Electronic Supplementary Material (ESI) for Materials Chemistry Frontiers.

Supporting Information

Eggshell Membranes based Water Electrolysis Cells

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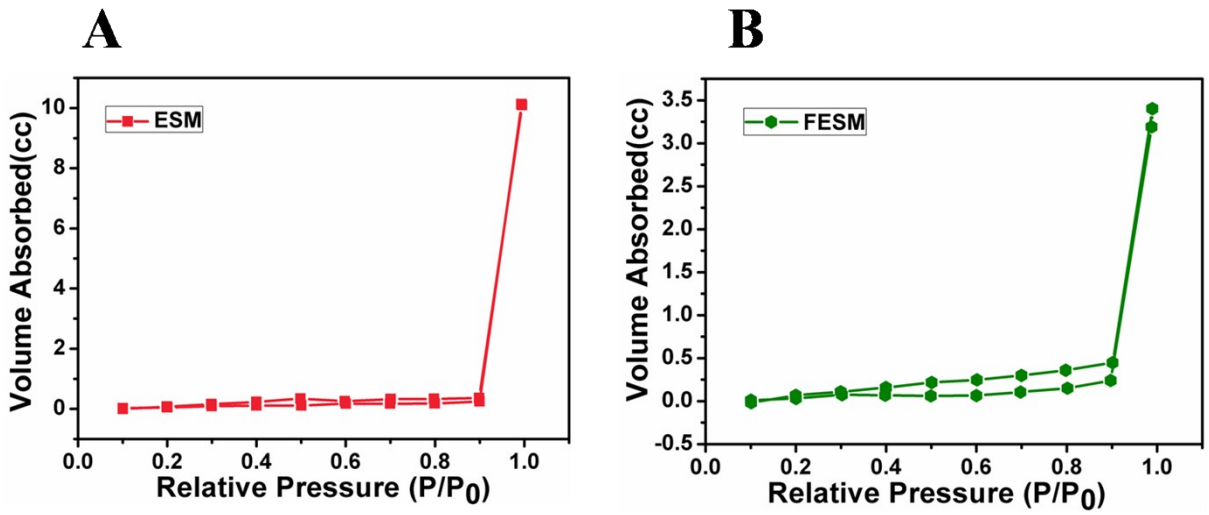

Fig. S1: BET isotherms of ESM and FESM.

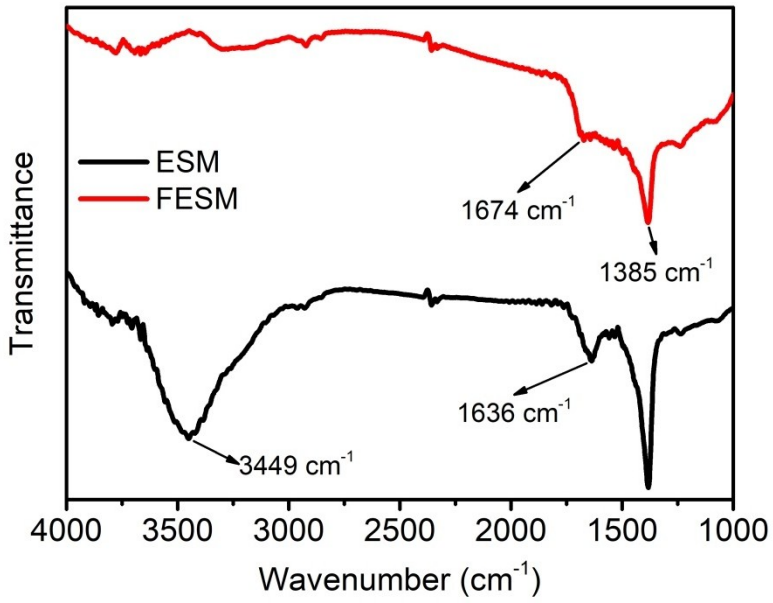

Fig. S2: Fourier Transform Infrared Spectra of ESM and FESM.

The complete FTIR spectra are shown in Fig. S1. The peak at 1385cm^{-1} is attributed to the Amide III band (N-H bend and C-N stretch) and the broad peak at 3449cm^{-1} is a cumulative response from the O-H stretch (3550cm^{-1} – 3200cm^{-1}) of water and N-H stretch from amine (3500cm^{-1} - 3300cm^{-1}) and amide (3700cm^{-1} - 3500cm^{-1}) groups of the proteins in the ESM.

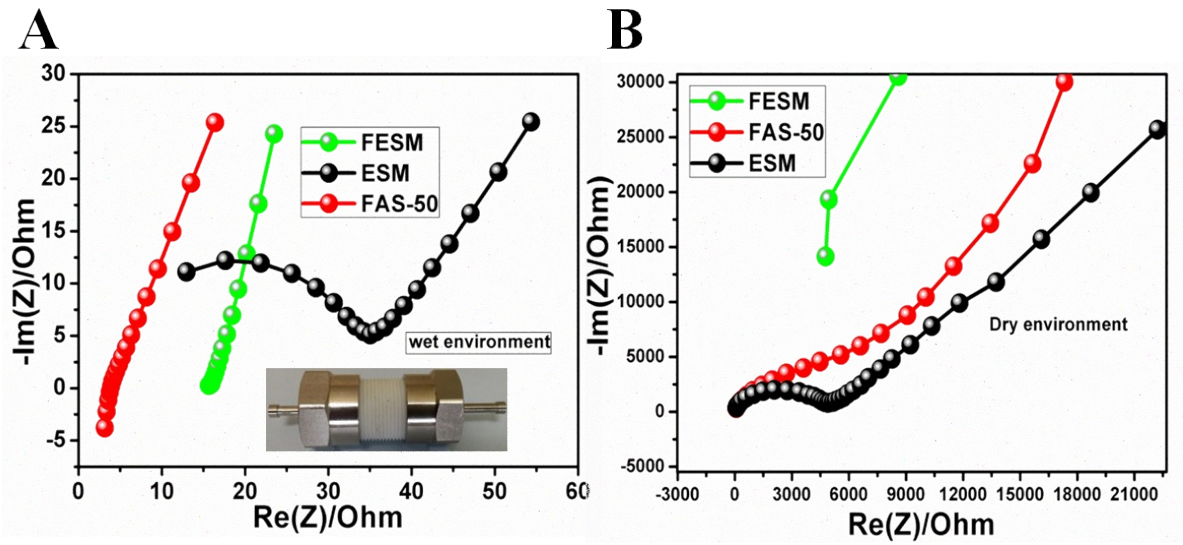

Fig. S3: Electrochemical Impedance Spectroscopy (Nyquist plots) performed in a Swagelok cell at room temperature in (A) wet and (B) dry (anhydrous) environments. Thicknesses of the dried membranes are as follows: ESM (0.07mm), FAS-50 (0.05mm), FESM (0.17mm). Thicknesses of the wet membranes are: ESM (0.08mm), FAS-50 (0.05mm), FESM (0.100mm). The inherent inductive component in the high frequency region of FAS-50 (wet) is not corrected. Lowering the R_b values of membranes is evident in the hydrated condition, indicating the conductivity of the samples.

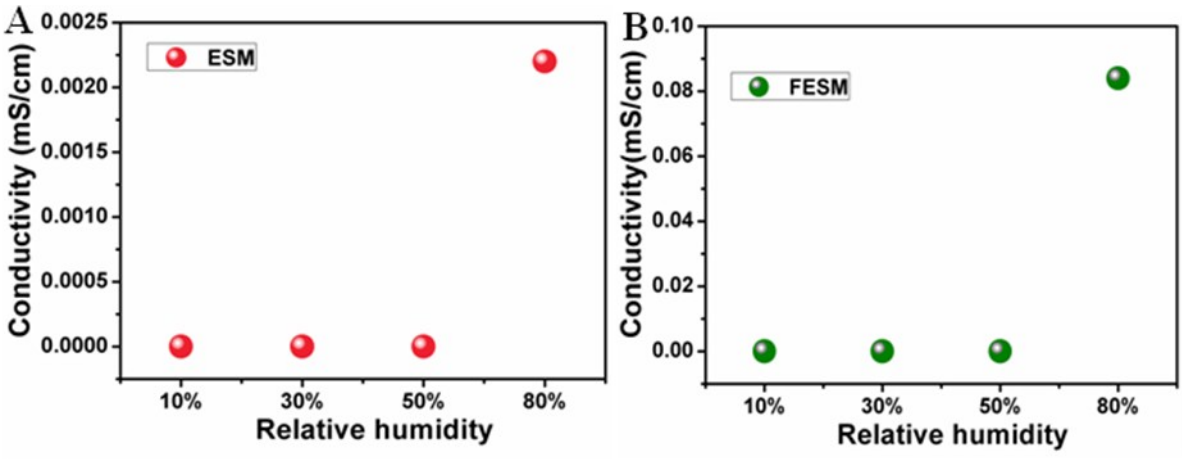

Fig. S4: Humidity dependent ionic conductivity variations in ESM and FESM.

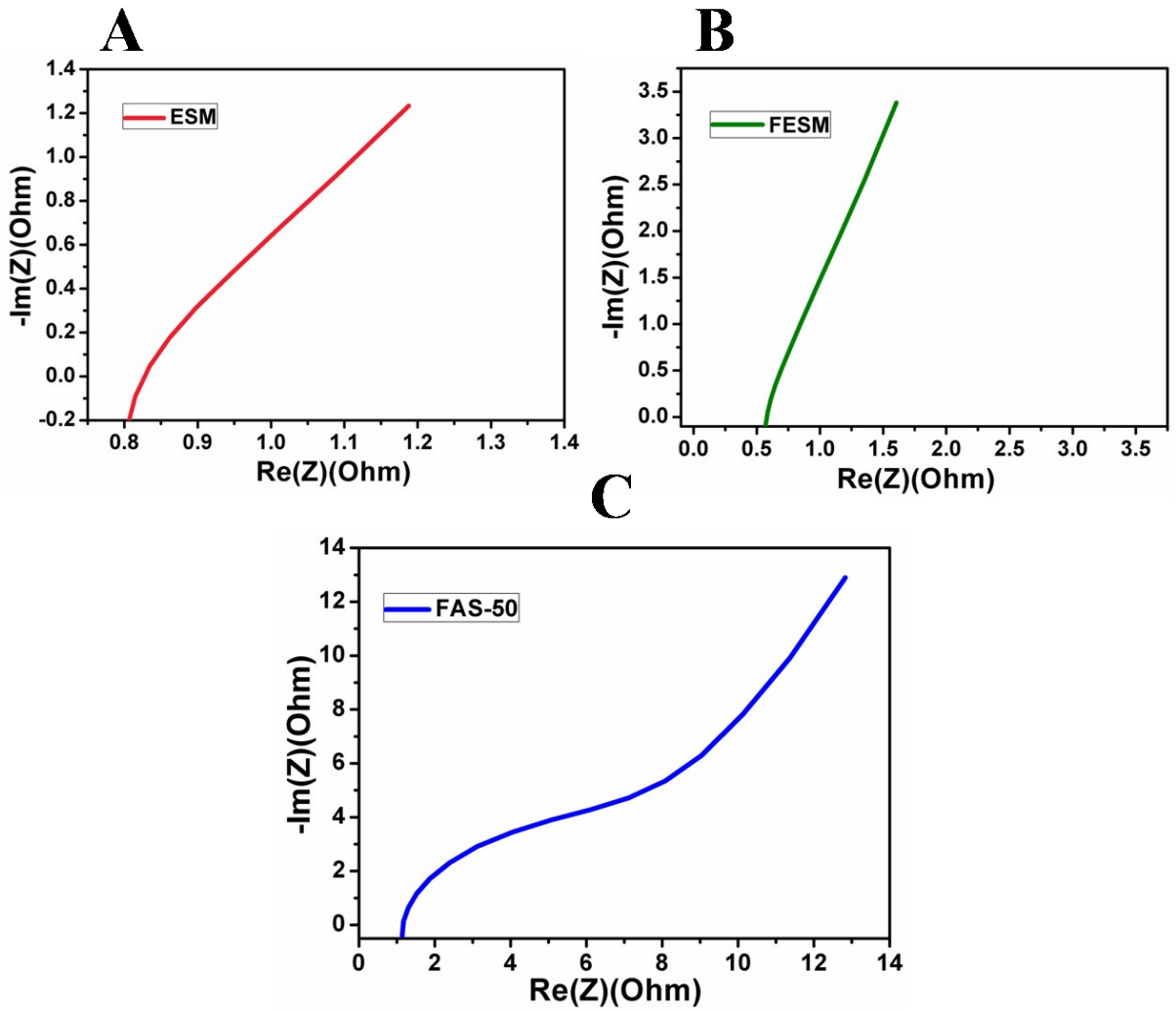

Fig. S5: Nyquist plot of ESM and FESM, FAS-50 membranes in 1M KOH.

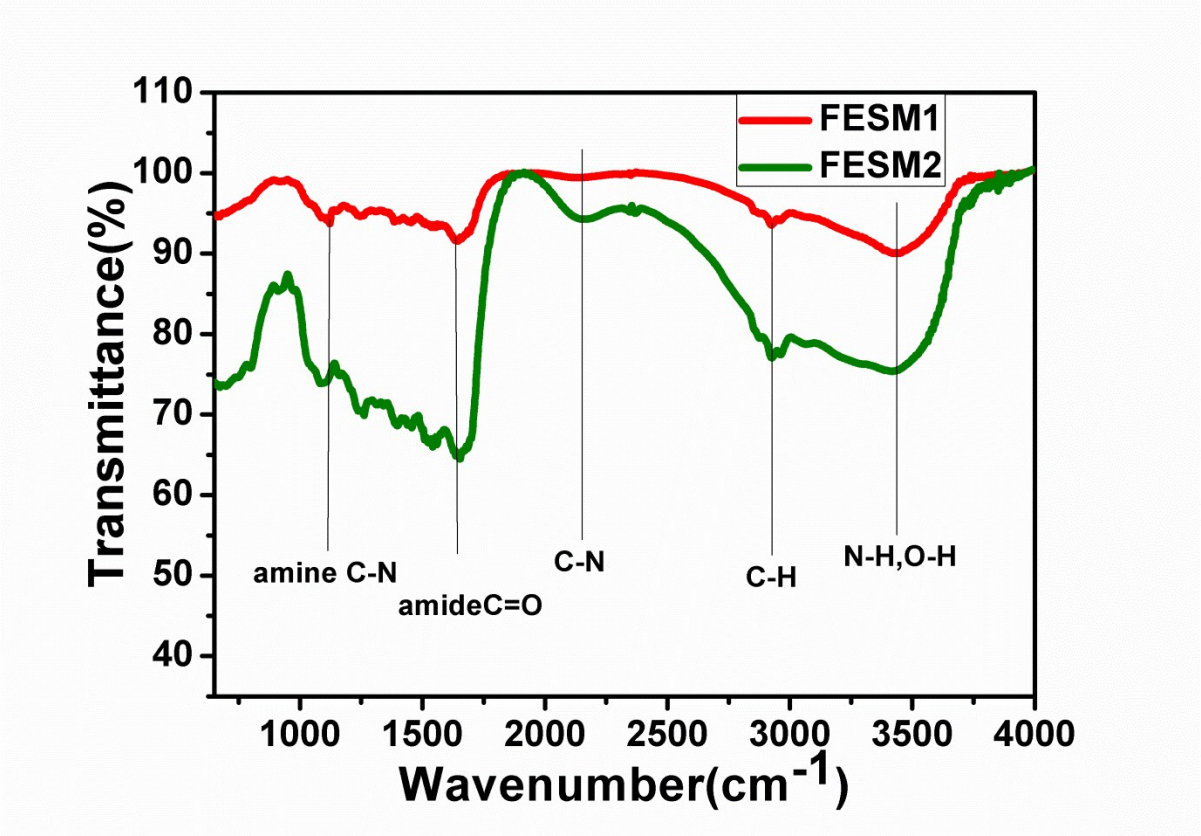

Fig. S6: The FTIR of two different FESM membranes (two different hen species) having different ionic conductivities. The FESM1 has lower conductivity than that of FESM2, which is correlating with the functional groups present in the samples.

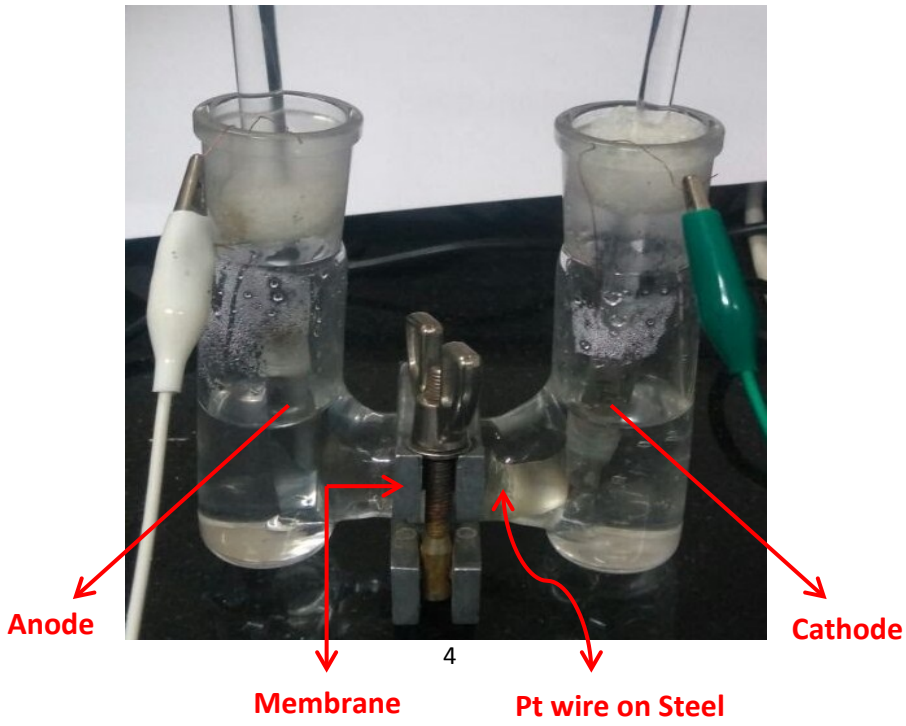

Fig. S7: The home-made alkaline water electrolysis setup used throughout the chronoamperometry experiments.

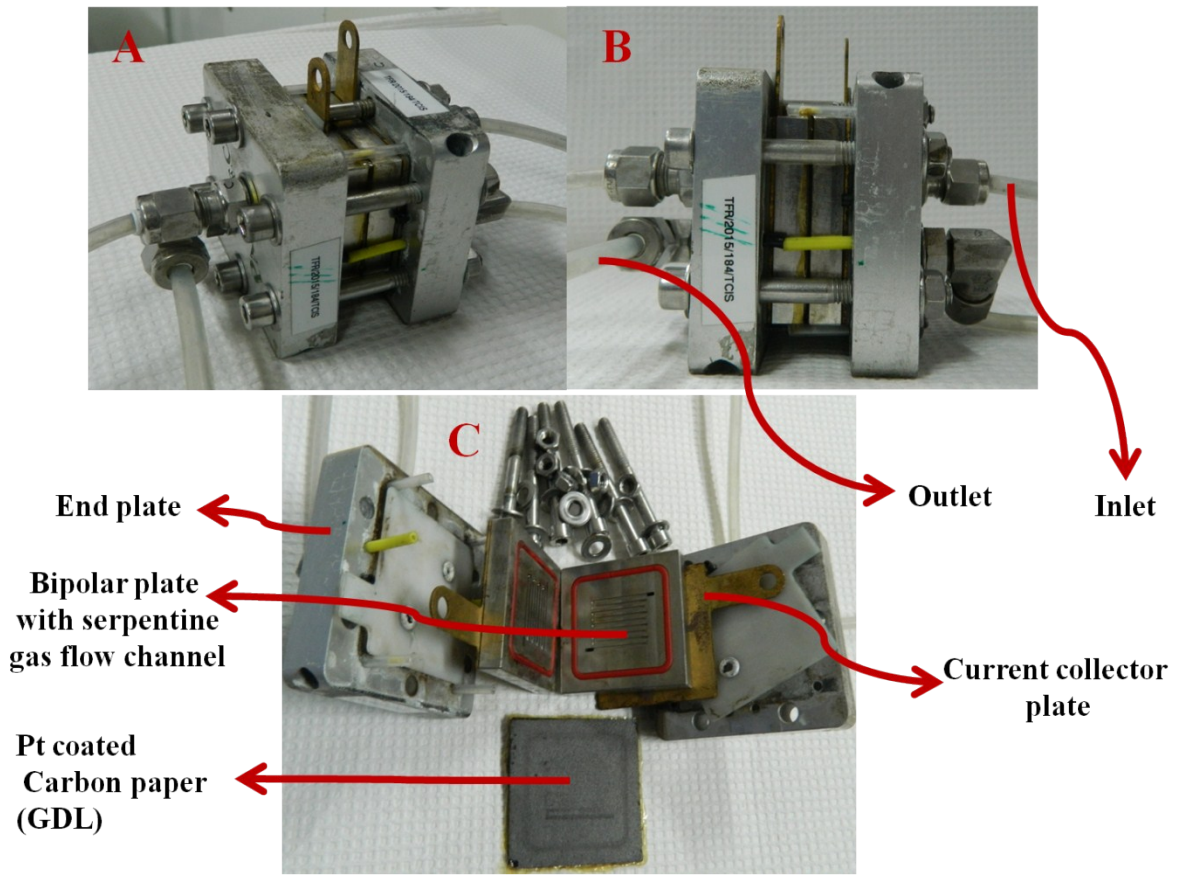

Fig. S8: The membrane-electrode assembly setup used for the alkaline water electrolysis chronoamperometry experiments. (A) & (B) showing assembled set-up whereas (C) is the disassembled arrangement with different parts.

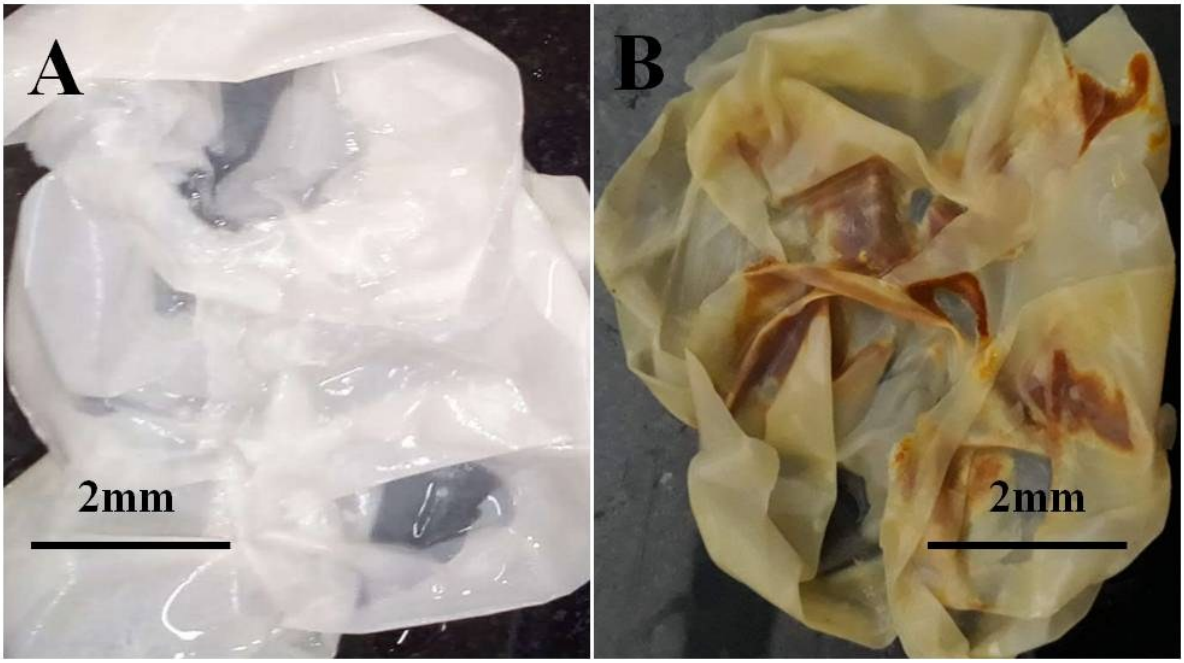

Fig. S9: The ESM (A) and FESM (B) membranes used for alkaline water electrolysis (MEA setup).

To quantify the catalytic activity of the electrode, electrochemically active surface must be determined. The active surface area of the Pt electrode (Pt wire) used in the water electrolysis setup is calculated by cyclic voltammetry.

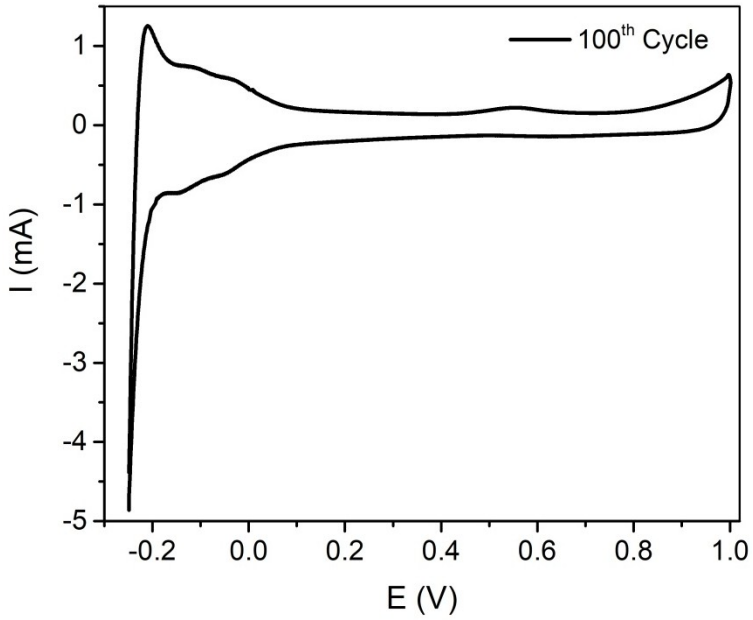

Fig. S10: CV (100th cycle) for platinum electrode in 0.5M H2SO4 solution performed at a scan rate of 200mV

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H^+ ions from the sulphuric acid are adsorbed on the surface of the Pt electrode during the reduction cycle. The adsorbed atoms of hydrogen are desorbed during the oxidation process.

$$H_{(ad)} \rightarrow H^+ + e^-$$

The number of electrons liberated during oxidation gives a measure of the number of desorbed hydrogen atoms which can be used to calculate the active surface area of the electrodes. The total charge corresponding to the hydrogen desorption is associated with the integral of the curve for a certain interval of potential, expressed as follows:

$$Q = \frac{1}{V_b} \times \int_{E_1}^{E_2} I.dE$$

Where V_b is the scan rate, I is the current and E is the associated voltage. The whole equation is divided by 210 $\mu C.cm^{-2}$ which is the theoretical electrical charge associated with monolayer adsorption of hydrogen on platinum.

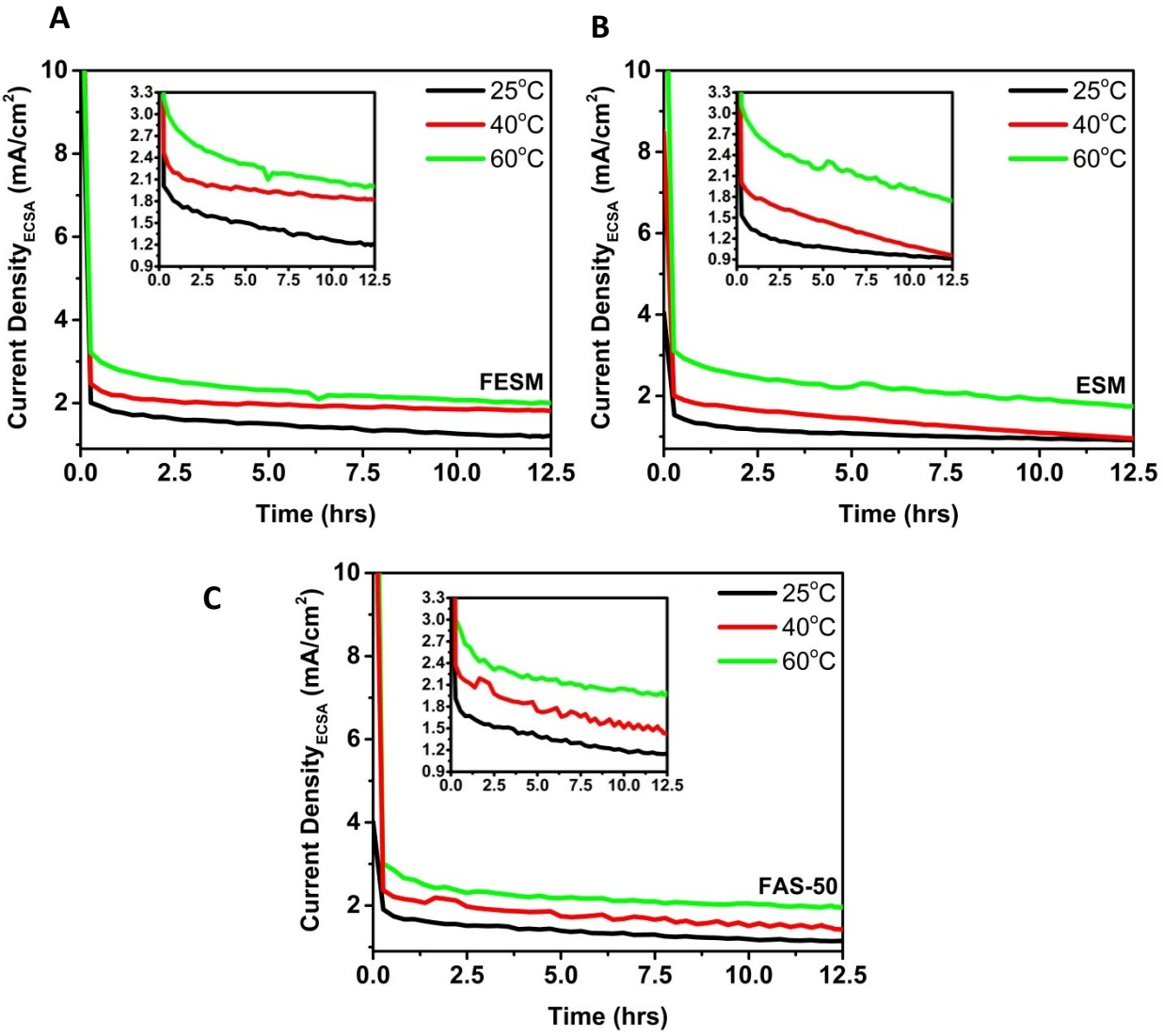

Fig. S11: Temperature dependent (at 25, 40 and 60 degrees) chronoamperometric (@ 2V) performed in 0.1M KOH. (A) FESM, (B) ESM, (C) FAS-50 membranes.

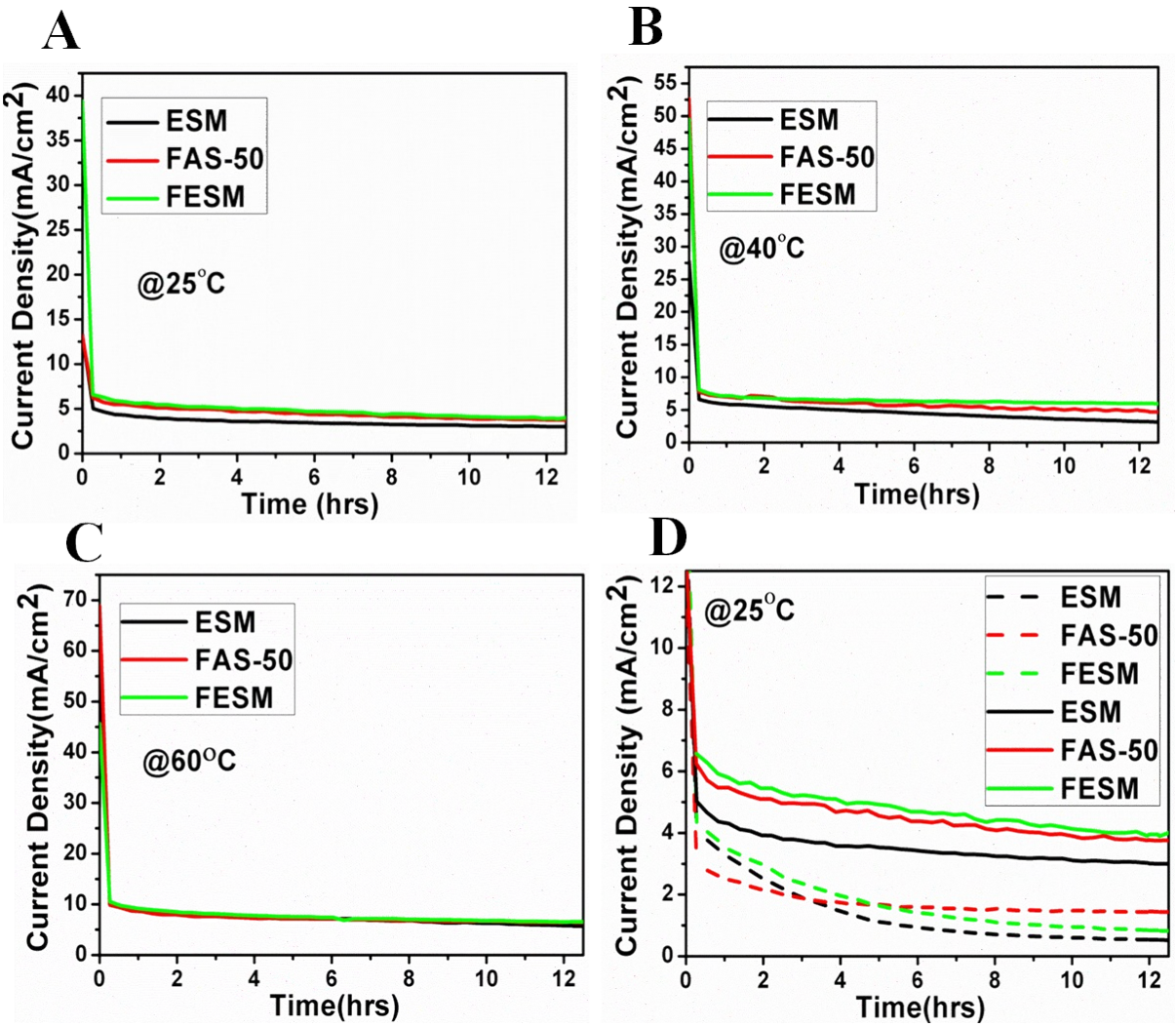

Fig. S12: Chronoamperometry (@ 2V) curves comparing performance of membranes at different temperature (A) 25°C, (B) 40°C, (C) 60°C (D) Comparison in basic (solid – 0.1M KOH) *vs* acidic (dotted – 0.1M HClO4) medium at 25°C(currents are normalized according to geometrical surface area.

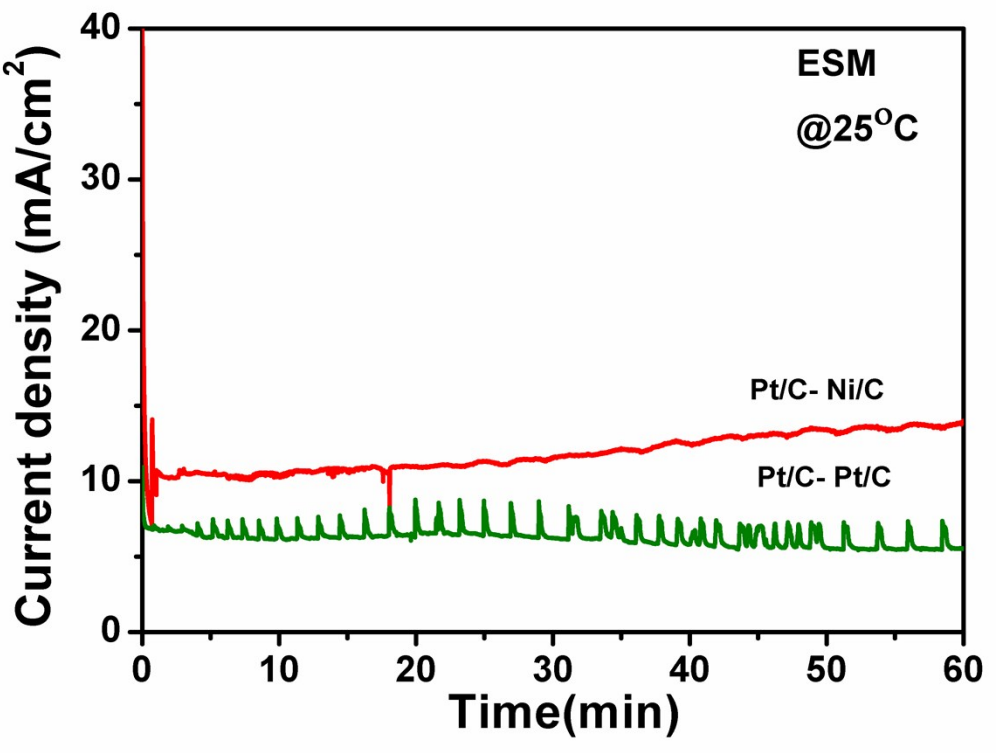

Fig. S13: Chronoamperometry (@ 1.6V) curve of ESM membrane with Pt/C cathode catalyst and Ni/C anode catalyst (red). The comparison is shown with the Pt/C-Pt/C catalysts system too (green).

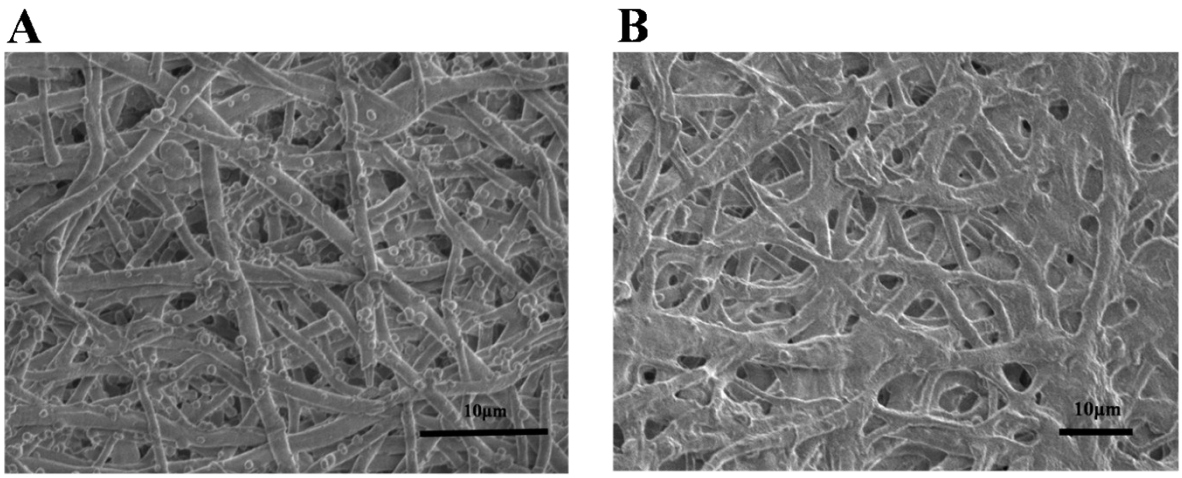

Fig.S14: FESEM images of (A) ESM and (B) FESM after 24 hours water electrolysis in 1M KOH.