Electronic Supplementary Material (ESI) for Sustainable Energy & Fuels.

Patterned Interlayer Enables a Highly-stable and Reversible Sodium Metal Anode for Sodium-metal Batteries

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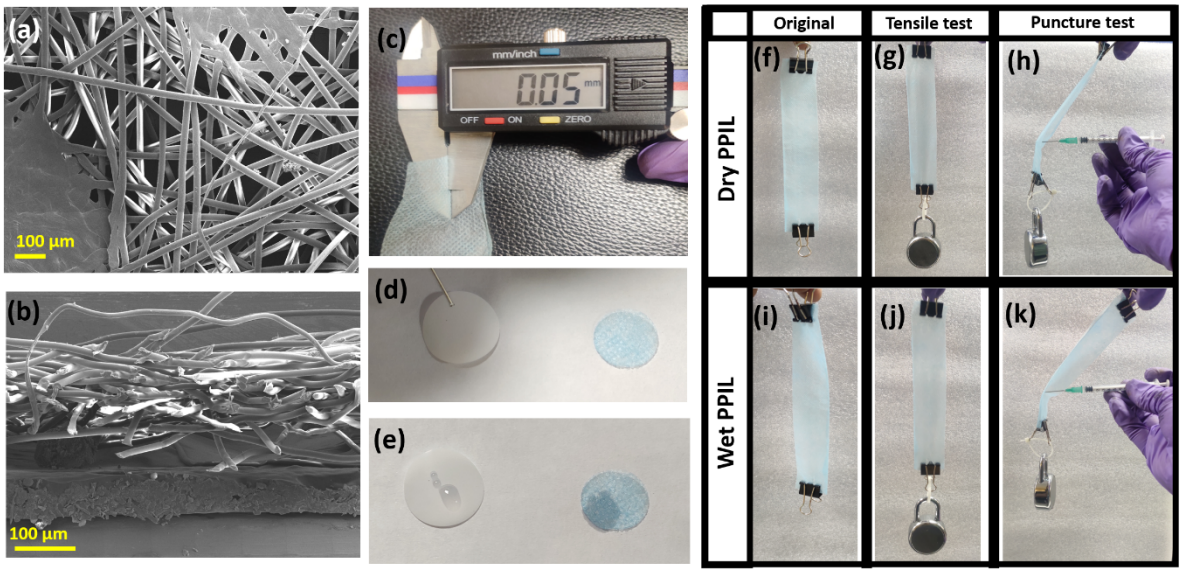

Fig. S1 (a, b) Micro-structure of PPIL fibre, cross-sectional image of as received PPIL after treatment (c) Thickness of PPIL fibre after applying a maximum pressure to compress (d) Celgard (PP-PE-PP) and PPIL fibre in dry condition (e) Celgard and PPIL fibre after putting 20 µl of electrolyte (f) original PPIL fibre without loading (g) PPIL fibre in tensile test with a mass of 70 gm (h) puncture test on PPIL fibre. All these tests are in dry condition of PPIL fibre (i) original PPIL fibre without loading (j) PPIL fibre in tensile test with a mass of 70 gm (k) puncture test on PPIL fibre. These all tests are in a wet condition of PPIL fibre

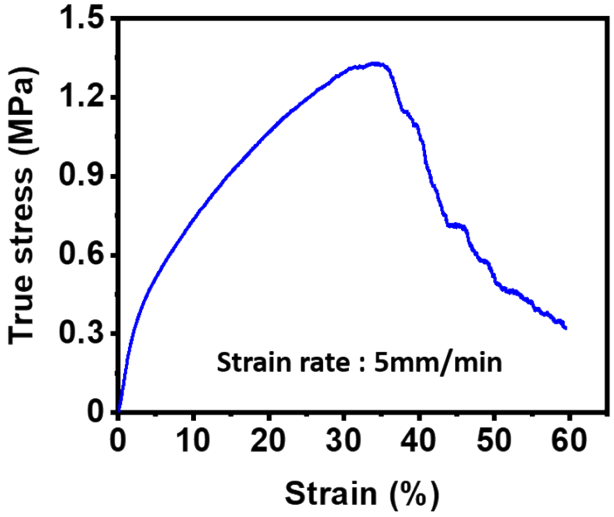

Fig. S2 Static tensile test of PPIL interlayer at 5 mm/min strain rate

Table-S1 Results of tensile test

$E_{modulus}$ (MPa)	σ_{max} (MPa)	%ϵ at F_{max}	σ_{break} (MPa)	%ϵ at break
9.4706	1.329979	33.7436	0.3189	59.4766

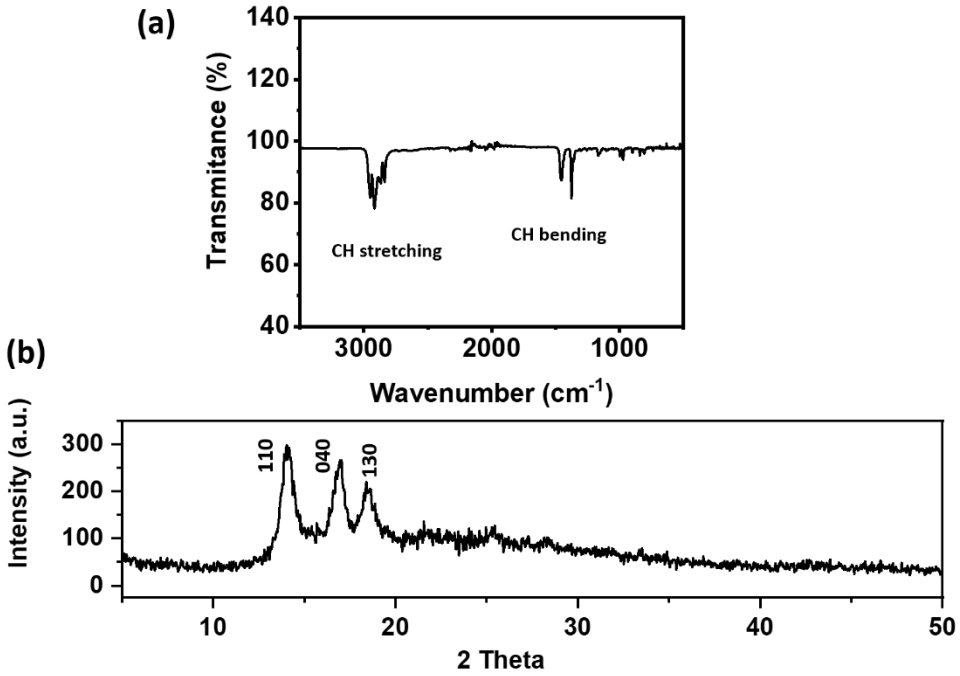

Fig. S3 (a) FTIR spectrum of PPIL fibre (b) XRD spectra of PPIL fibre

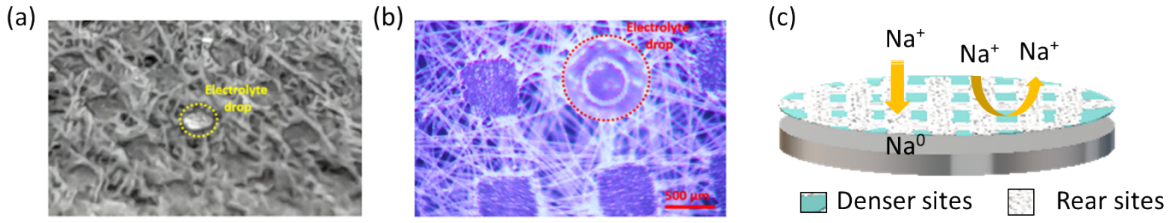

Fig. S4 (a) Digital image of the electrolyte droplet over the PPIL patch, and (b) Optical image of the electrolyte droplet over the PPIL patch (c) schematic of Na deposition through rear

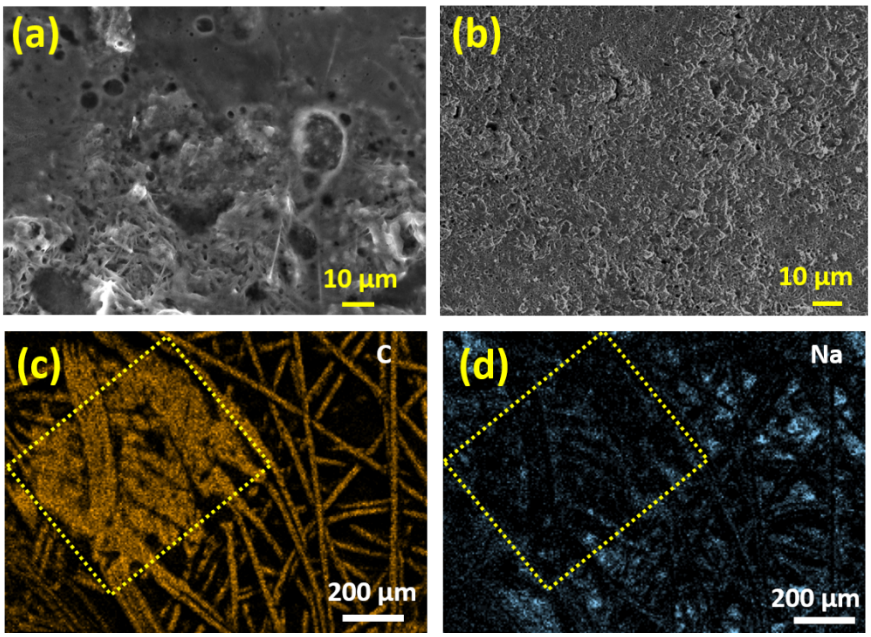

Fig. S5 Morphological analysis of Na metal surface after 10 cycles at 10 mA cm^{-2} current density and 1 mA h cm^{-2} capacity (a) Na metal surface without PPIL (b) Na metal surface after removing the PPIL interlayer, showing smooth and uniform morphology (c, d) Na metal surface with PPIL showing guided deposition through. All these tests are in ether-based electrolyte.

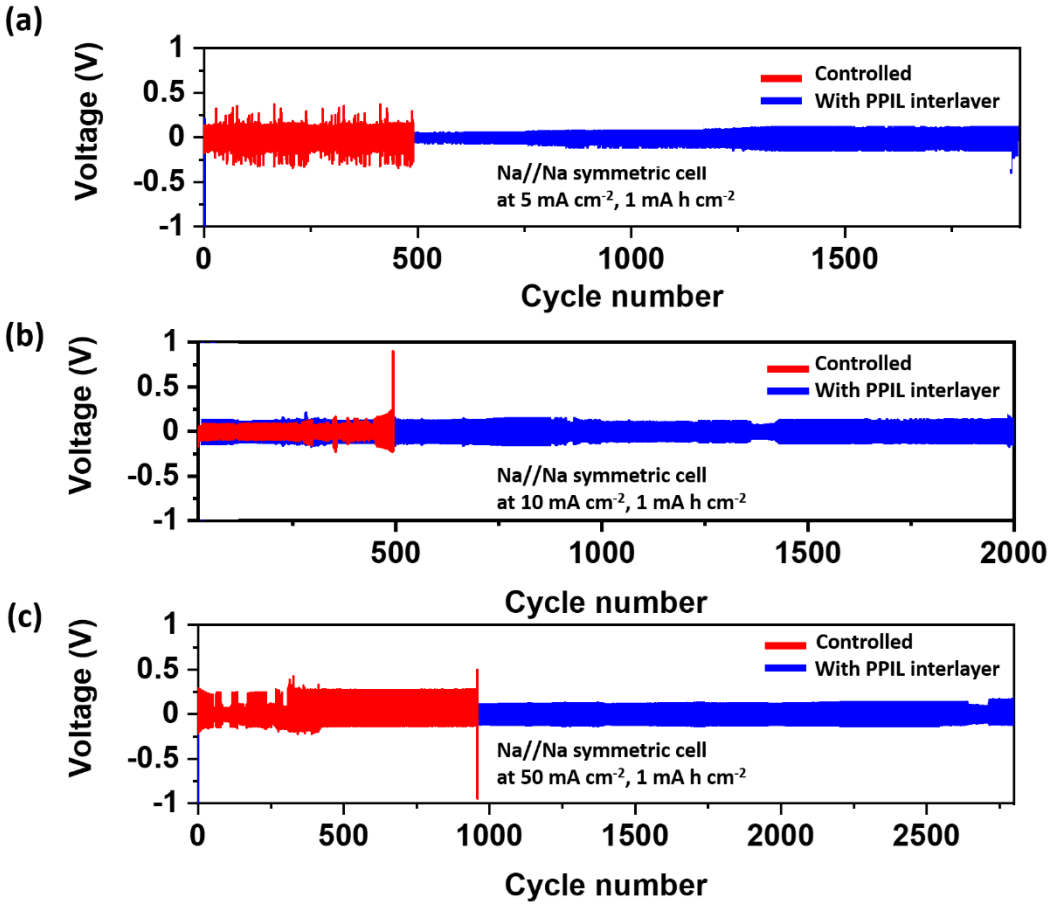

Fig. S6 Galvanostatic cyclic performance of controlled and PPIL protected Na//Na symmetric cell, at (a) 5 mA cm^{-2} (b) 10 mA cm^{-2} and (c) 50 mA cm^{-2} in ether-based electrolyte

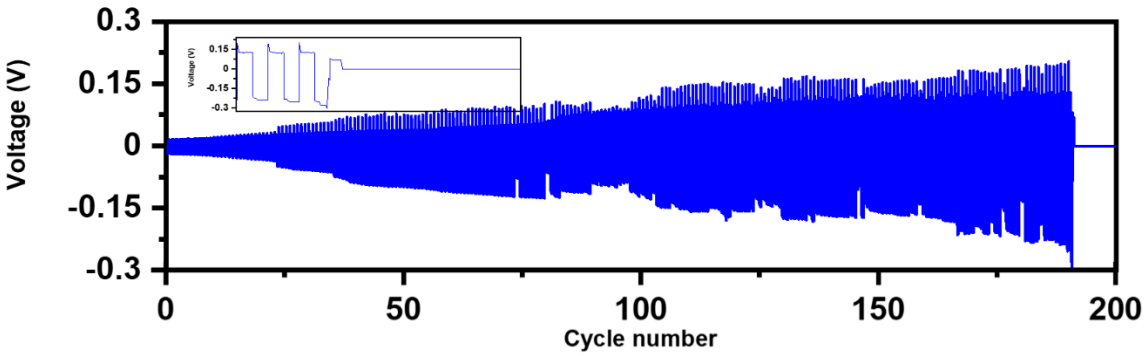

Fig. S7 Stripping/plating sodium in sodium symmetric cell configuration (Na//Na) with PPIL (2 layers) as a diaphragm at a current density of 10 mA cm^{-2} and a capacity of 1 mAh cm^{-2}. Inset shows an enlarged view of the voltage profile.

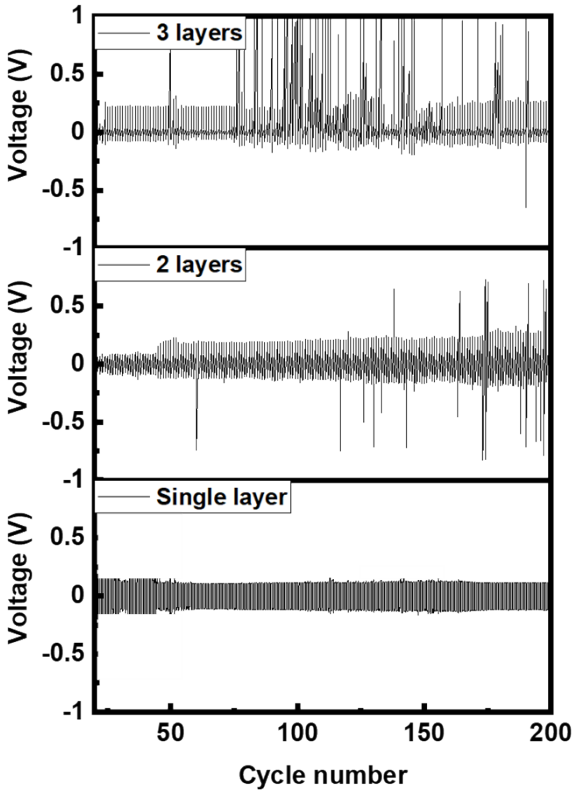

Fig. S8 Galvanostatic cycling of Na//Na symmetric cell with multiple layers of PPIL protective interlayer at 10 mA cm^{-2} current density and 1 mA h cm^{-2} capacity. It was noticed that the single layer of PPIL was optimum with uniform deposition and comparatively less overpotential.

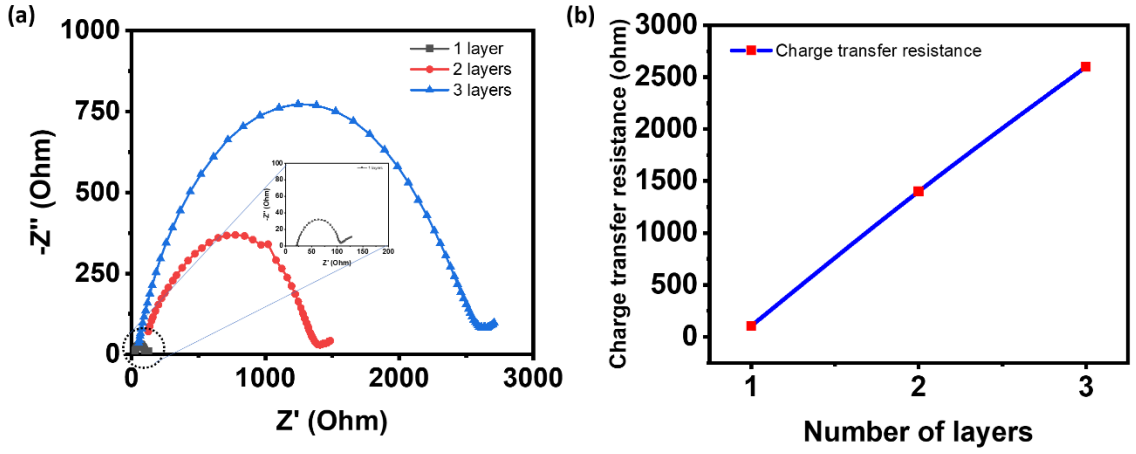

Fig. S9 (a) EIS of Na//Na symmetric cell in PPIL protected with multiple layers, in carbonate based electrolyte. (b) Charge transfer resistance with respect to multiple layers of PPIL

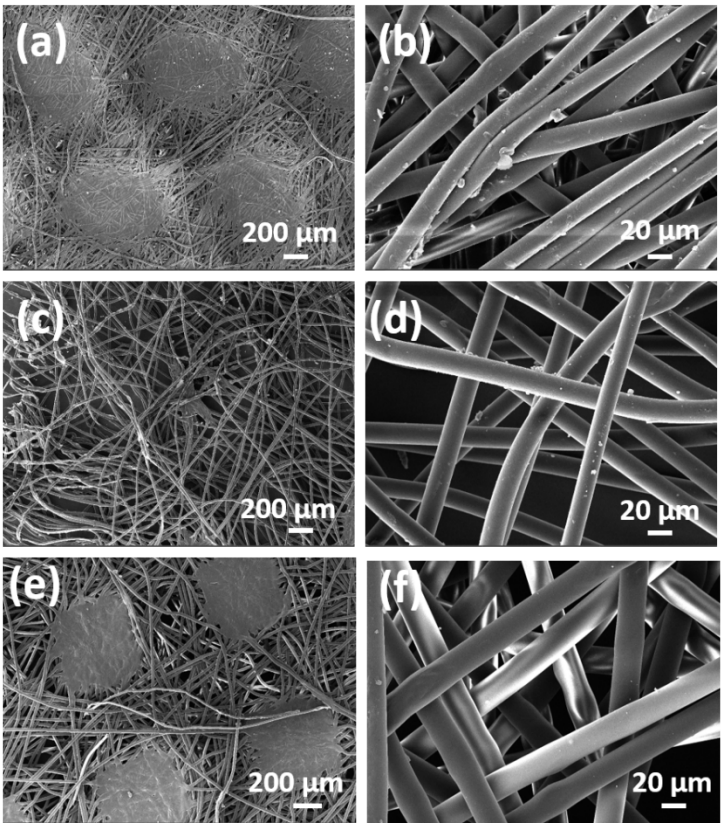

Fig. S10 FESEM images of PPIL fibre (a, b) dense patches (c, d) without patches (e, f) optimum patches

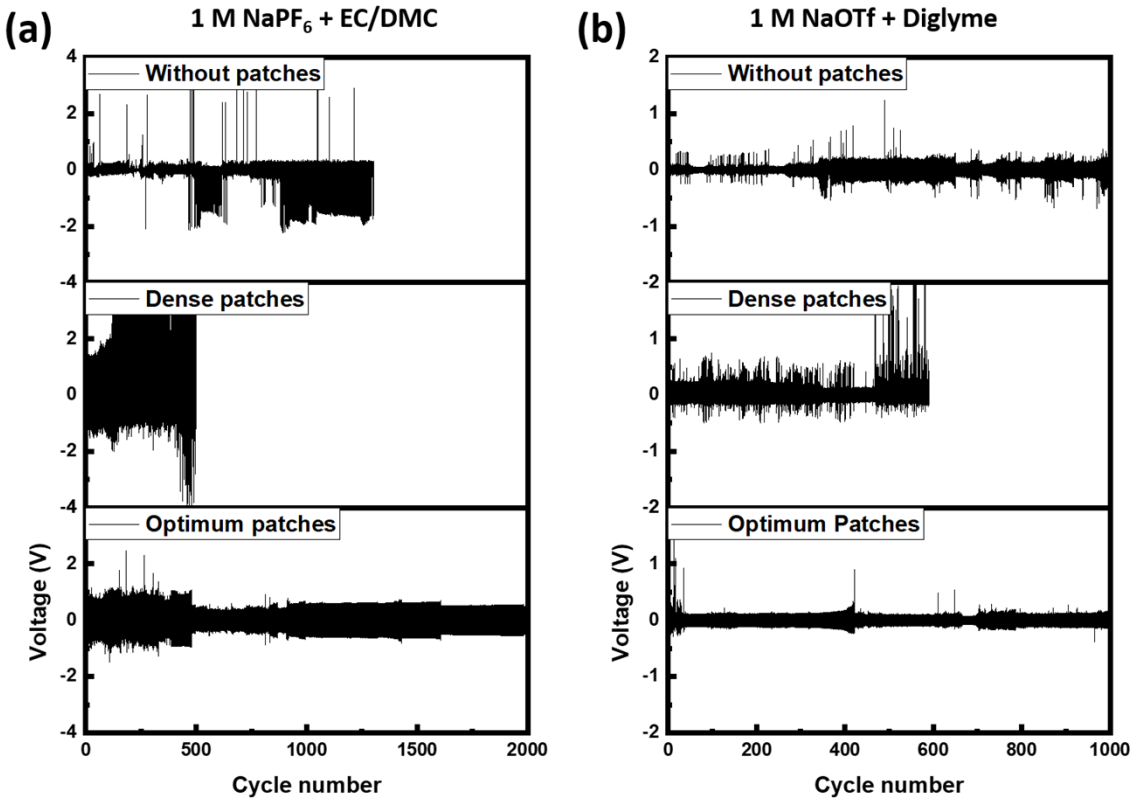

Fig. S11 Galvanostatic cycling performance of Na//Na symmetric cell at 10 mA cm^{-2} current density and 1 mA h cm^{-2} capacity for three different types of fibres, i.e., without patches, dense patches and optimum patches in (a) Carbonate and (b) Ether-based electrolyte.

In the Randles-Sevcik equation, the Na-ion apparent diffusion coefficient (D) can be computed[1].

$$Ip = 0.4463nFAC\left(\frac{nFvD}{RT}\right)^{1/2}$$

Where, F is Faraday's constant, 96455 C mol^{-1}L, n is the number of mol participating in the reaction (for 1 redox peak, n is generally 1), A is the working electrode area (1 cm^2), C is concentration of sodium ions in the working electrode (mol cm^{-3}), v is scan rate, R is gas constant (8.314 J mol^{-1} K^{-1}), T is temperature (298.15 K) and Ip is the peak current.

Table S(T1) Parameters used to calculate the diffusion coefficient

Scan rate (v) (mV s^{-1})	square root of scan rate	Peak current (mA) (With PPIL)	Peak current (mA) (Without PPIL)
0.5	0.7071	0.8913	0.6346
1.5	1.2247	1.3591	1.0910

2	1.4142	1.6056	1.2419
3	1.7320	2.0275	1.6911

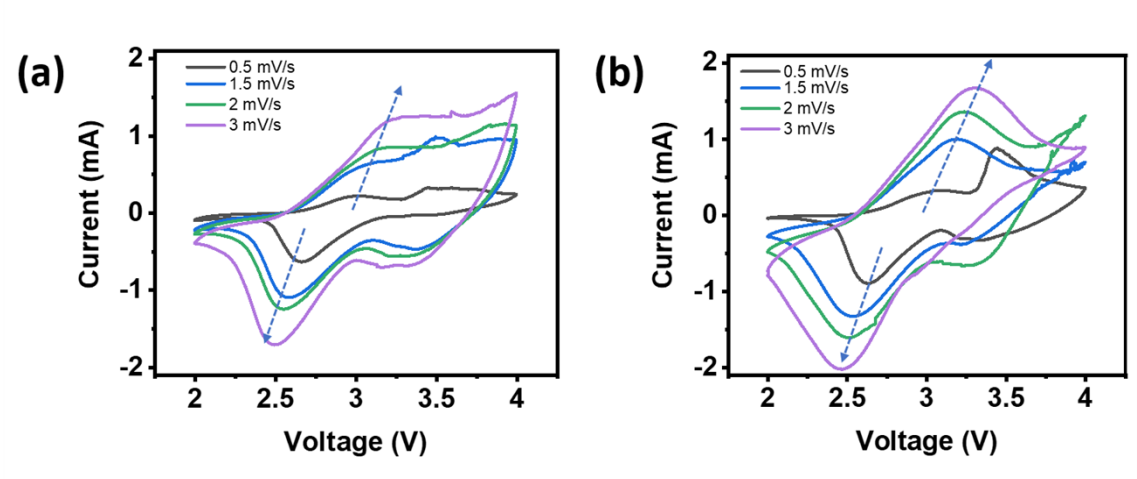

Fig. S12 Cyclic voltammetry of Na//PB full cells at different scan rates (a) without PPIL (b) with PPIL

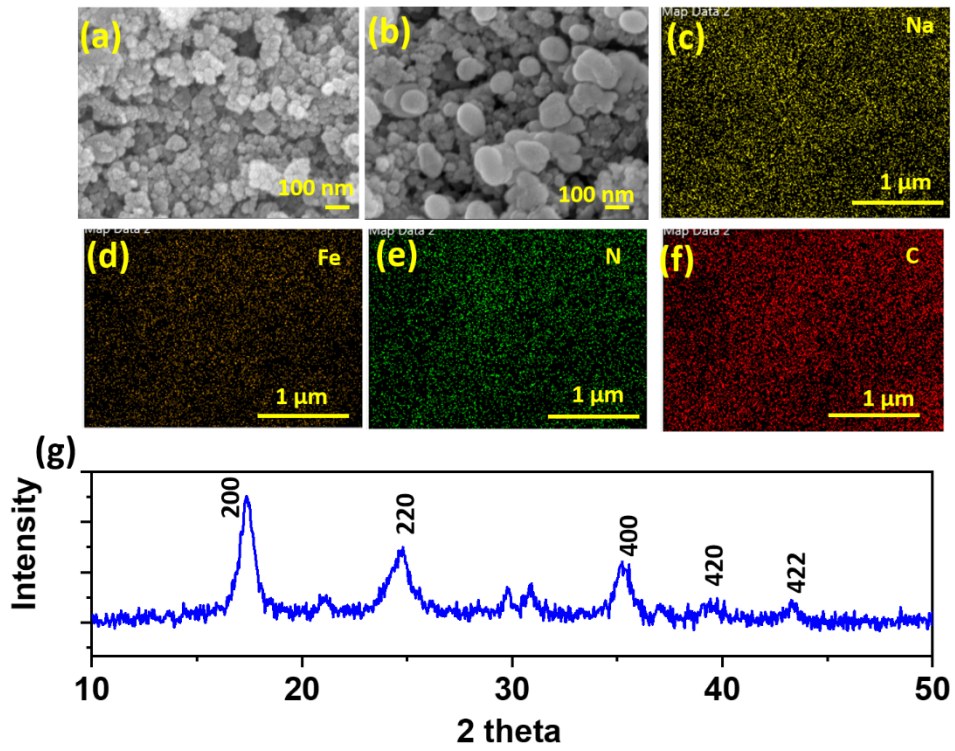

Fig. S13 (a, b) FESEM images of the as-synthesized PB material (c-f) EDX mapping of the elements present in the PB (g) XRD spectrum of as-synthesized PB powder

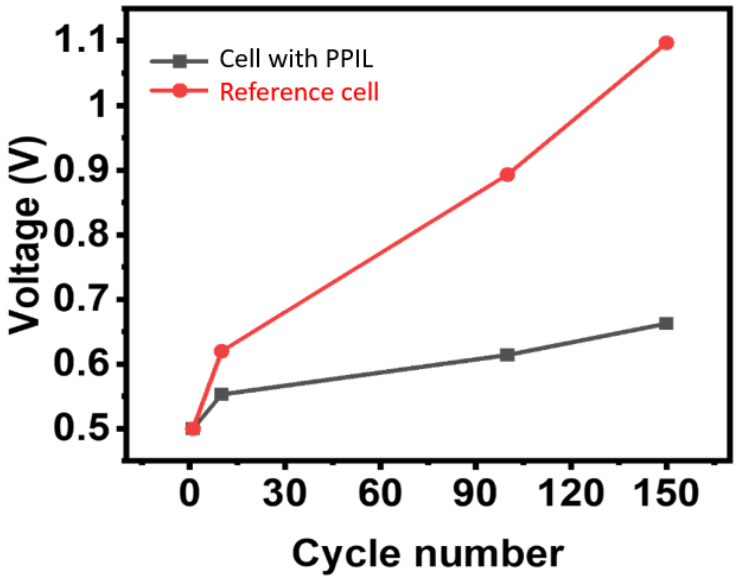

Fig. S14 Polarization of controlled and PPIL protected cell for different cycle number in ascending order

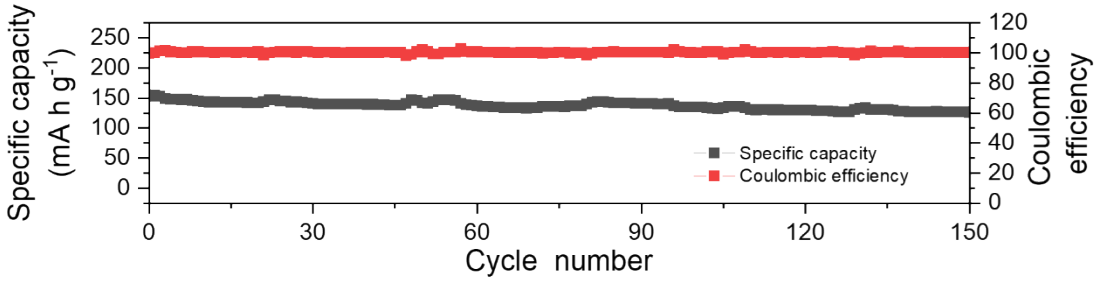

Fig. S15 Cyclic performance of Na//PB full cell with PPIL protective layer at 500 mA g^{-1} in carbonate-based electrolyte

References:

1 H. Li, Y. Wang, J. Jiang, Y. Zhang, Y. Peng and J. Zhao, *Electrochim. Acta*, 2017, **247**, 851–859.