Supporting Information for

High Stress-Driven Voltages in Net-Like Layer-Supported Organic-Inorganic Perovskites

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Figure S1. Lower magnification top SEM surface micrographs of a) SnO₂ NF b) PPS-Co



Figure S2. Evolution of temperature on PET/ITO surface during ultrasonic treatment, at 40kHz, measured by a remote thermometer. It is seen that the thermal process at 5W for 4 minutes (black line), reminiscent of the maximum conditions employed to prepare our test samples has little thermal updraft on the process (<5°C).



Figure S3. XRD pattern of a spin coated pristine PVDF film, measured at room temperature. The pattern is consistent with that reported in reference ¹.



Figure S4. Effect of MAPbI₃ and UVPT on PVDF nucleation. (a) Attenuated FTIR spectra and (b) XRD patterns of spincoated PVDF films after different treatments. i pristine PVDF, ii PVDF subjected to UVPT, iii PVDF/MAPbI₃, iv PVDF/MAPbI₃ subjected to UVPT. The optimized values for UVPT and MAPbI₃ concentration were used as revealed in the experimental section. For proper comparison, only the main PVDF peaks have been indicated in both the FTIR spectra and XRD pattern.

From both FTIR and XRD patterns, it can be seen that both ultrasonic vibration and incorporation of MAPbI₃ enhance the electroactive β -phase content. In the XRD, this is shown by the disappearance of the 2 θ α -phase peak at ca. 18.0° whereas the (110) (200) β phase peak proliferates. Also, there is a more intense β -phase peak when PVDF was treated with both MAPbI₃ and then subjected to UVPT (**S4 iv**). Similarly, the α absorption bands in the FTIR spectra ii, iii and iv are seen to reduce whereas the β -phase bands increase. This further confirms the electroactive phase nucleating tendency of both addition of MAPbI₃ and UVPT process, which improve the voltage harvesting potential of PVDF containing material.

Peak Position (20)		FWHM		Crystallite size D (nm)	
А	В	А	В	А	В
26.52905	26.55862	4.49904	1.13104	1.814174393	7.216844645
33.80709	33.76357	3.76745	1.08414	2.203882166	7.657736363
37.69456	37.87166	1.07241	0.90143	7.827575167	9.317207896
51.73913	51.77778	3.13272	0.81217	2.81833393	10.87271858
54.50128	54.74692	0.61745	0.61557	14.47256818	14.53284712
57.87724	57.96865	0.5404	0.72742	16.79820467	12.47886173
61.86701	61.8144	0.76015	0.73402	12.18393828	12.61419874
64.95068	64.72168	0.73699	0.91408	12.77748042	10.2889592
65.97369	65.90709	0.89134	0.7114	10.6256498	13.30826083
71.29339	71.32045	0.5075	0.62438	19.26319128	15.65989579
78.77603	78.71594	0.65212	0.82704	15.76242848	12.42330788
81.74278	83.81162	0.33658	0.66222	31.21342051	16.11897807
	Average crystallite size D (nm)			12.7404769	11.48825807

Table S1. Crystallite sizes of free SnO₂ NF and SnO₂ NF in the PPS-Co.

* A represents the pristine (free) SnO₂ NF membrane while B represents the SnO₂ NF phase in the PPS-Co composite

According to the Scherrer equation ²,

$$D = \frac{\kappa \lambda}{\beta \cos \theta} \qquad \qquad Eqn. \, S1$$

where D is the crystallite size (nm), $\kappa = 0.9$ (Scherrer constant), $\lambda = 0.15406$ (wave length of source, nm), β is the peak width at half maximum in radians and $\theta = 2\theta/2$ is the peak position. Pursuant to Eqn. S1, as the cos θ (peak position) increases/shifts to the right, the crystallite size, D ultimately decreases and vice versa.

The average crystallite size (D) of SnO_2 NF estimated from the Scherrer equation shows a reduction after ultrasonic vibration of the membranes. Five samples were used in each case and average peak position as well as the FWHM values have been presented in the Table S1 above.



Figure S5. FTIR spectrum of PPS-Co film kept in the ambient for 7 days prior to testing.



Figure S6. XRD spectra of MAPbI₃ perovskite films subjected to various UVPT vibration conditions. Expanded (100) and (211) peak positions are revealed further on the side, with determined FWHM values for the (211) plane reflections.

The ultrasonic generator employed for our tests has an optimal power output of 50W at a frequency of 40kHz. Consequently, the effective power applied to the device (P_{eff}) is obtained by the relationship;

 $P_{eff} = p * 50$ where p is the percentage rating entered.

It is clear that the (110) is the most intense peak in each of the patterns while the (211) reflection shows more intensity than (213) (distinctive tetragonal polymorph MAPbI₃ peaks).³ Since these reflections are easily noticeable, they were chosen to identify the most efficient vibration conditions for the prepared MAPbI₃ film. The different UVPT XRD patterns obtained show decreasing tetragonal phase intensities (211) in the order; 5%>25%>15%>0%, whereas the overall MAPbI₃ perovskite quality (110) decreased in the order; 5%>15%>25%>0%. Therefore, the film subjected to 5% UVPT (2.5W) with (110) and (211) reflections at around 14.3° and 23.6° respectively, was considered the best choice for formation of the devices.



Figure S7. The proposed voltage generating mechanism of (a) PPS-Co and (b) SnO₂ NF, MAPbI₃ device. The cross-sectional SEM images are zoomed out for each.



Figure S8. Output current and voltage for the MAPbI₃ and SnO₂ NP/ MAPbI₃ devices during direct top surface loading and when subjected to bending. (a)-(d) PET/ITO/MAPbI₃, (e)-(h) PET/ITO/SnO₂ NP/MAPbI₃. (a), (c), (e) and (g) are waveforms for the results obtained on direct vibration of the device top surface, while (b), (d), (f) and (h) are obtained from the bending tests.

Supporting Information References

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