Supplementary Information (SI) for Sustainable Energy & Fuels.


# Supporting Information

# Moisture-Induced Ionovoltaic Electricity Generation Using Lead Free 2-Diamensional $Cs_3SbBiBr_9$ Perovskite

*Ashna K. Pramod* [a, b], *Sudip K. Batabyal* [a, b*]

[a] *Department of Physics, Amrita School of Physical Sciences, Coimbatore, Amrita Vishwa Vidyapeetham, India*

[b] *Amrita Center for Industrial Research & Innovation (ACIRI), Amrita School of Engineering, Coimbatore, Amrita Vishwa Vidyapeetham, India.*

***Corresponding Author Email:*** *s_batabyal@cb.amrita.edu

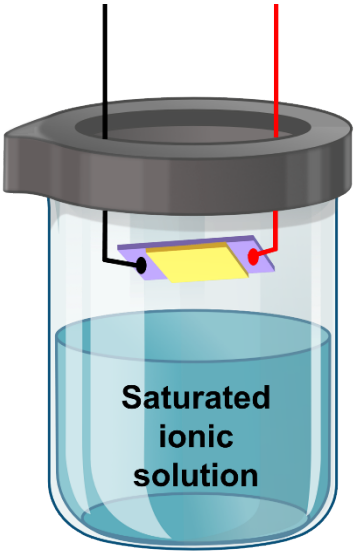


**Fig.S1: Schematic representation of $Cs_3SbBiBr_9$ ionovoltaic device measurement setup**

**Table 1. Calculated lattice parameters of the lead-free perovskite powders $Cs_3Sb_2Br_9$, $Cs_3Bi_2Br_9$ and $Cs_3SbBiBr_9$**

| Perovskite | Lattice parameters | | | | | |
|---|---|---|---|---|---|---|
| | Theoretical (Å) | | | Experimental (Å) | | |
| | a | b | c | a | b | c |
| $Cs_3Bi_2Br_9$ | 7.97 | 7.97 | 9.86 | 8.03 | 8.03 | 9.67 |
| $Cs_3Sb_2Br_9$ | 7.93 | 7.93 | 9.71 | 7.92 | 7.92 | 9.74 |

| | | | | | | |
|---|---|---|---|---|---|---|
| $Cs_3SbBiBr_9$ | 7.93 | 7.93 | 9.71 | 7.91 | 7.90 | 9.73 |

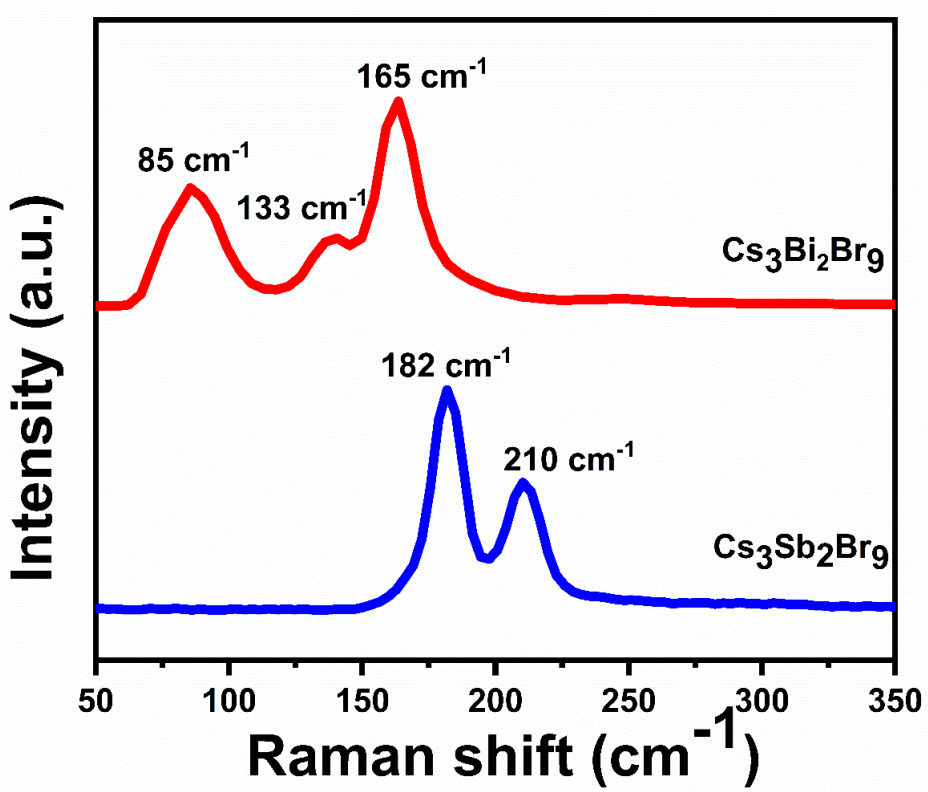


**Fig.S2: Raman spectra of $Cs_3Sb_2Br_9$ and $Cs_3Bi_2Br_9$**

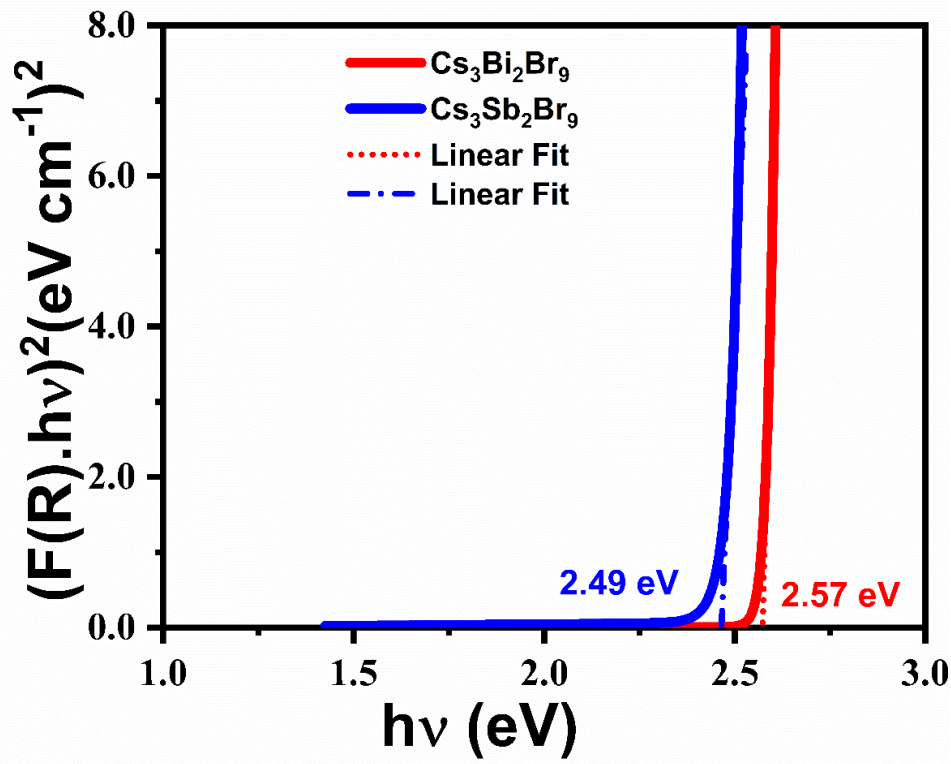

**Fig.S3: Band gap of $Cs_3Sb_2Br_9$ and $Cs_3Bi_2Br_9$**

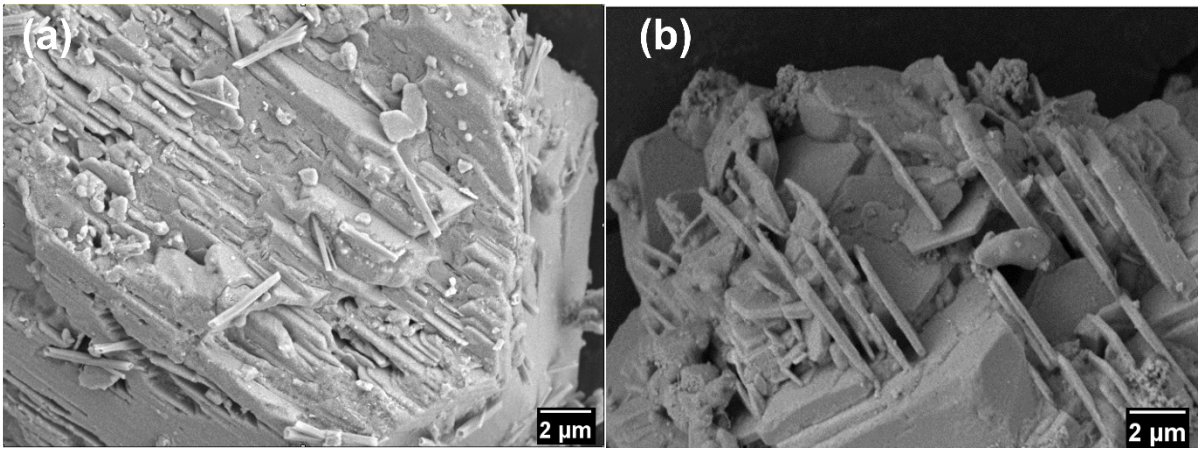


**Fig.S4: SEM image of pristine $Cs_3SbBiBr_9$ thick blocks with layered structure**

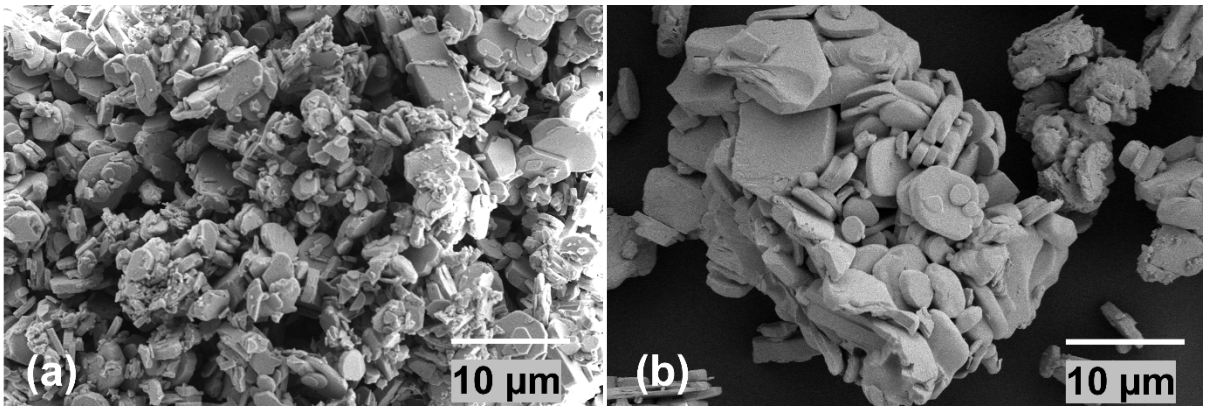


**Fig.S5: (a) SEM image of lead -free perovskite $Cs_3Sb_2Br_9$ powder; (b) SEM image of lead -free perovskite $Cs_3Bi_2Br_9$ powder hexagonal morphology**

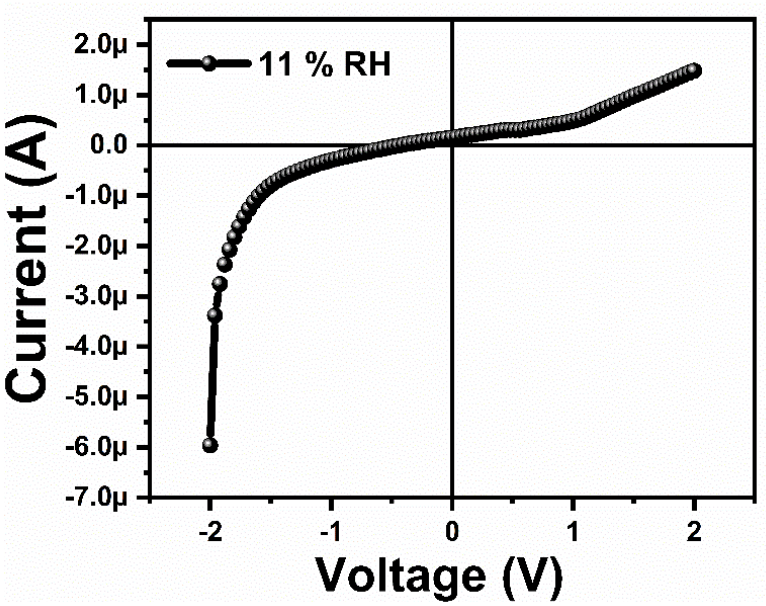


**Fig.S6: Zoomed in view of the I-V curve at11 % RH**

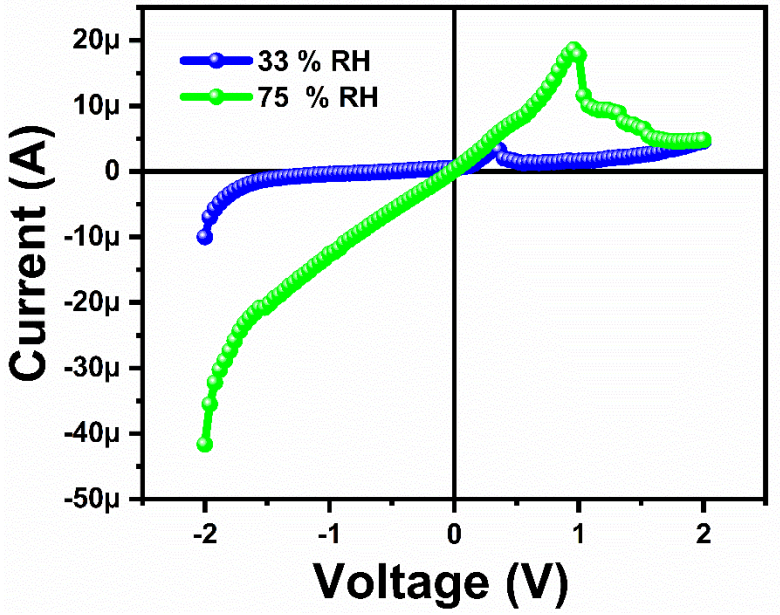


**Fig.S7: Current-voltage curves measured at 33 % and 75 % RH**

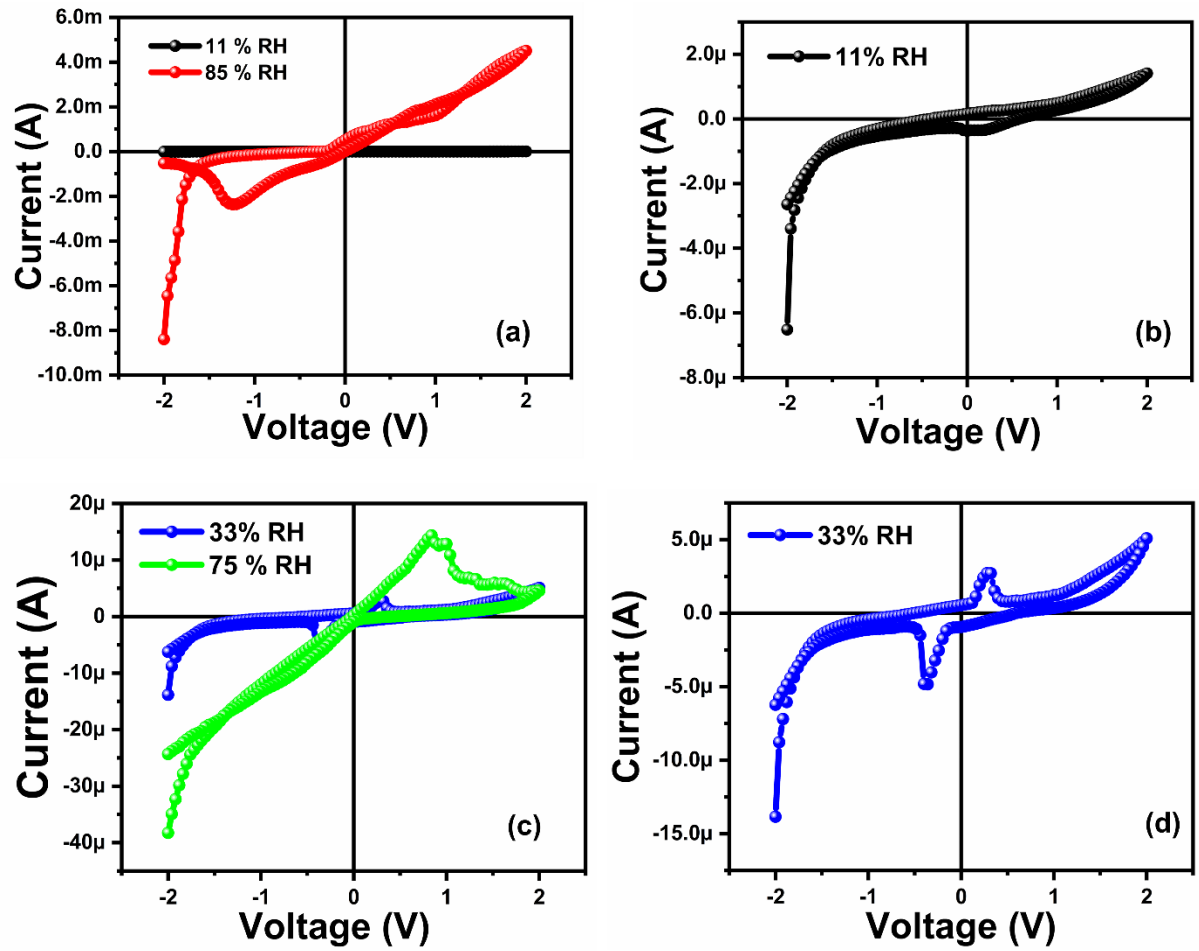


**Fig.S8: I-V loop demonstrating energy storage behavior;(a) I-V loop at 11and 85% RH; (b) Zoomed in view of the I-V loop curve at 11 % RH;(c) I-V loop at 33 and 75% RH; (b) Zoomed in view of the I-V loop curve at 33 % RH**

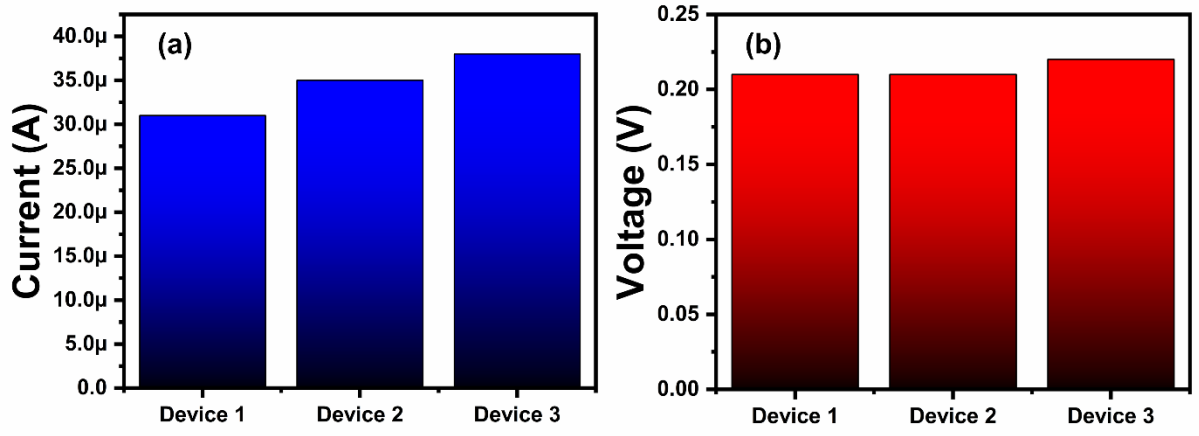


**Fig.S9: Statistical data for three ionovoltaic devices**

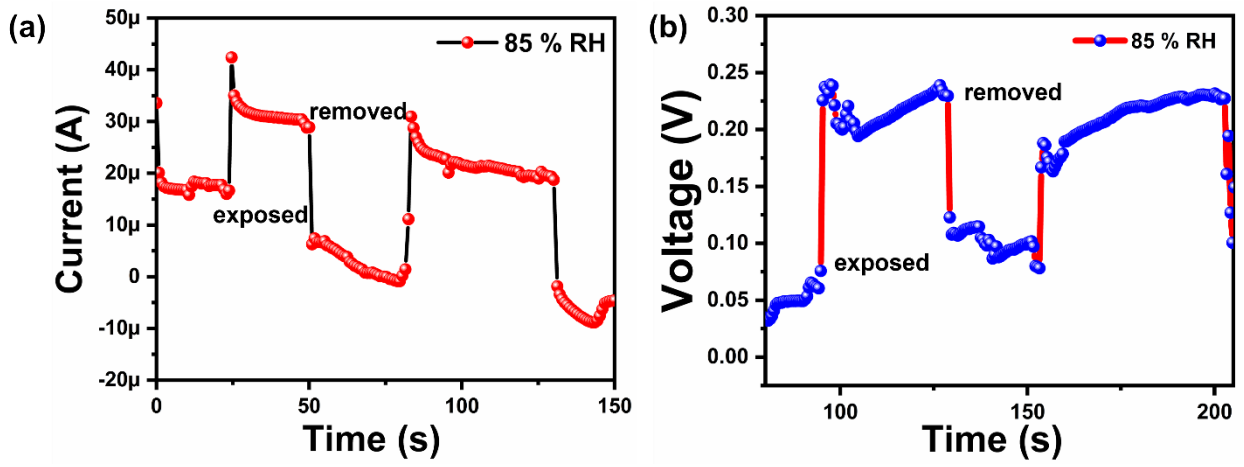


**Fig.S10: (a) Current output was measured during sequential exposure and removal from the 85% RH;(b) Voltage output was measured during sequential exposure and removal from the 85% RH**

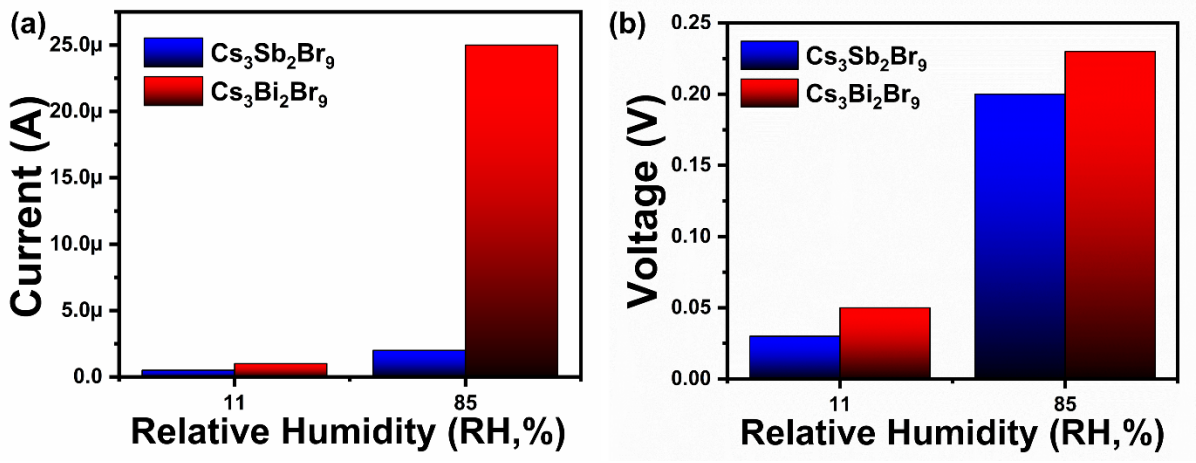


**Fig.S11: I-t and V-t measurement of the $Cs_3Sb_2Br_9$ and $Cs_3Bi_2Br_9$ ionovoltaic device exposed to varying level of relative humidity**

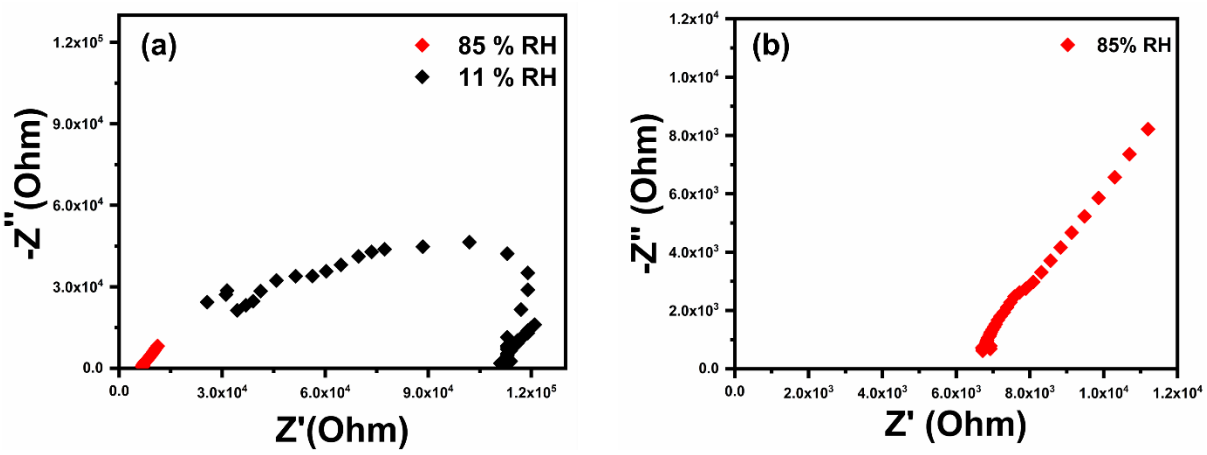


**Fig.S12: (a) presents the Nyquist plots obtained for the ionovoltaic device when subjected to relative humidity level of 11% and 85%; (b) Zoomed image of 85 % RH**

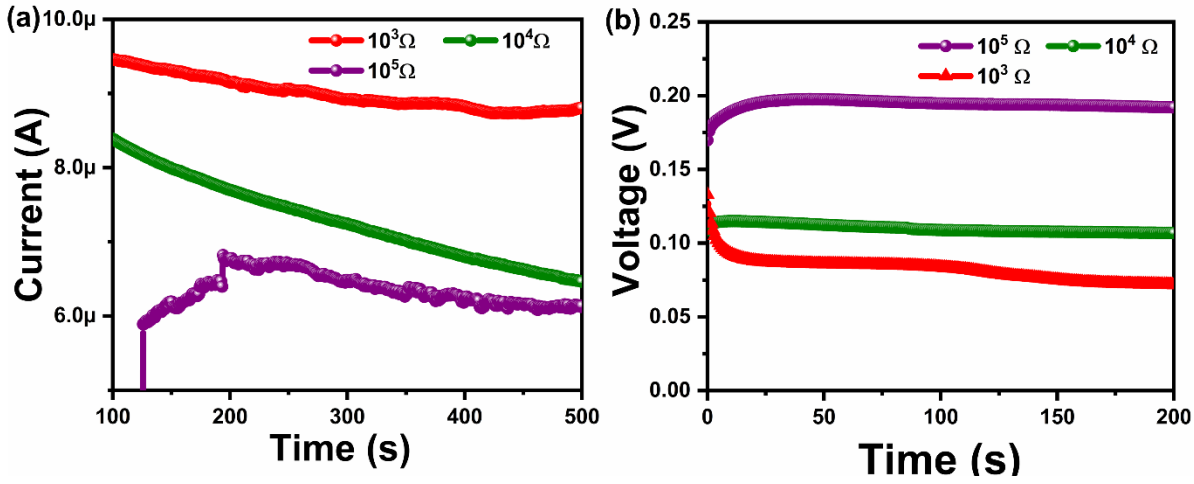


**Fig.S13: (a) I-t measurement showing varying resistances; (b) V-t measurement illustrating varying resistances**

**Table 2: Power density calculation at 85% RH with varying resistance**

| Resistance | $I_{sc}$ (A) | $V_{oc}$ (V) | Area (1.5 cm×0.2cm=0.3cm$^2$) | Current density J=I/A (μA/cm$^2$) | Power density (μW/cm$^2$) |
|---|---|---|---|---|---|
| $10^3$ | $9.5\times10^{-6}$ | 0.08 | 0.3 | 31 | 2.53 |
| $10^4$ | $6.3\times10^{-6}$ | 0.108 | 0.3 | 21 | 2.31 |
| $10^5$ | $6.1\times10^{-6}$ | 0.2 | 0.3 | 20 | 4.09 |

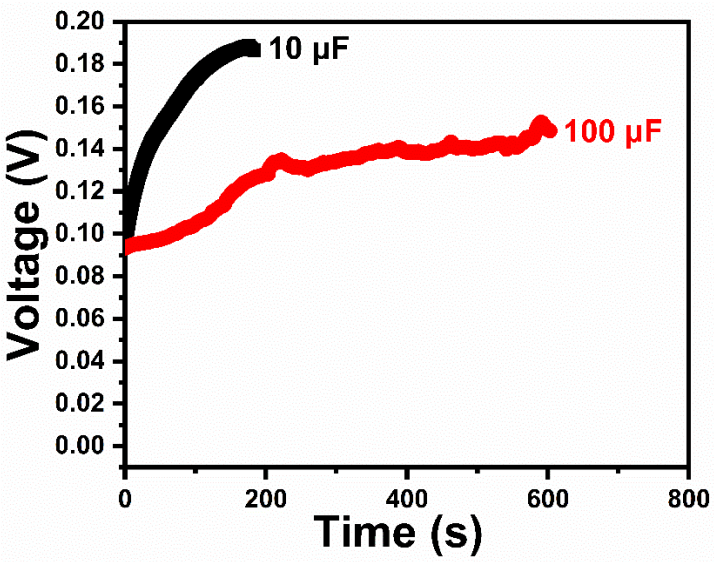


**Fig.S14: Illustrates the charging behavior of capacitors with capacitances of 10 µF and 100 µF using single ionovoltaic devices in an environment with 75% RH**