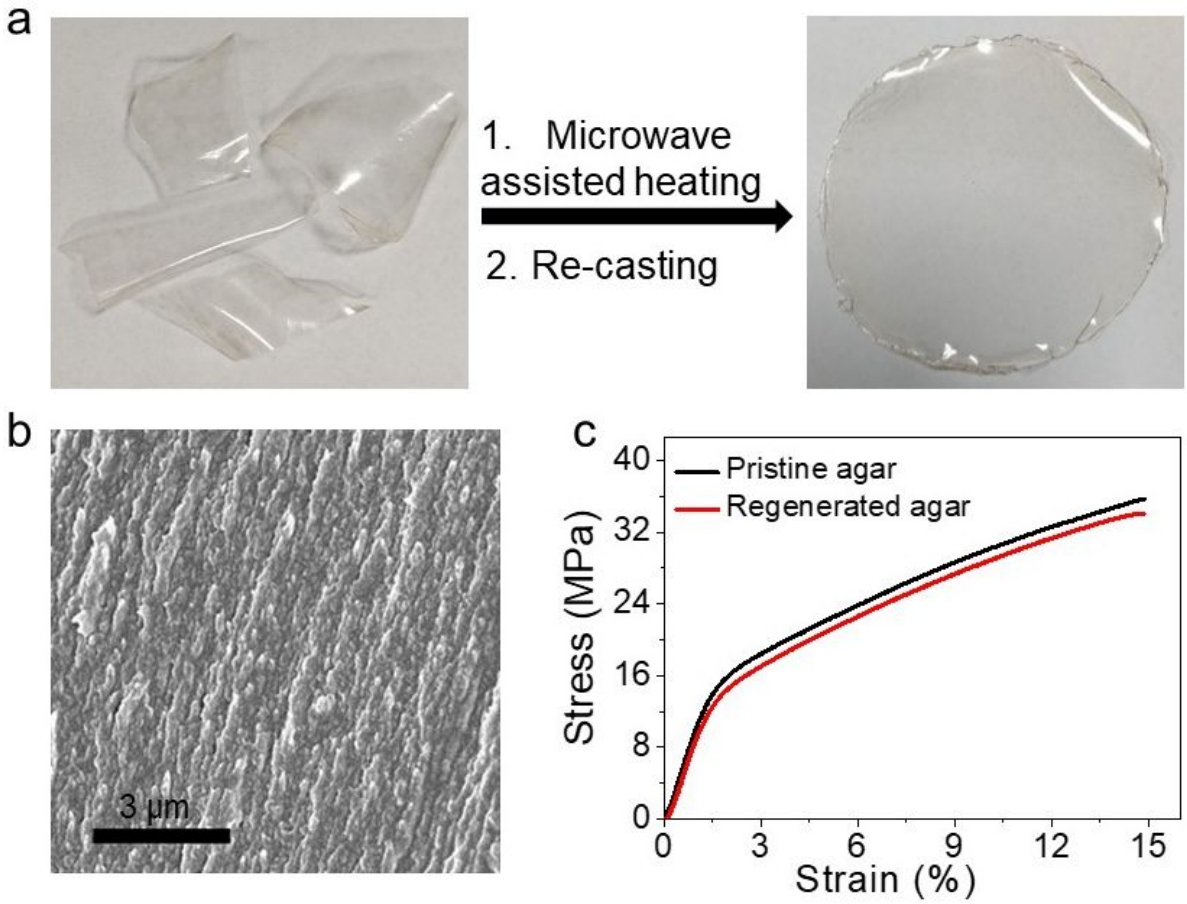

Figure S11: Regeneration energy harvesting devices: (a) Photographs showing recycling of gel membranes, (b) Surface FESEM image of regenerated gel membrane, and (c) comparison of stress-strain curve of regenerated and pristine gel membrane.

Recycling of agar gel membranes: The used pieces of agar gel membranes were easily recycled by simply re-melting and re-casting. For example, broken agar membranes are placed on a Petri dish and microwaved for 2-3 minutes. The microwave assisted heating melts the agar membranes and form a gelatinous solution which is allowed to dry at 50 ° C in a vacuum oven for several hours to obtain free standing gel membranes.

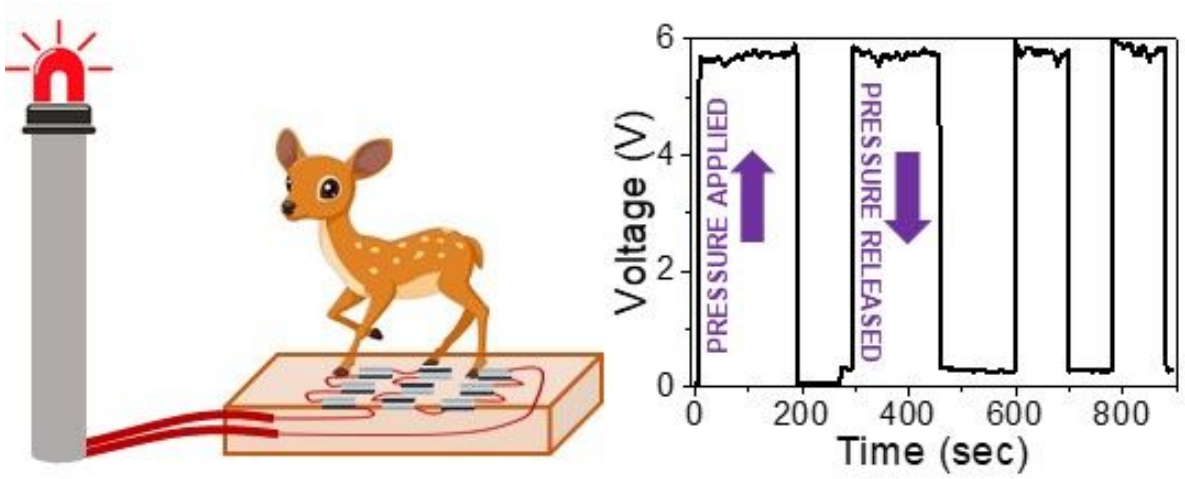

Figure S 12: Application of pressure responsive device: A proof of concept demonstrating an animal sensor

Table S1: A comparison of electrochemical performance of this work with other moisture batteries

Sl. No.	**Materials used**	**OCP (V)**	**Current density**	**Ideal Humidity (RH%)**	**Voltage at lowest humidity (V)**	**Reference**
1	PANI foam/Mg	1.84 V	--	50 - 90 %	~0.23 V at 20 % RH	1
2	Li foil and graphene oxide film	2.7 V	360 μA cm^{-2}	90 %	1 V at 20 % RH	2
3	Mg/Zn anode and PANI coated polyurethane sponge	1.7 V	--	60-100 %	~0.1 V at 20 % RH	3
4	Al-Agar gel-V_2O_5	1.3 V	35 μA cm^{-2}	65 %	1 V at 15 % RH	This work

Reference

1. Xie, P.; Rong, M. Z.; Zhang, M. Q. Moisture Battery Formed by Direct Contact of Magnesium with Foamed Polyaniline. *Angew. Chem. Int. Ed.*, **2016**, *55*, 1805-1809.

2. Ye, M.; Cheng, H.; Gao, J.; Li, C.; Qu, L. A respiration-detective graphene oxide/lithium battery. *J. Mater. Chem. A* **2016**, *4*, 19154-19159.

3. Fang, Z.; Feng, J.; Fu, X.; Li, J.; Hu, X.; Xie, X.; Yu, D. Humidity and Pressure Dual-Responsive Metal−Water Batteries Enabled by Three-In-One All-Polymer Cathodes for Smart Self-Powered Systems. *ACS Appl. Mater. Interfaces* **2020**, *12*, 23853-23859.