

Supplementary Information

Results and Discussion

EDAX Spectrum of the recycled powder

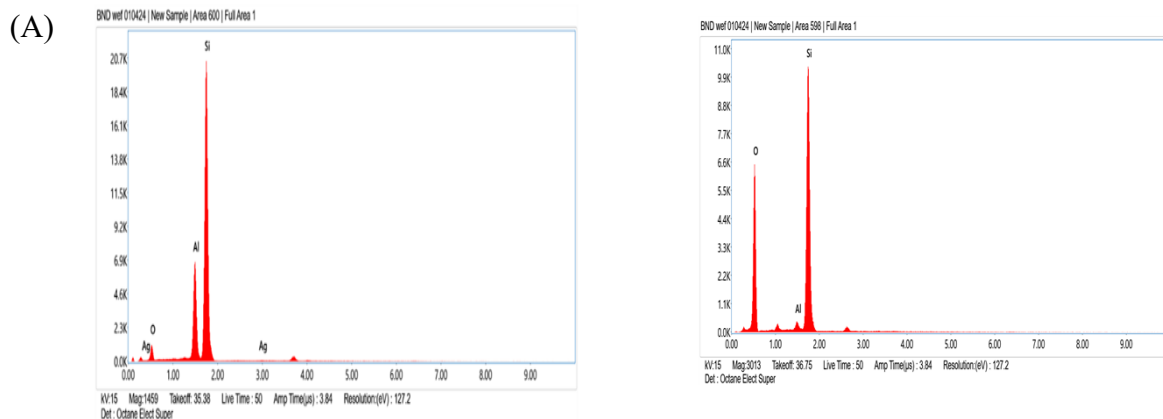
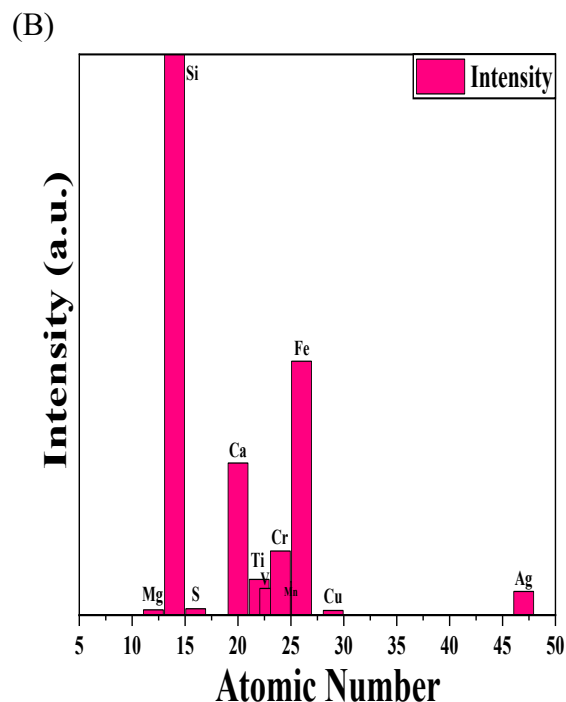


Figure S1. EDAX spectrum of silicon solar cell scraps powder (A) before chemical treatment and (B) after chemical treatment

(A)

At. numb.	Element	Series	Intensity	Concentration
7	N		0	< 0.0001%
41	Nb	K	0	< 0.0001%
28	Ni	K	0	< 0.0004%
27	Co	K	0	< 0.0073%
15	P	K	0	< 0.0135%
13	Al	K	0	< 0.0543%
11	Na	K	0	< 0.5085%
47	Ag	K	420	0.0002 ± 0.0000%
29	Cu	K	82	0.0012 ± 0.0007%
25	Mn	K	595	0.0135 ± 0.0044%
16	S	K	114	0.0182 ± 0.0104%
22	Ti	K	637	0.0231 ± 0.0043%
23	V	K	476	0.0365 ± 0.0120%
24	Cr	K	1143	0.0439 ± 0.0071%
12	Mg	K	93	0.0923 ± 0.0833%
26	Fe	K	4527	0.1211 ± 0.0067%
20	Ca	K	2712	0.1273 ± 0.0089%
14	Si	K	403318	99.5227 ± 0.0272%



X- ray Fluorescence Spectroscopy

Figure S2. (A) X-ray fluorescence spectroscopy data table and (B) Atomic number v/s Intensity graph from the table

EDAX Spectrum of the prepared electrodes

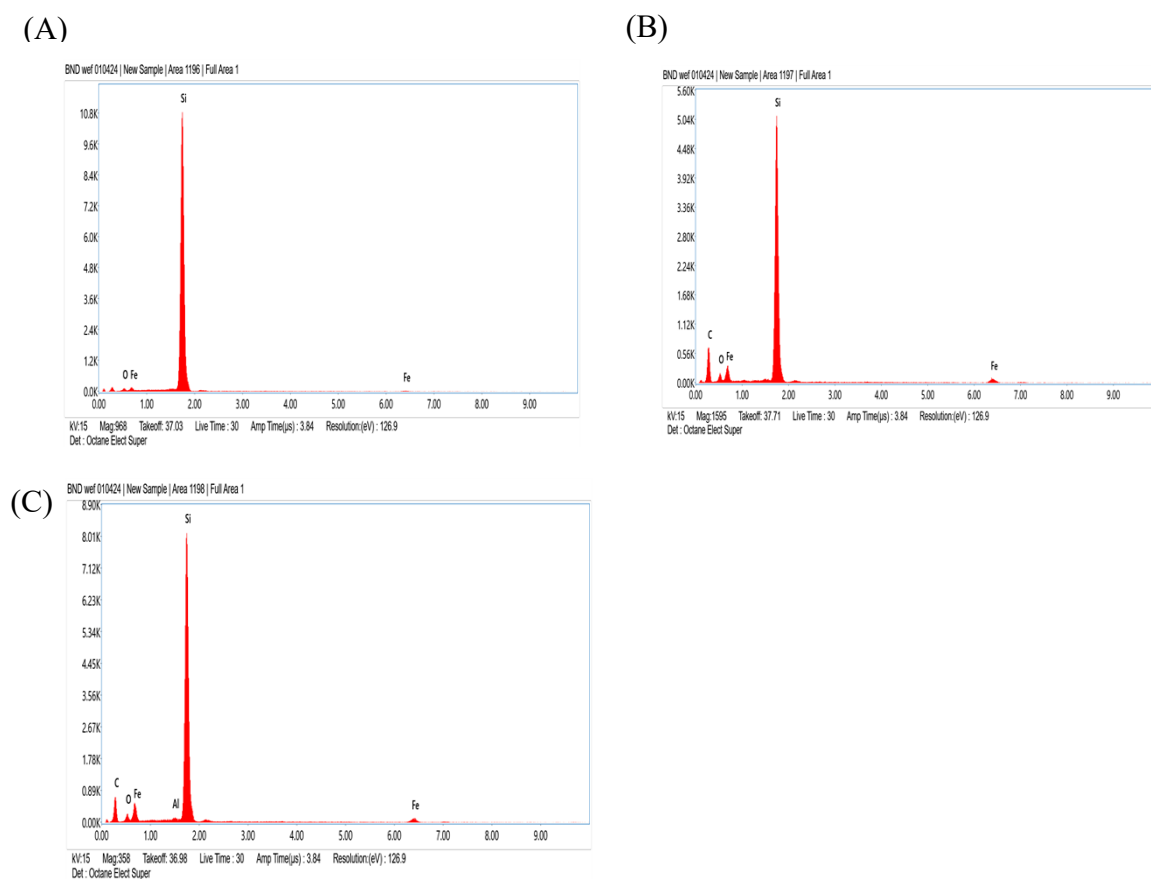


Figure S3. EDAX spectrum of electrodes prepared over (A) Cu foil, (B) ITO substrate and (C) graphite sheet

Galvanometric charge – discharge results analysis

The long-term cycling stability and Coulombic efficiency of the three different electrodes such as silicon composite slurry-coated copper foil substrate, ITO substrate, and graphite sheet substrate were evaluated over 500 charge and discharge cycles at a constant current of 0.005 A. As shown in the Fig. S4A, the silicon composite slurry coated copper foil electrode shows good electrochemical stability by maintaining a capacity retention of ~ 99 % throughout the complete 500 GCD cycles. The coulombic efficiency remains highest up to 87 % with minimum fluctuations in the charge - discharge behaviour.

The Fig. S4B highlights the plot between capacity retention % and coulombic efficiency % as a function of number of cycles which we got from the galvanometric charge – discharge data of 500 cycles for the recycled silicon composite electrode prepared over ITO substrate, that shows comparatively lower electrochemical performance. Although the capacity retention percentage remains good that is ranging from ~ 95 % to 100 %, but the coulombic efficiency shows significant fluctuations mainly during the initial cycles followed by eventual stabilization. This characteristic behaviour suggests the presence of higher internal resistance along with the probability of interfacial degradation as compared to that of the other two substrates.

In the Fig. S4C the slurry coated prepared graphite sheet electrodes exhibits appreciably consistent cycling behaviour with capacity retention percentage approaching ~ 95 % after prolonged cycling. The increment in coulombic efficiency was initially observed and then it stabilizes near ~95–98%, indicating improved electrochemical reversibility after initial activation. The continuous improvement over cycles can be attributed to the increase in the stability of the electrode along with the formation of a solid electrolyte interface.

Hence, out of the three different electrodes, Copper foil and graphite sheet electrode shows better performance and reversibility as compared to that of the ITO substrate.

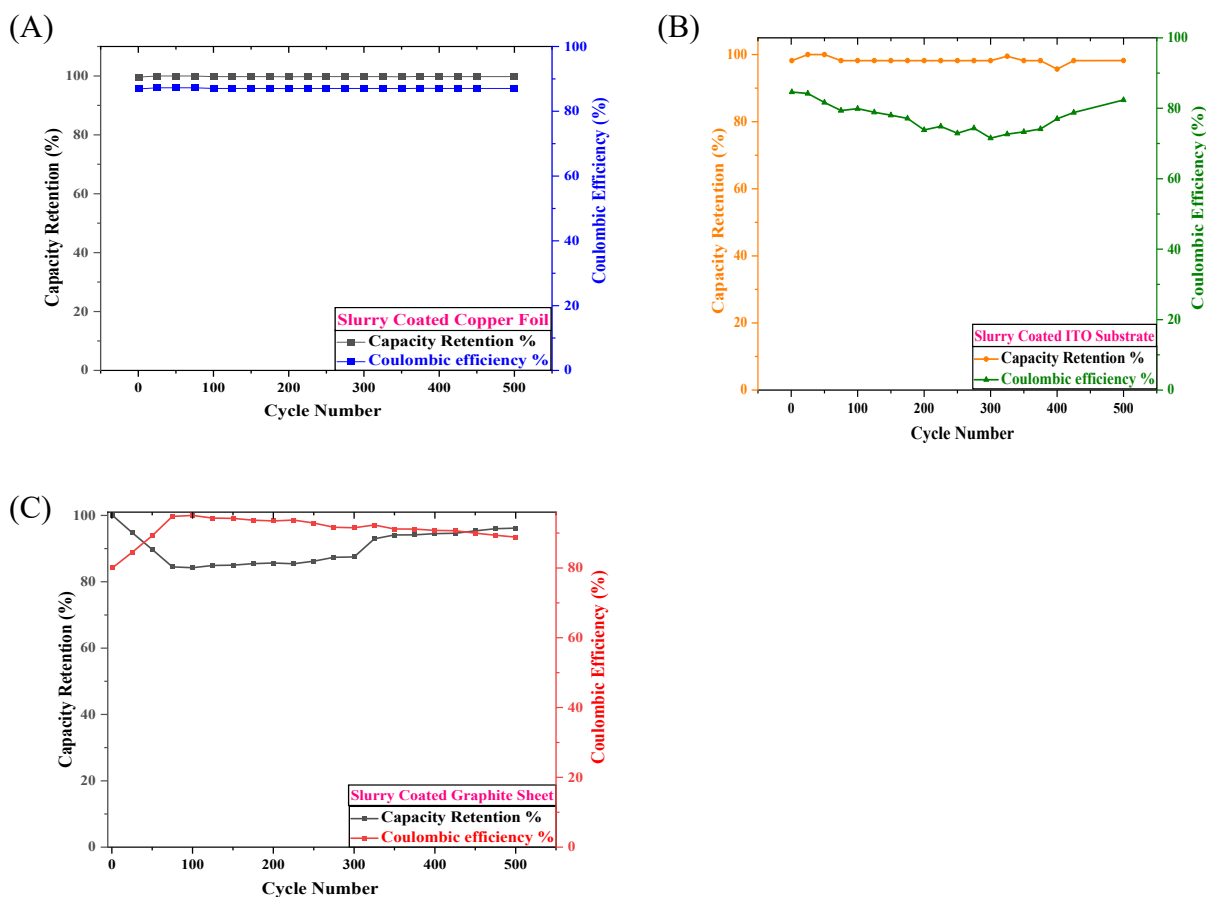


Fig. S4 Long-term cycling stability and Coulombic efficiency of slurry coated electrodes calculated from GCD measurements at a constant current of 0.005 A over 500 cycles. The variation of capacity retention % and coulombic efficiency % with the number of cycles are plotted for all electrodes. In (A) the slurry coated copper foil electrode showing stable capacity retention as well as consistent coulombic efficiency. The Fig. (B) describes slurry coated ITO substrate exhibiting appreciable capacity retention along with comparatively fluctuating Coulombic efficiency and finally in (C) the slurry coated graphite sheet signifying sustained electrochemical performance with gradual enhancement in its coulombic efficiency.

The electrochemical performance parameters are calculated based on the measurement of Galvanometric charge – discharge cycles extending up to 500 cycles. The value of specific capacitance was calculated from the GCD curves using the following equation -:

$$C_P = \frac{I \times \Delta t}{m \times \Delta V}$$

(1)

where I represent the applied current, Δt is the discharge time, m represents the mass of the active material, and ΔV corresponds to the applied potential window. In addition, the coulombic efficiency (CE%) and capacitance retention % were calculated using the calculated specific capacitance values and plotted in the y-axis v/s number of cycles.

Electrochemical impedance spectroscopy fitted plots images (from software)

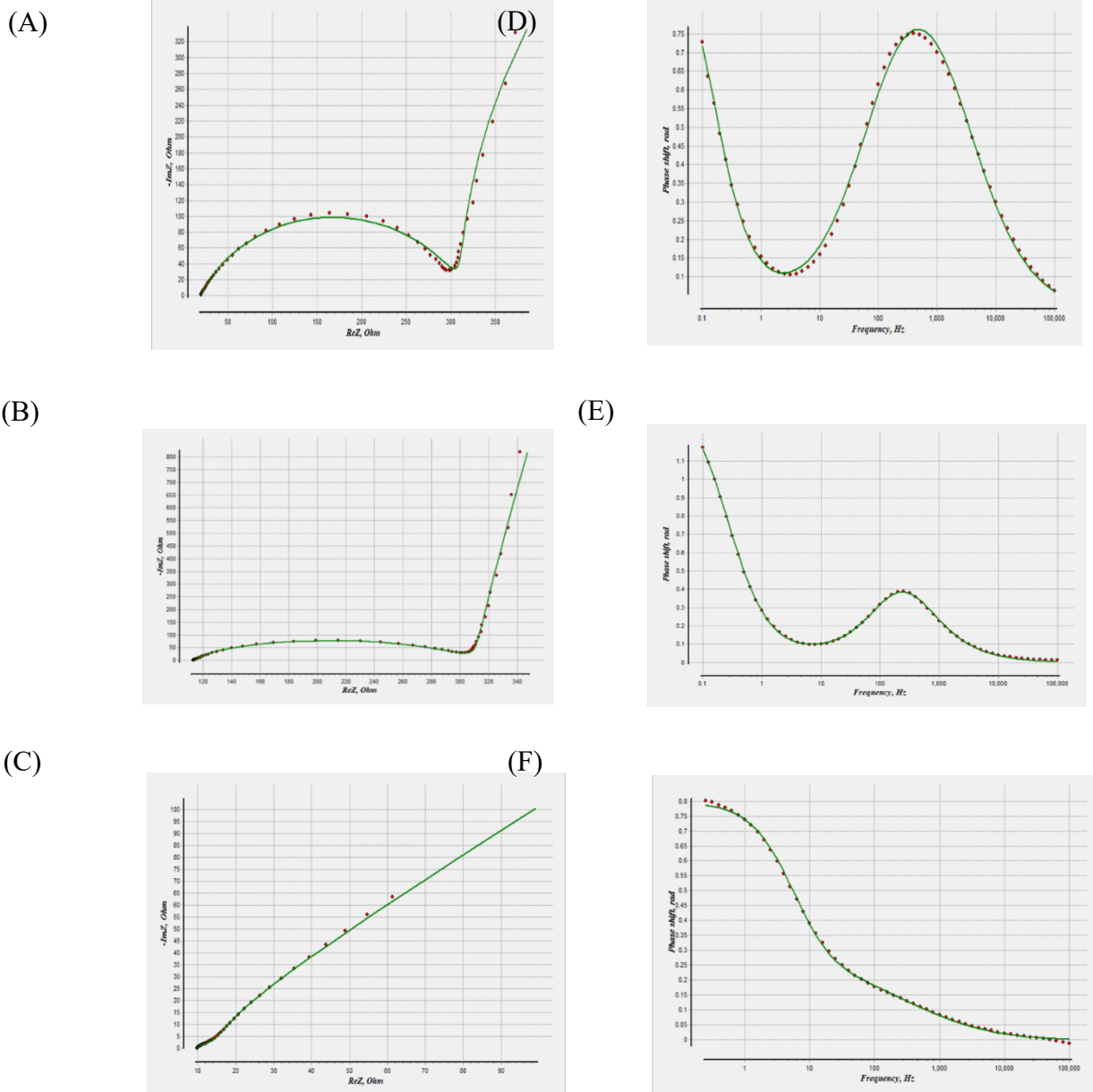


Figure S5. Fitted EIS plots of (A) slurry coated Cu foil electrode (B) slurry coated ITO substrate, (C) slurry coated graphite sheet electrode and Bode Plots of (D) slurry coated Cu foil electrode (E) slurry coated ITO substrate, (F) slurry coated graphite sheet electrode

Material/ Electrode System	Specific Capacitance	Stability	Electrolyte	GCD Current Density	CV Scan Rate	Reference
rGO/n-SiO₂ Composite	166.9 F/g	95.5 %	1 M KOH	0.5–5 A g⁻¹	5-100 mVs⁻¹	Ristiana et al.
rGO/SiO₂/TiO₂ composite	180 F/g	84 %	1 M KOH	1-10 A g⁻¹	5-100 mVs⁻¹	Anwer et al.
Graphene /SiO₂ composite	176 F/g	~ 85 % - 90%	1 M KOH	0.5–5 A g⁻¹	2-100 mVs⁻¹	RSC Adv., 2017
Graphene /SiO₂/MnO composite	298 F/g	91.5 %	1 M KOH	1–5 A g⁻¹	5-50 mVs⁻¹	Perez- Chavez et al., 2025
Micro and mesoporous SiC spheres	253.7 F/g	85% - 90%	1 M Na₂SO₄	0.5–5 A g⁻¹	5-100 mVs⁻¹	Kim et al. 2015
SiC porous Nanofibers	189.4 F/g	~ 85 %	3 M KOH	0.2 A g⁻¹	5-50 mVs⁻¹	Zhao et al.2016
Recycled Si/CTAB/Resin	400 mAh/g	~ 100 %	1 M LiPF₆ in EC: DMC	0.5 A g⁻¹	-----	Maryam et al.
Porous SiC/C composite	194.8 F/g	~ 80 %	6 M KOH	0.2 A g⁻¹	-----	Liu et al.
Recycled Si/SiO ₂ /CNT (Graphite Sheet as current collector)	163.92 F/g	~ 95 %	1 M LiClO ₄ in Propylene carbonate	5 A g ⁻¹	5-100 mVs ⁻¹	This work
Recycled Si/SiO ₂ /CNT (Cu foil as current collector)	143.23 F/g	~ 98 %	1 M LiClO ₄ in Propylene carbonate	5 A g ⁻¹	5-100 mVs ⁻¹	This work
Recycled Si/SiO ₂ /CNT (ITO as current	30.53 F/g	~ 95 %	1 M LiClO ₄ in Propylene carbonate	5 A g ⁻¹	5-100 mVs ⁻¹	This work

collector)						
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Table 1S. Comparison Table of Reported Silicon based electrodes with this experimental Work