Electronic Supplementary Material (ESI) for Energy & Environmental Science.

Supplementary Information

Intermediate Temperature Fuel Cells via an Ion-Pair Coordinated Polymer Electrolyte

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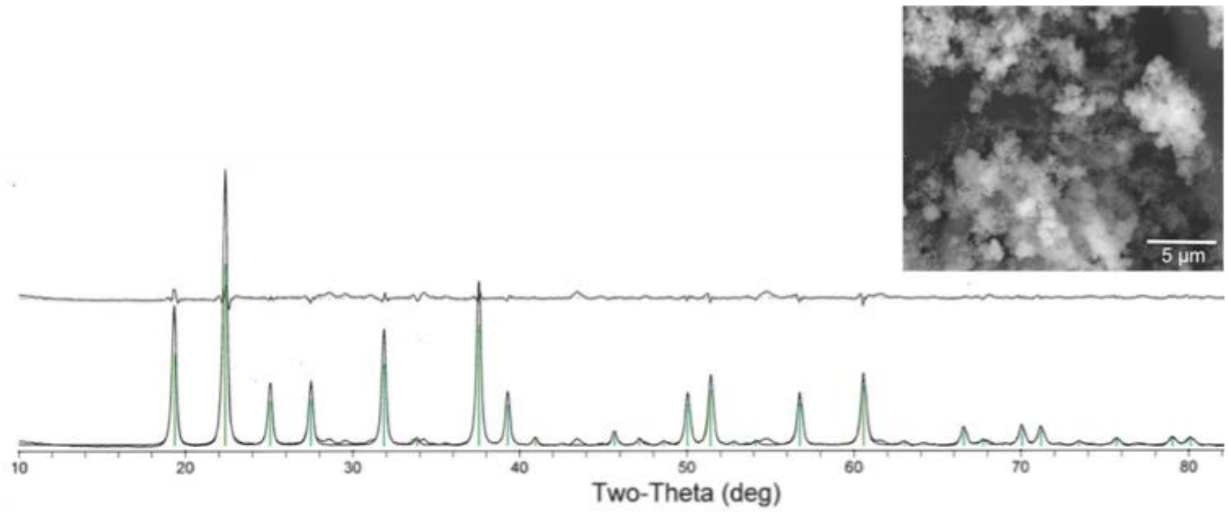

Figure S1. XRD pattern of SnP_2O_7 with P:M ratio of 3.5 measured via XRF synthesized with solution precipitation process. Whole pattern fitting structure refinement (JADE MDI, SnP_2O_7 PDF 00-029-1352) yielded a lattice parameter of 7.940 Å with a crystallite size of 49.6nm. Inset SEM image shows particle agglomerates of ~100 nm in diameter.

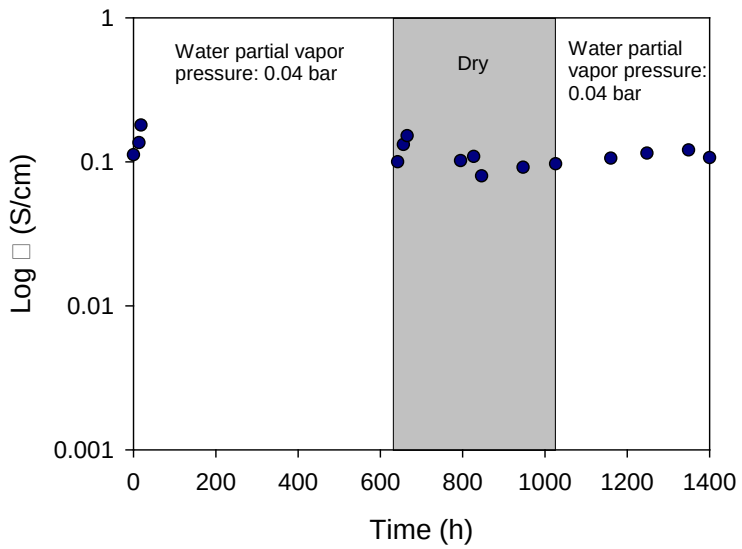

Figure S2. Proton conductivity of SnP_2O_7 pellet under humidified H_2/O_2 and dry H_2/O_2 feed; Data collected at 200 °C.

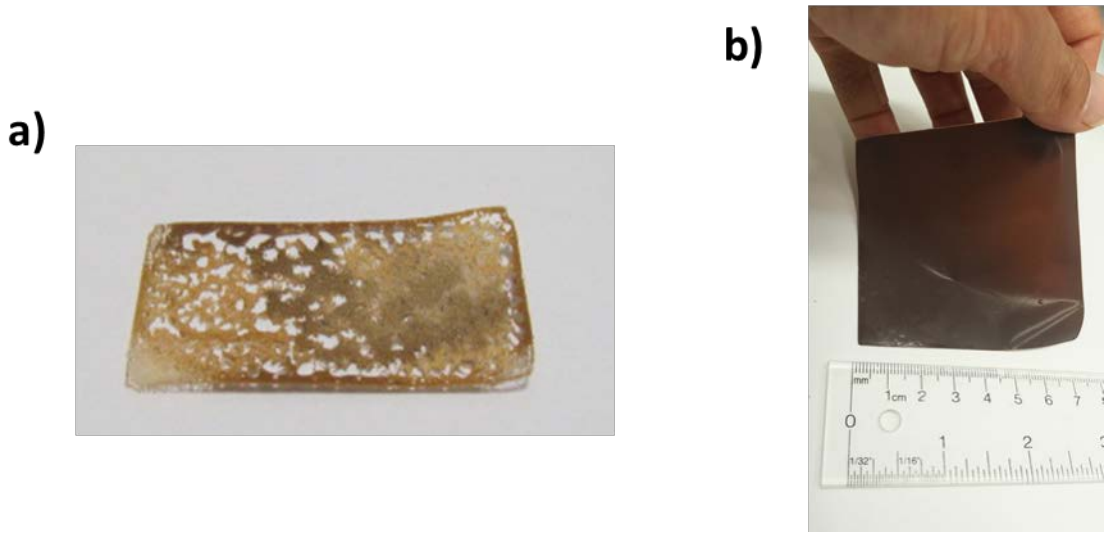

Figure S3. Membrane images (a) 80 wt.% SnP_2O_7/Radel composite membrane (b) 90 wt.% SnP_2O_7/Nafion composite membrane.

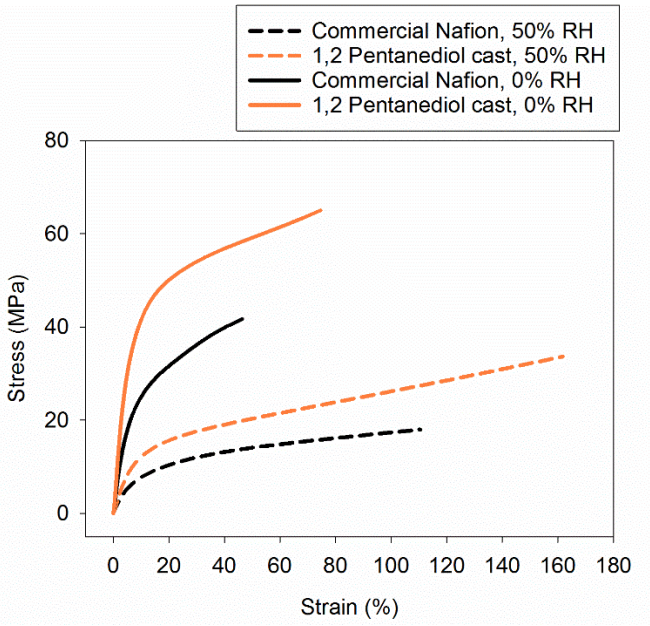

Figure S4. Tensile property comparison between commercial Nafion (Na^+ form, NR 212) and 1,2 pentanediol cast Nafion (Na^+ form) at 50 °C and 0 and 50% RH.

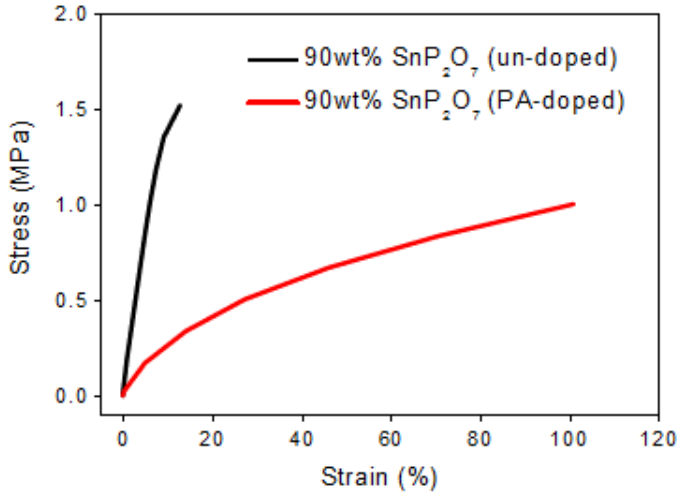

Figure S5. Stress-strain curves of SnP_2O_7-Nafion composite membrane; the tensile properties were measured at 50 °C and 0% RH.

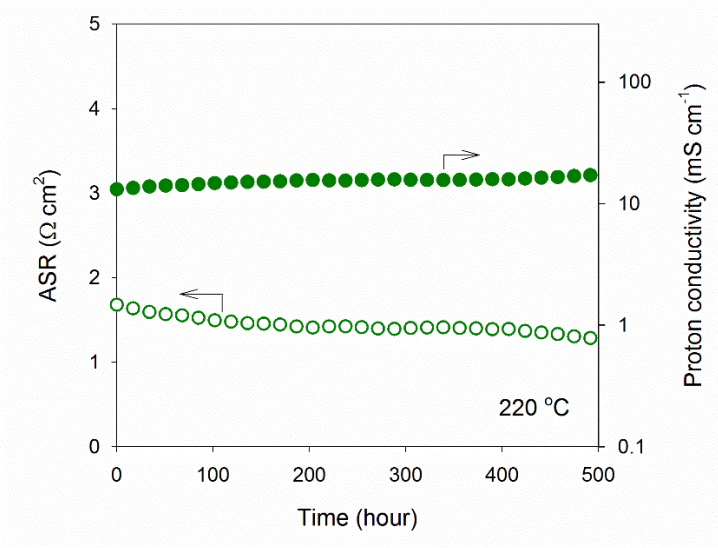

Figure S6. Area specific resistance and through-plane proton conductivity of phosphoric acid doped SnP_2O_7-Nafion composite membrane (thickness, t = 220 μm) at 220 °C as a function of time.

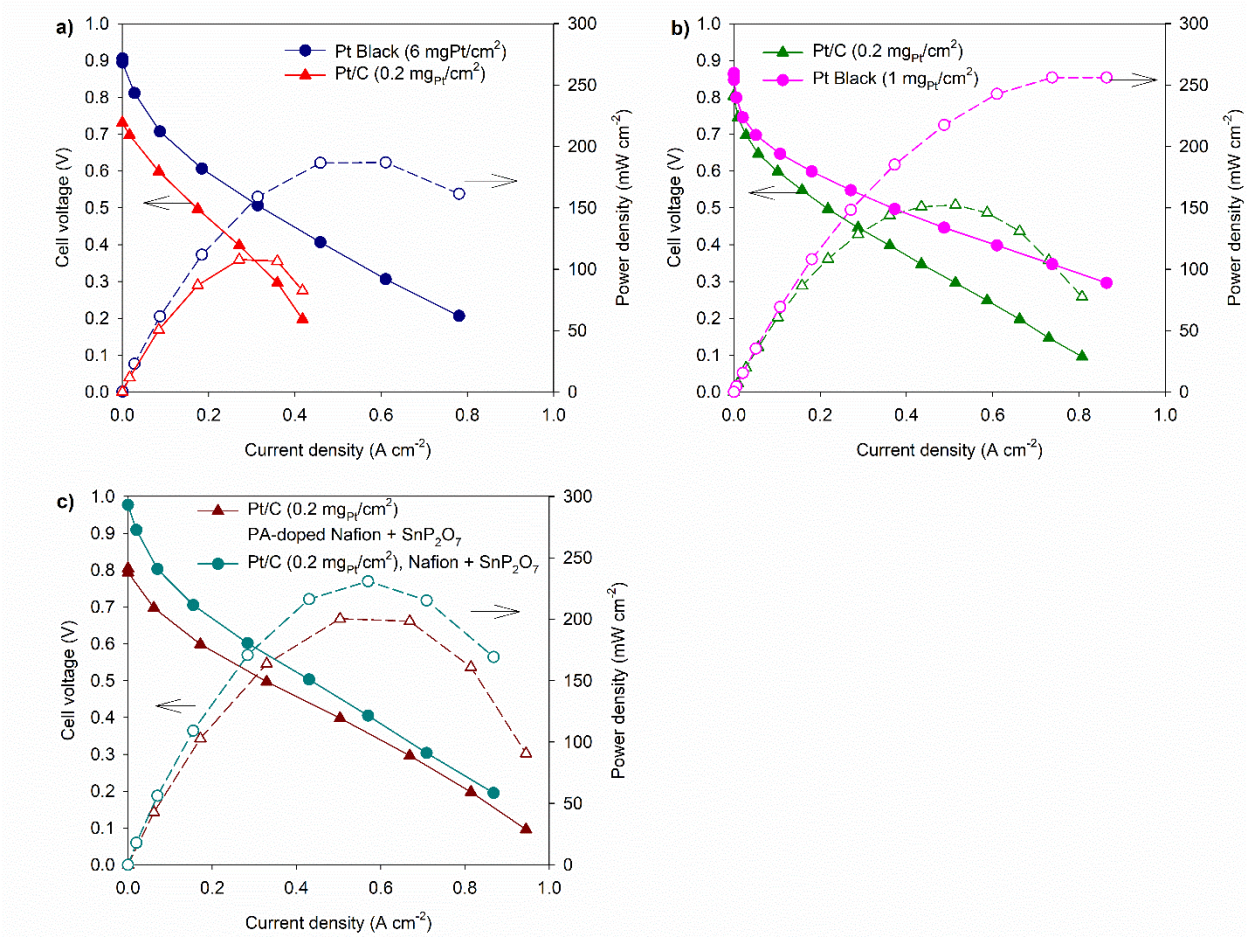

Figure S7: SnP_2O_7 particles mixed with Pt black (6 mg_{Pt}/cm^2) or Pt/C (0.2 mg_{Pt}/cm^2). The cells were tested at 240 °C under 30 psig backpressure. (b) membrane: 90 wt.% SnP_2O_7/Nafion composite membrane (thickness: 100 μm), electrode: vacuum deposited Pt (1 mg_{Pt}/cm^2) or Pt/C (0.2 mg_{Pt}/cm^2) on un-doped SnP_2O_7 particles. The cells were tested at 220 °C under 30 psig backpressure. (c) membrane: 90 wt.% SnP_2O_7/Nafion composite membrane (thickness: 180 μm), electrode: SnP_2O_7 particles mixed with Nafion and Pt/C (0.2 mg_{Pt}/cm^2), The cells were tested at 200 °C under 30 psig backpressure.

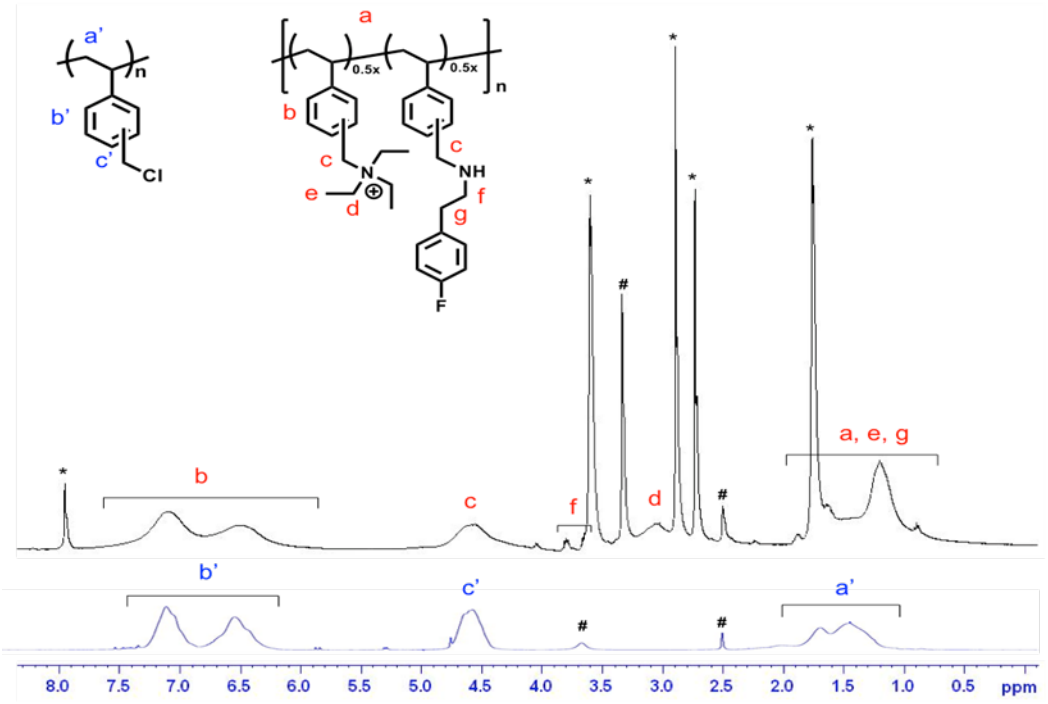

Figure S8. ^{1}H NMR characterization. Chloride form of quaternized polystyrene copolymer (QAS-Cl): δ 7.8-6.1 (br, 12H, -Ar**H**), 5.0-4.2 (br, 4H, -ArC**H$_2$**N-), 5.0-4.2 (br, 4H, -ArC**H$_2$**N-), 3.9-3.6 (m, 2H, -NC**H$_2$**CH$_2$Ar), 3.05 (br, 6H, -ArCH$_2$N(C**H$_2$**CH$_3$)$_3$), 1.8-0.3 (br, 17H, -CH$_2$CHAr-, -N(CH$_2$C**H$_3$**)$_3$, ArC**H$_2$**CH$_2$N-). poly(vinylbenzyl chloride) (PS-bzCl): δ 7.4-6.2 (br, 3H, -Ar**H**), 4.8-4.3 (br, 2H, -ArC**H$_2$**Cl), 2.2-1.1 (br, 3H, -C**H$_2$**C**H**Ar-).[1]

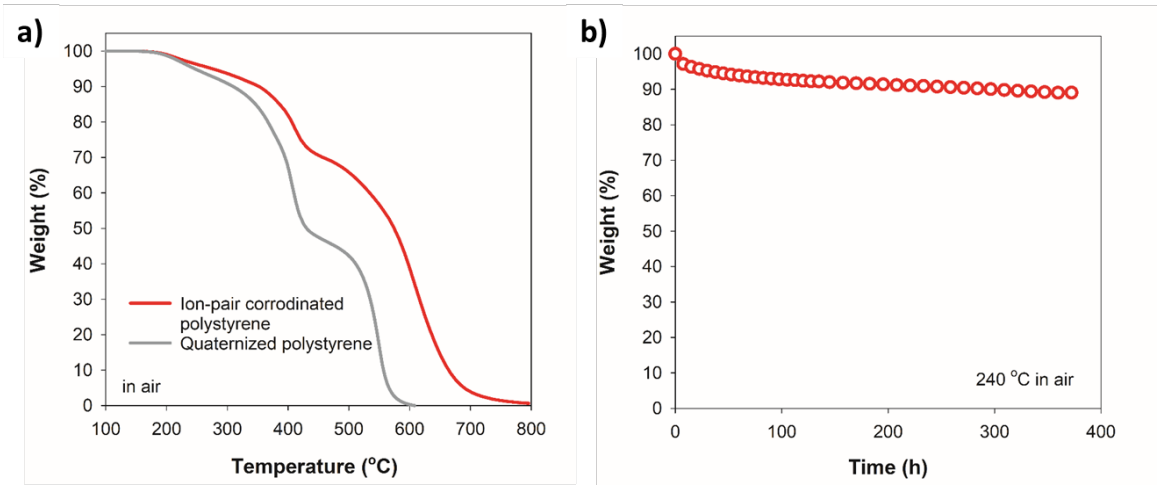

Figure S9. (a) Thermo-oxidative stability of the quaternized and ion-pair coordinated polystyrene in air (b) Thermal gravimetric analysis isotherm of the ion-pair coordinated polystyrene at 240 °C.[1]

Reference

1. K.-S. Lee, J. S. Spendelow, Y. K. Choe, C. Fujimoto and Y. S. Kim, *Nature Energy*, 2016, ***1***, 16120.