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

Chemically Grown $Co_2P_2O_7$ Microplates: Extrinsic Pseudocapacitance Enriched Ultraflexible All-Solid-State Supercapacitor

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Supporting information S1

Materials characterization

The phase identification and purity of the prepared thin film were performed by using an X-ray diffractometer (XRD, Rigaku, Japan) with Cu k_α radiation (λ = 1.5418 A^o). X-ray photoelectron spectroscopy (XPS) measurements were acquired on Thermo scientific Inc., UK using Al as the excitation source. Thermo-Nicolet 6700 visible spectrometer with 532 nm laser was used to analyse Raman spectrum. Thermo Nicolet, Avatar 370 was involved to execute Fourier transform infrared spectroscopy (FTIR). Surface morphological characteristics were examined via field emission-scanning electron microscopy (FE-SEM, JSM-7800F, JEOL) equipped with energy dispersive X-ray spectroscopy (EDS) (Oxford, X-max). The high-resolution transmission electron microscopy (HRTEM) micrographs were produced from JEOL JEM-2100F instrument. The nitrogen adsorption-desorption isotherms were recorded on ASAP2010, Micromeritics to estimate Brunauer-Emmett-Teller (BET) surface area and pore-size distribution.

Electrochemical tests

The electrochemical scrutiny of developed product was conducted at room temperature using PARSTAT-4000 potentiostat/galvanostat (Princeton Applied Research, USA) through various analysis techniques like cyclic-voltammetry (CV), galvanostatic charge-discharge (GCD) and electrochemical impedance spectroscopy (EIS). Firstly, a standard three-electrode configured system in an aqueous electrolyte of 1 M KOH was employed to perform the electrode studies of as-prepared binder-free $Co_2P_2O_7$ thin film sample. The reference and counter electrodes used here were Ag/AgCl and platinum wire, respectively. Furthermore, two-electrode arrangement with counter (CE) and reference (RE) probes together as one terminal

and working (WE) probe as another, was employed to govern the electrochemical functioning of device.

Calculations

The electrode's specific capacitance (C_s) was calculated from CV curves at different voltage sweeping rates, as follows;

$$C_s\left(F\,g^{-1}\right) = \frac{\int i(V)dV}{m\,\nu\,V} \qquad (1)$$

where, $\int i(V)dV$ stands for CV integral area, m is the mass loading, ν denotes sweep rate, and V signifies active potential window of electrode.

Meanwhile, the capacitance values in different current densities can be obtained from GCD curves using eqn. given below;

$$C_s\left(F\,g^{-1}\right) = \frac{I\int Vdt}{m\,(V_f - V_i)^2} \qquad (2)$$

here, $\int Vdt$ accounts for the area under galvanostatic discharge curve.

As for the $Co_2P_2O_7$ based FSSD, its capacitance can be evaluated from above eqn. using mass loading as 2m. Subsequently, energy density (E) and power density (P) calculations were based on following eqns.;

$$E\left(W\mathrm{h}\,kg^{-1}\right) = \frac{0.5\,C_s V^2}{3.6} \qquad (3)$$

$$P\left(W\,kg^{-1}\right) = \frac{3600\,E}{\Delta\,t} \qquad (4)$$

where, Δt stands for discharge time.

Supporting information S2

Electrochemically active surface area (EASA) measurement

EASA of prepared $Co_2P_2O_7$ electrode was estimated from CV measurement by plotting non-faradaic current (i_{dl}) against the scan rate (ν) (Fig. S1) as represented by following expressions [1]:

$$i_{dl} = C_{dl}\nu \qquad (5)$$

$$EASA = \frac{C_{dl}}{C_s} \qquad (6)$$

where, Cs represents specific electrochemical double layer capacitance conventionally lying between 15 to 50 μF cm^{-2} which gives ECSA value of 183.4 m^2 g^{-1} for prepared $Co_2P_2O_7$ electrode.

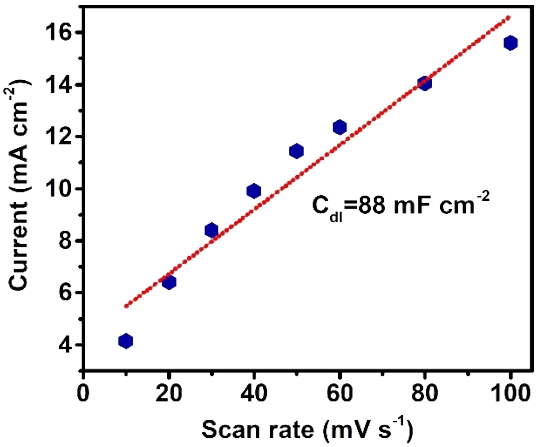

Fig. S1. EASA measurement: plot of non-faradaic current against scan rate.

Supporting information S3

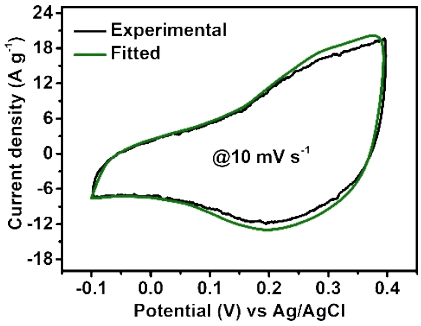

Fig. S2. Estimated and measured total current values of the $Co_2P_2O_7$ electrode at a scan rate of 10 mV s^{-1}.

Supporting information S4

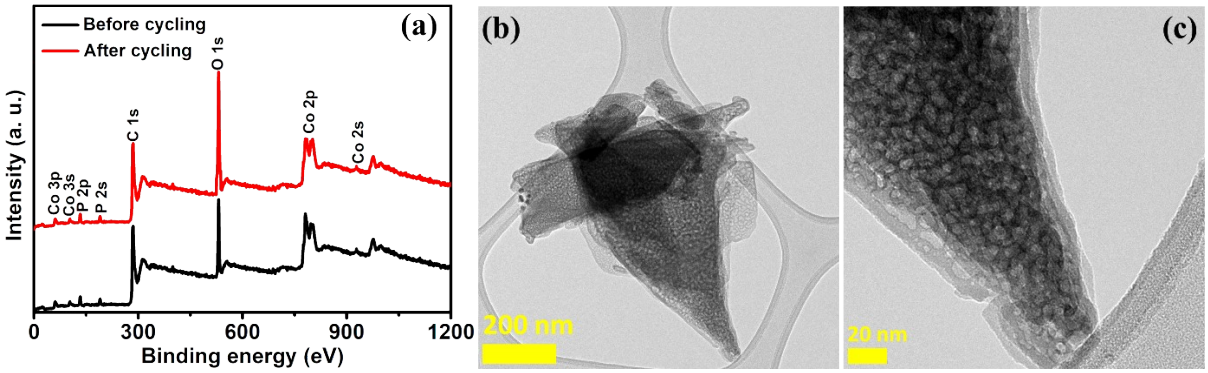

Figure: S3 (a) XPS survey scan spectra of $Co_2P_2O_7$ before and after 5000 cycles; (b & c) HRTEM images of $Co_2P_2O_7$ after 5000 cycles.

Reference

[1] L. K. Bommineedi, B. Pandit, and B. R. Sankapal, Int. J. Hydrog. Energy, 2021, 46, 25586.