Supplementary Information

Lead-free halide perovskites for high-performance thin-film flexible supercapacitor application

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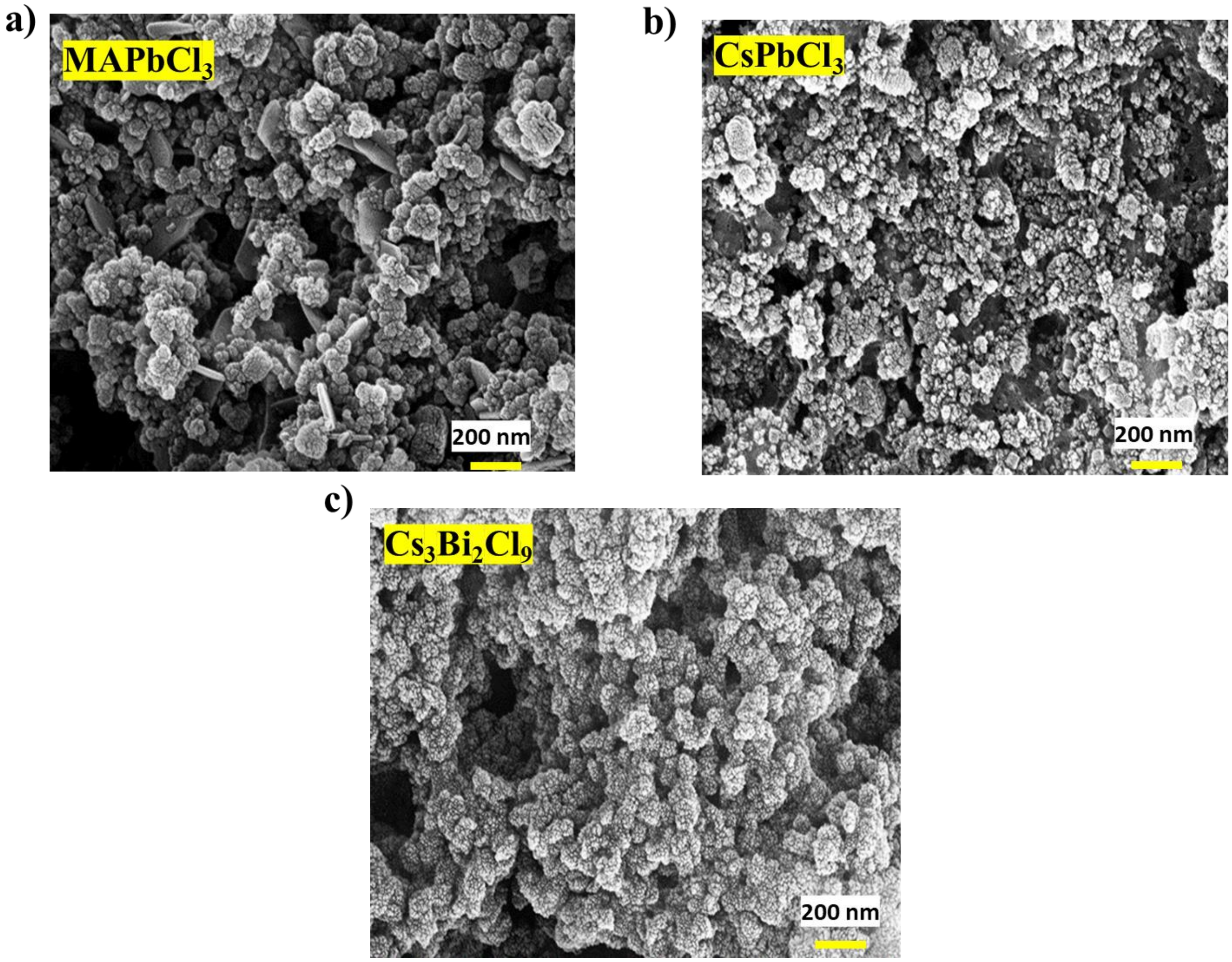

Figure S1: FeSEM Image of synthesized powder a) $MAPbCl_3$ b) $CsPbCl_3$ c) $Cs_3Bi_2Cl_9$

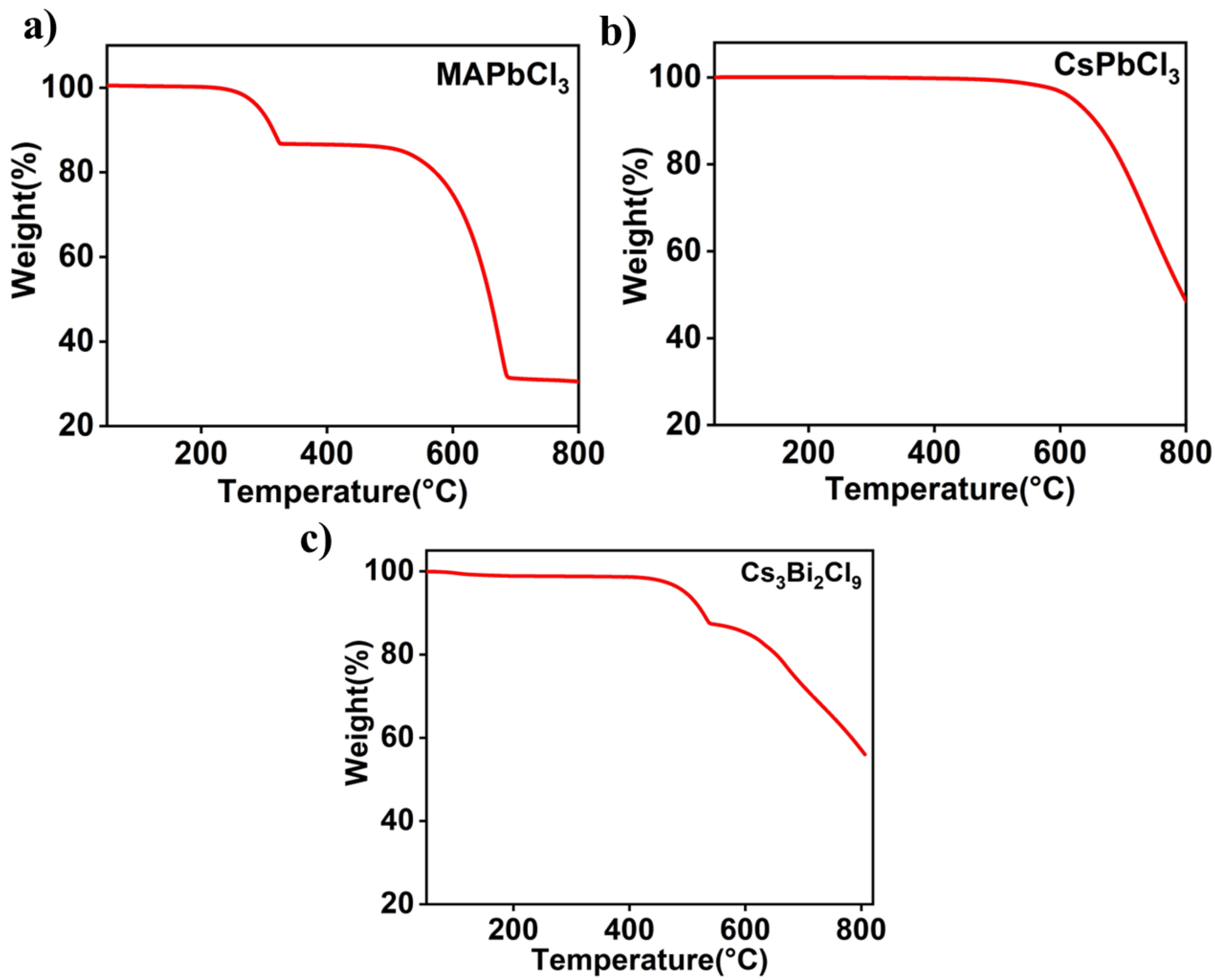

Figure S2: Thermogravimetric Analysis (TGA) curve of a) $MAPbCl_3$ b) $CsPbCl_3$ c) $Cs_3Bi_2Cl_9$

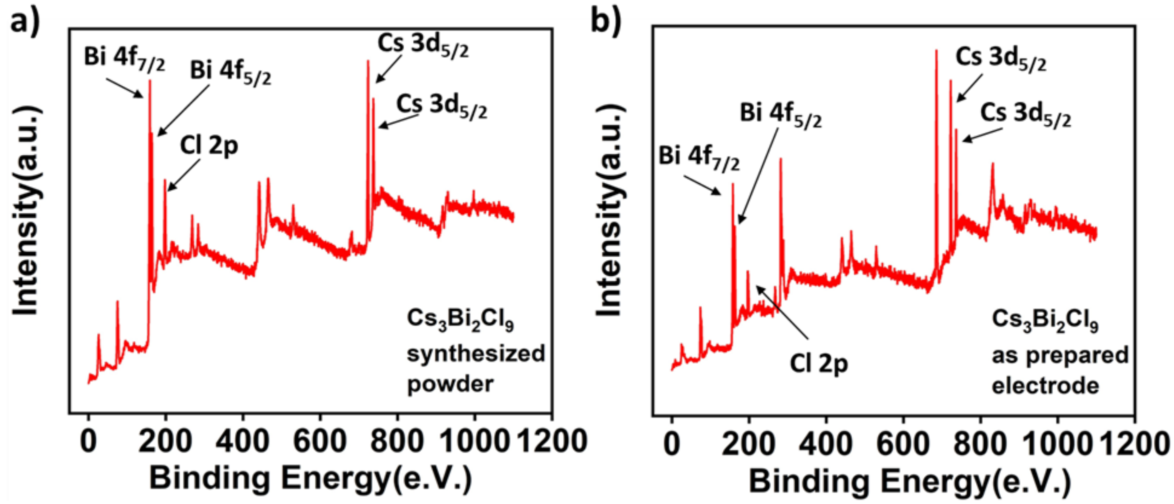

Figure S3: Full scan XPS spectra a) $Cs_3Bi_2Cl_9$ synthesized powder b) $Cs_3Bi_2Cl_9$ as prepared electrode

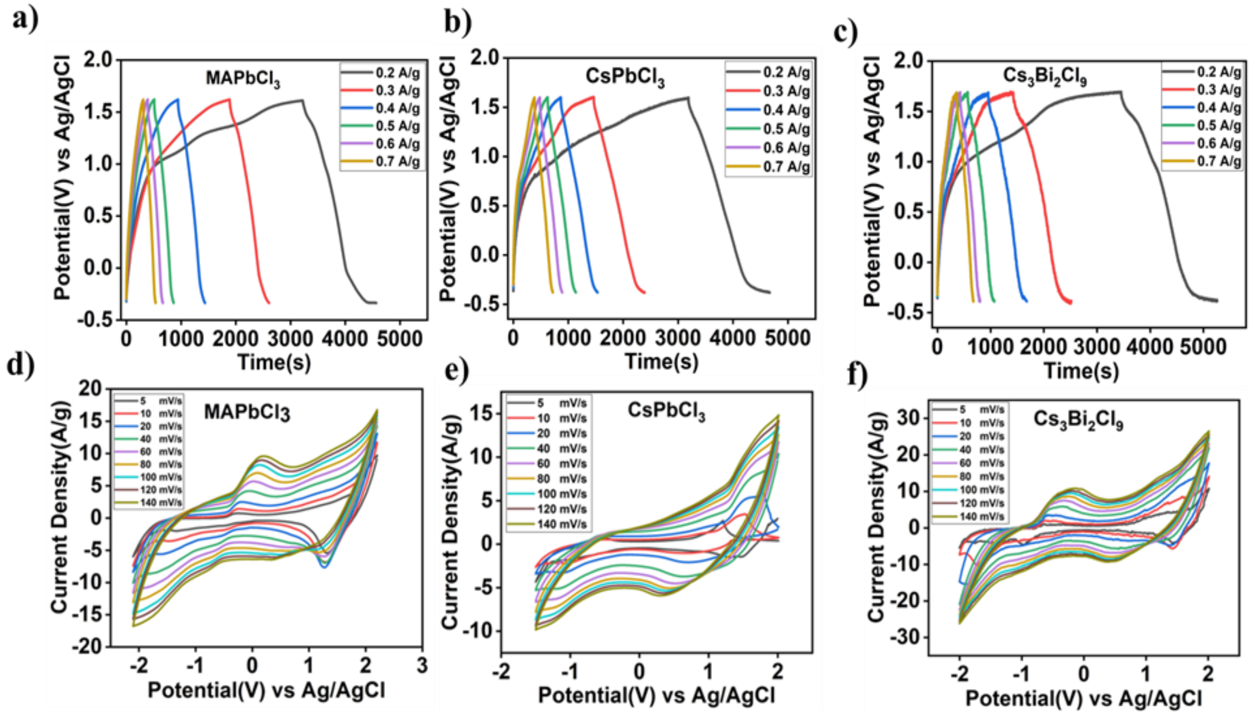

Figure S4: Galvanometric Charge Discharge (current density range- 0.2 A/g to 0.7 A/g) and Cyclic Voltammetry curve (scan rate range- 5 mV/s to 140 mV/s) in three electrode system for a,d) $MAPbCl_3$ b,e) $CsPbCl_3$ c,f) $Cs_3Bi_2Cl_9$ electrodes

Calculation

The **specific capacitance, energy density and power density** can be calculated from the GCD curved by the following relations:

$$\text{Specific Capacitance, Cs (F/g)} = I \int V \cdot dt / mV^2 \qquad \text{S1}$$

$$\text{Energy Density (Wh/kg), E} = C_s(\Delta V)^2 / 7.2 \qquad \text{S2}$$

$$\text{Power Density (W/kg), P} = E \times 3600/t \qquad \text{S3}$$

Here, I is the current (A), V is the potential window (Volt), m is mass of active material (g), and t is the discharging time.

In case of CV following relation can be used to calculate the specific capacitance:

$$\text{Cs(F/g)} = \text{A''}/\text{m}^* \text{ s}^* \Delta V \qquad \text{S4}$$

Where A" is the area under CV curve, s is the scan rate(mV/s) and ΔV is the voltage window.

In case of two electrode system, the areal capacitance (mF/cm^2) areal energy density (Wh/cm^2) and power density (W/cm^2) can be calculated from following relations:

$$\text{Areal Capacitance, } C_A\ (mF/cm^2) = I \int V \cdot dt / A.\, V^2 \qquad \text{S5}$$

$$\text{Areal Energy density, } E_A\ (Wh/cm^2) = C_A (\Delta V)^2 / 7200 \qquad \text{S6}$$

$$\text{Areal Power density, } P_A\ (W/cm2) = E_A / t \qquad \text{S7}$$

Where A is active electrode area and t is discharging time in hours

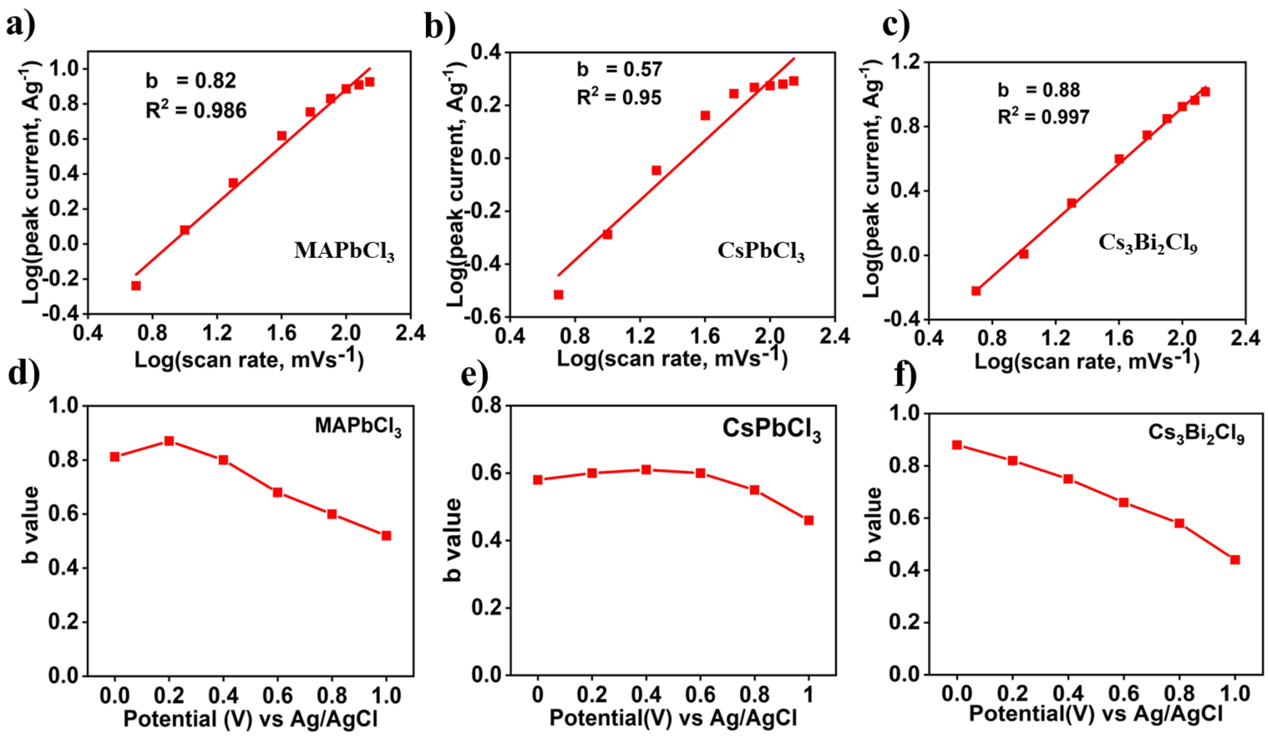

Figure S5: Graph between log peak current v/s log scan rate for b value and variation of b value with applied bias a, d) $MAPbCl_3$ b,e) $CsPbCl_3$ c,f) $Cs_3Bi_2Cl_9$ (CV scan rate range- 5mV/s to 100 mV/s)

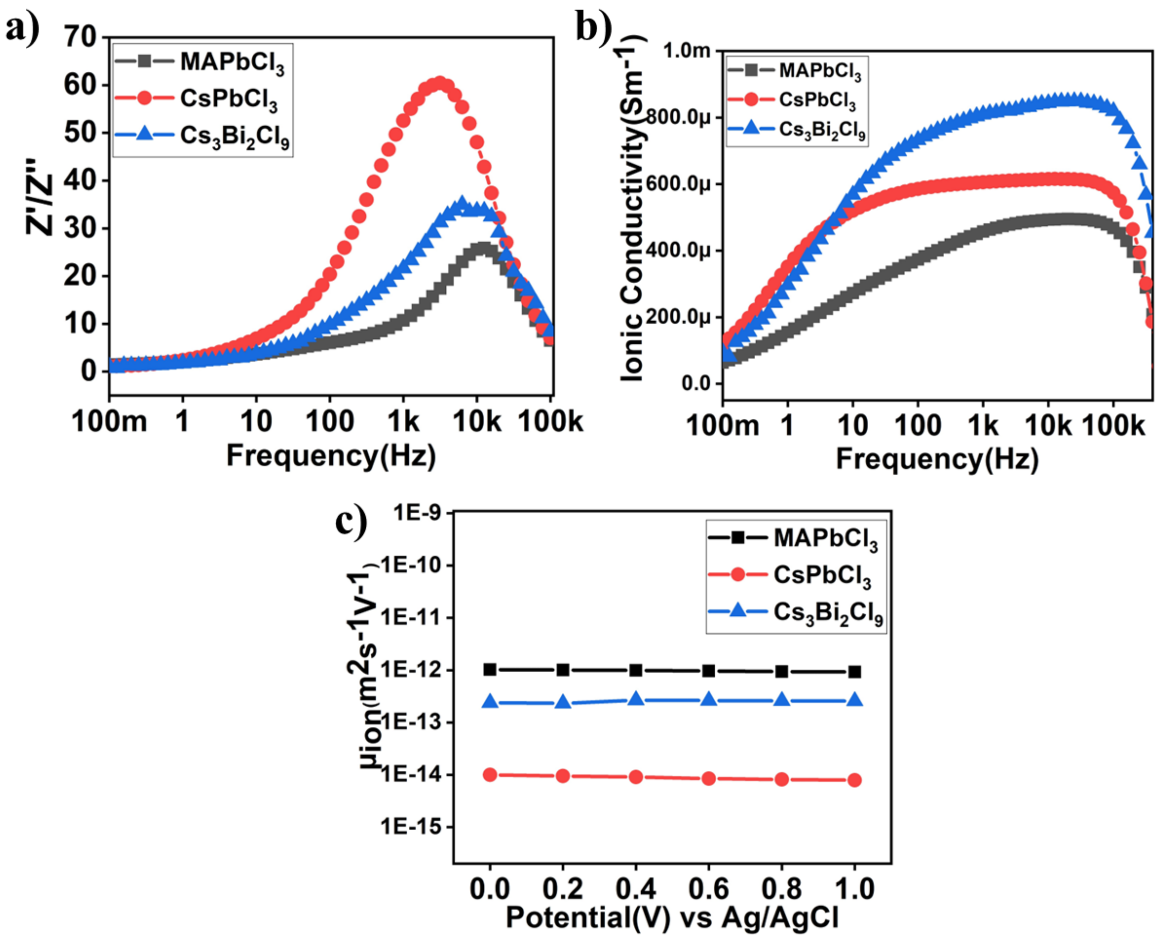

Figure S6: a) Tangent loss plots b) Variation of Ionic mobility with voltage c) Ionic conductivity variation with frequency (Frequency range- 100 mHz to 100 kHz)

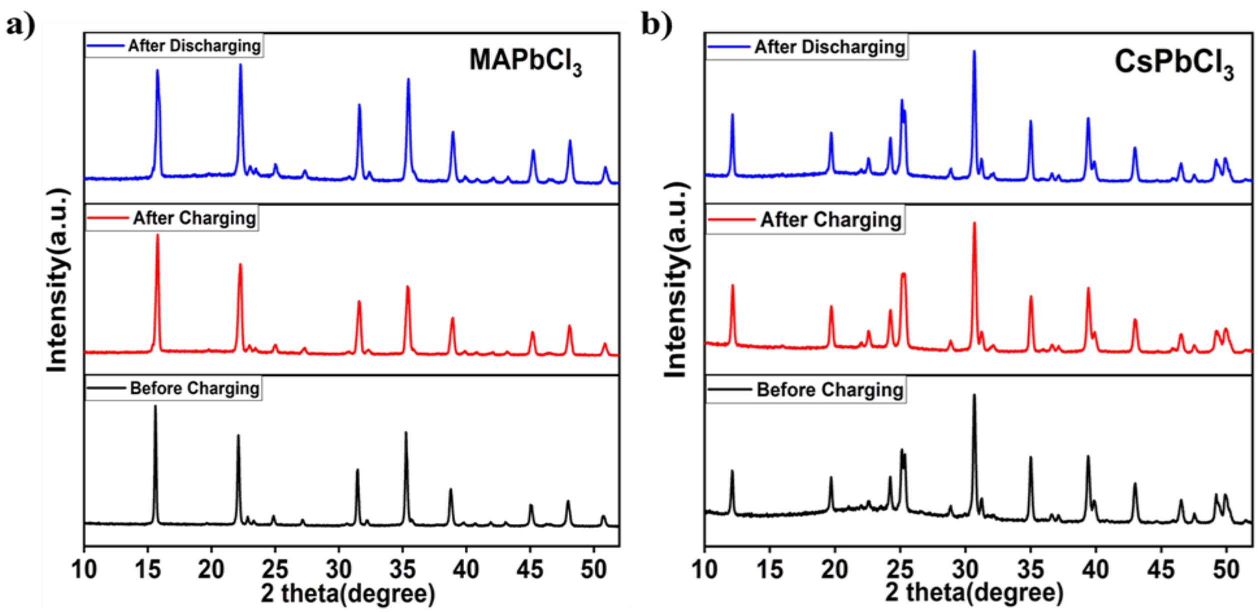

Fig. S7: Ex situ XRD of a) $MAPbCl_3$ b) $CsPbCl_3$

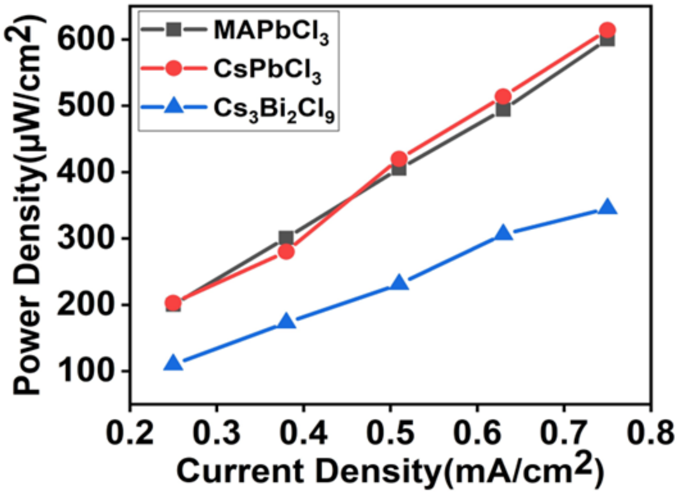

Fig. S8: Power density variation of various perovskite-based supercapacitor devices

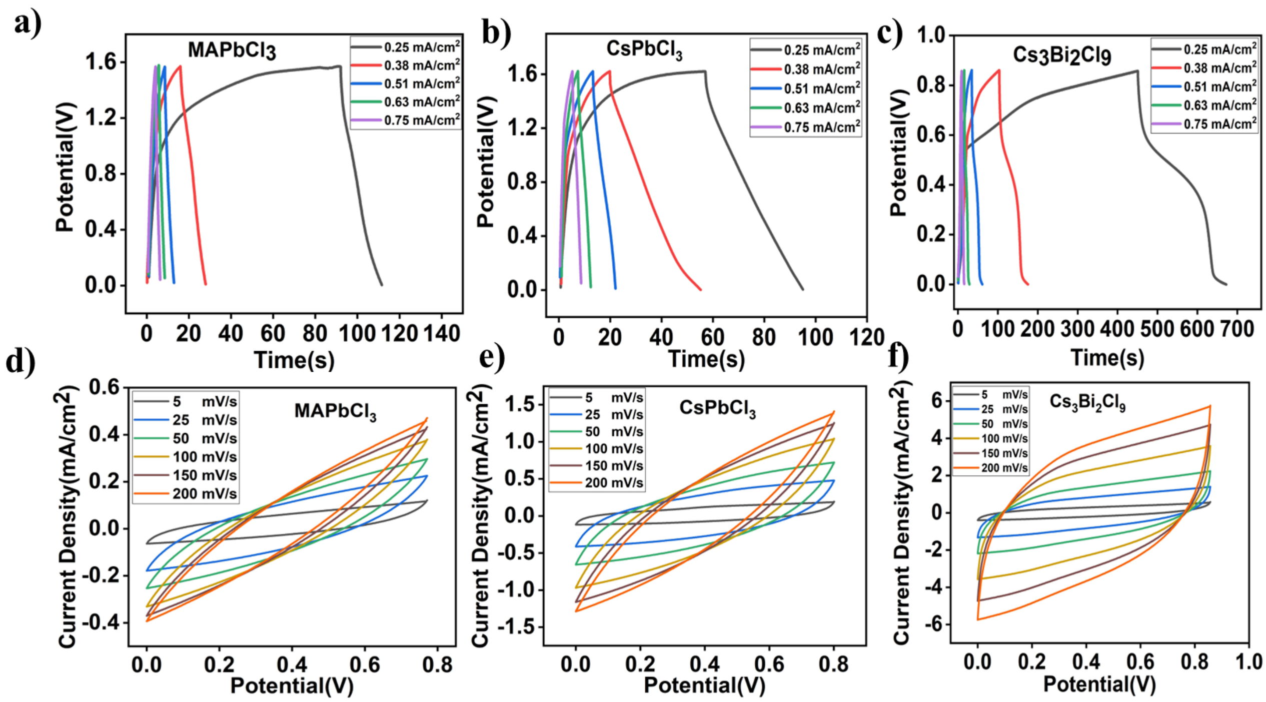

Figure S9: Galvanometric Charge Discharge curve (current density range- 0.25 A/g to 0.75 A/g) and CV curve (scan rate range- 5 mV/s to 200 mV/s) a, d) $MAPbCl_3$ b, e) $CsPbCl_3$ c,f) $Cs_3Bi_2Cl_9$

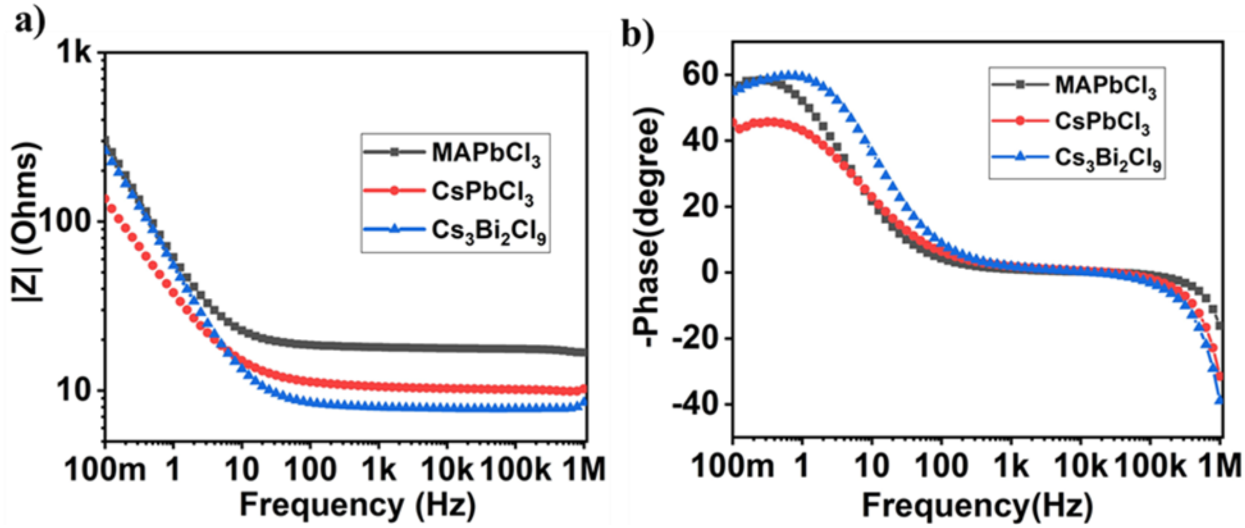

Figure S10: a) Bode magnitude b) Bode phase plot of various supercapacitor devices

Table S1: Fitting Parameters (linear fitting) for bending angles (Linear stage)

Model	**Linear**
Equation	**y = a+ b*x**
Weight	**No weighing**
Intercept	**99.64143±0.40**
Slope	**-0.03948± 0.004**
Residual Sum of Square	**1.422257**
Pearson's r	**-0.97895**
R-Square (COD)	**0.95834**
Adj. R-Square	**0.94793**

Table S2: **Fitting Parameters (exponential fit) for bending cycles (Linear Stage)**

Model	**Exponential**
Equation	**y = y0 + A1*exp(R0*x)**
y0	**89.58732 ± 0.56123**
A	**10.2067 ± 0.77066**
R0	**-0.03267 ± 0.00662**
Reduced Chi-Sqr	**0.47955**
R-Square (COD)	**0.98321**
Adj. R-Square	**0.97201**

Table S3: Fitting Parameters (linear fitting) for twisting angles (Angular Stage)

Model	Linear
Equation	y = a+ b*x
Weight	No weighing
Intercept	100.58±0.60465
Slope	-0.11067± 0.008
Residual Sum of Square	1.828
Pearson's r	-0.99181
R-Square (COD)	0.98369
Adj. R-Square	0.97825

Table S4: **Fitting Parameters (exponential fit) for twisting cycles (Angular stage)**

Model	Exponential
Equation	y = y0 + A1*exp(R0*x)
y0	82.10863 ± 1.84842
A	16.80643 ± 1.75487
R0	-0.01311 ± 0.00369
Reduced Chi-Sqr	1.15311
R-Square (COD)	0.98173
Adj. R-Square	0.96954

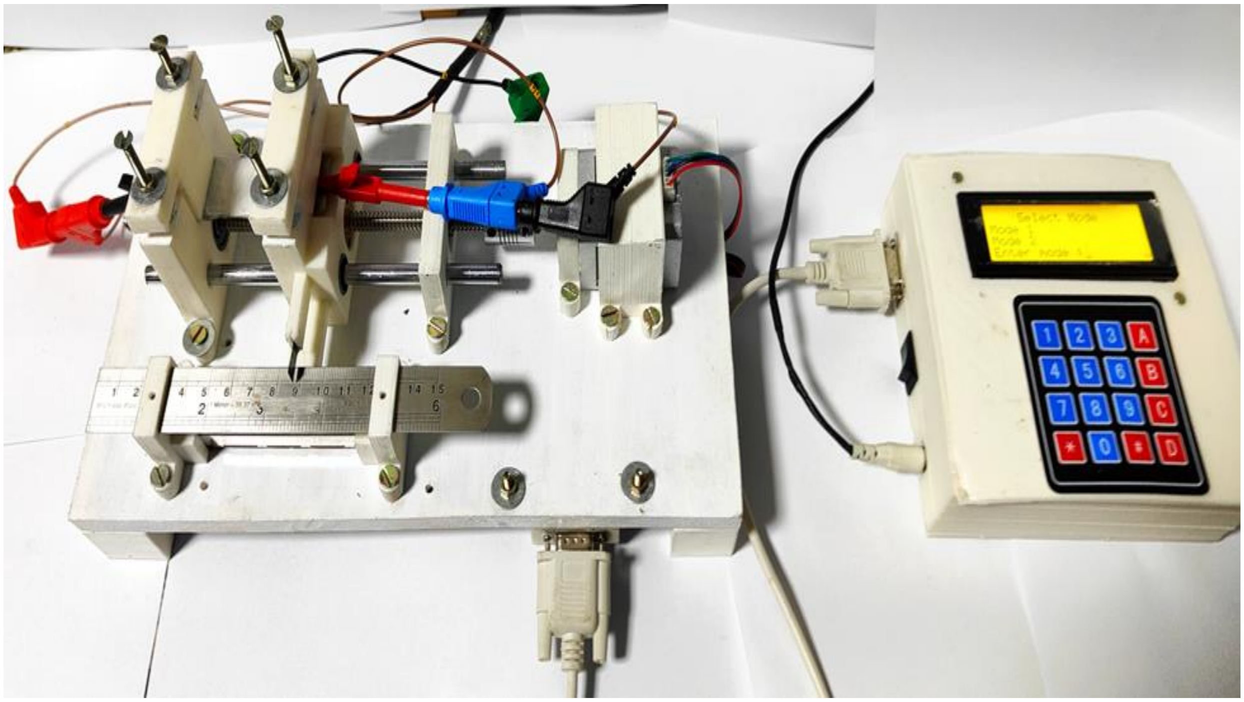

Figure S11: Linear Stage with substrate holder for bending angle and bending cycle measurements

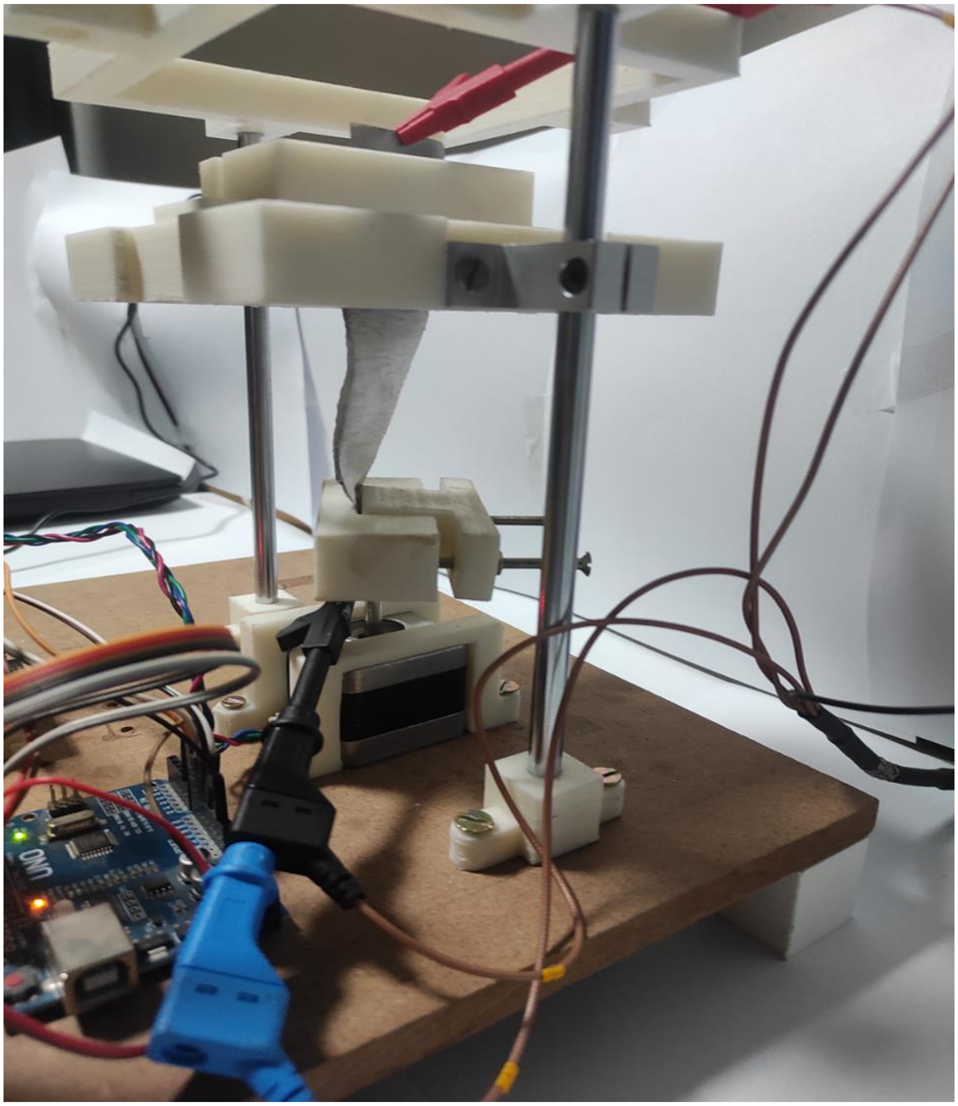

Figure S12: Angular Stage for twisting angle and twisting cycle measurements