

## Supplementary information

### Reduced graphene oxide derived from used cell graphite, and its green fabrication as eco-friendly supercapacitor

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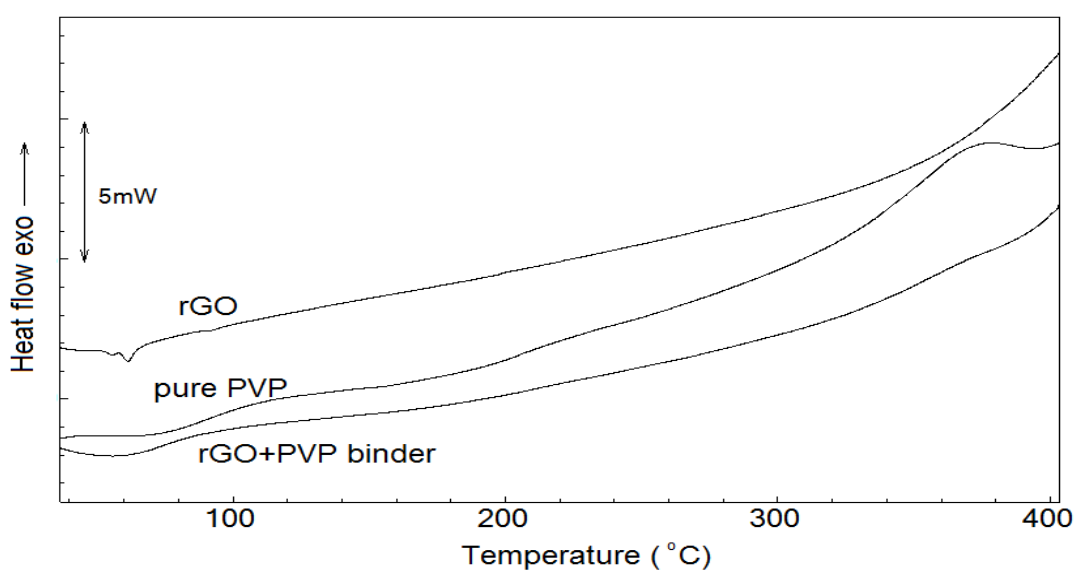
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#### Electrical conductivity

The electrical conductivity was determined using four-point probe method (SES instruments). The electrical conductivity of screen printed battery derived rGO+PVP binder was 0.011 S cm<sup>-1</sup>, whilst commercial derived rGO+PVP binder was 0.047 S cm<sup>-1</sup>.

#### Characterization

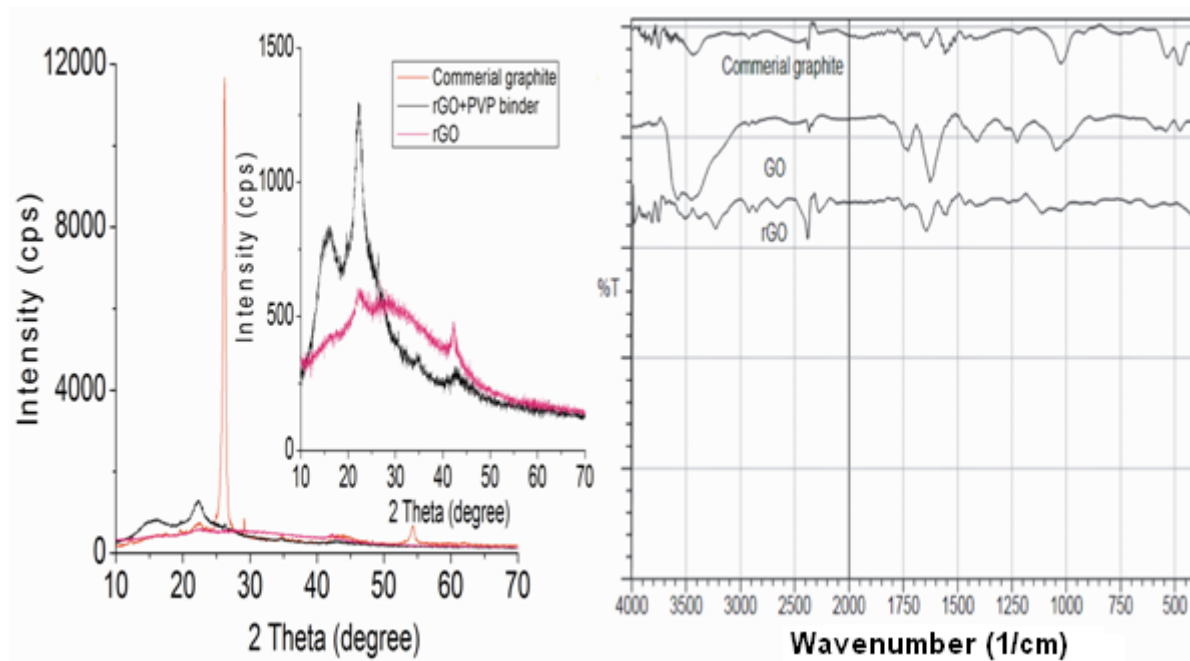
##### Differential scanning calorimetry studies



**Fig. S1** DSC thermograms of rGO, rGO+PVP binder and pure PVP.

In Fig. S1, the battery derived rGO thermogram shows decomposition of moisture at 70 °C, while PVP thermogram shows glass transition temperature at 130 °C and followed peak at decomposition temperature (380 °C). In rGO+PVP binder thermogram, the peak of decomposition temperature was absent indicating that there is some interaction between rGO and PVP binder as confirmed by FTIR method.

### XRD and FTIR studies

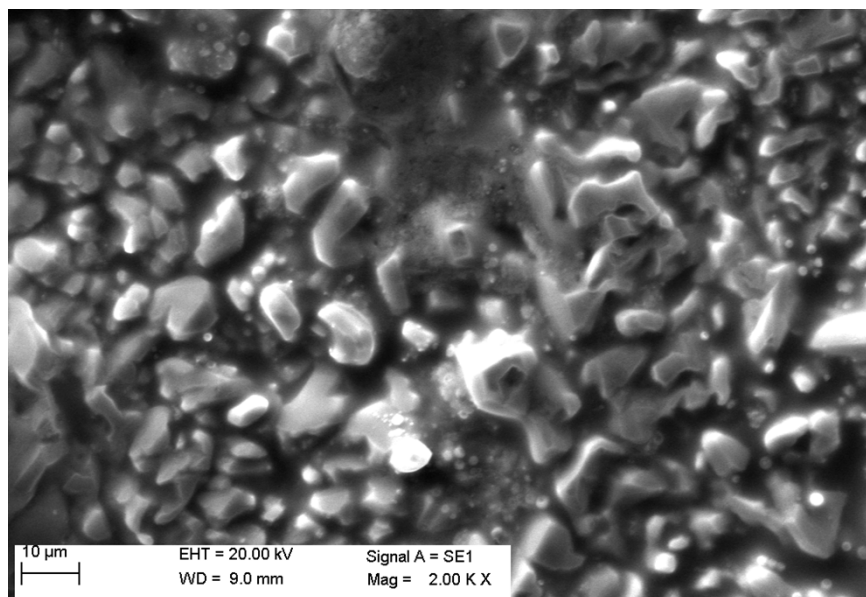


**Fig. S2.** (left) XRD pattern of commercial graphite, rGO+ PVP binder and rGO, (right) FTIR spectra of commercial graphite, GO and rGO.

Commercial graphite powder exhibited less intensity compared to battery graphite, indicating that battery graphite is more crystalline in nature. rGO XRD pattern showed broad peak with low intensity peaks of typical graphene indicating few layers of graphene are stacked with some defects. rGO+ PVP binder shows two peaks due to presence of amorphous PVP chains and few layers of graphene.

FTIR spectra of commercial graphite, GO and rGO showed similar peaks as that of battery graphite and thus corresponding peaks can be interpreted, respectively.

## SEM analysis

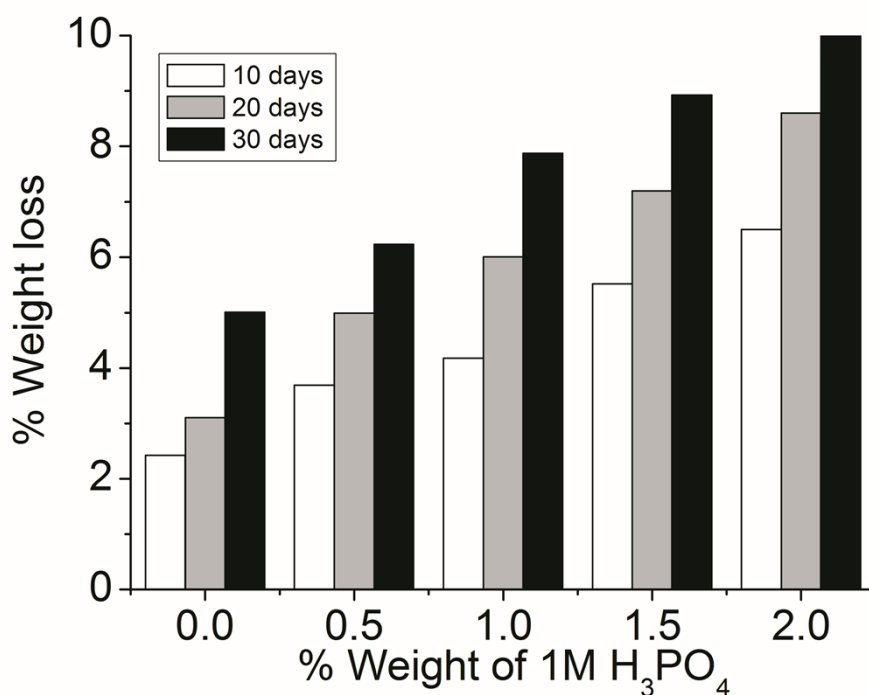


**Fig. S3.** SEM image of battery graphite powder

The SEM image of battery graphite (Fig. S3) shows hexagonal rods with lattice defects due to grinding of the battery graphite rod. Non-uniformity in particle size would have been overcome during oxidation and exfoliation of graphite and GO.

## Soil burial degradation studies

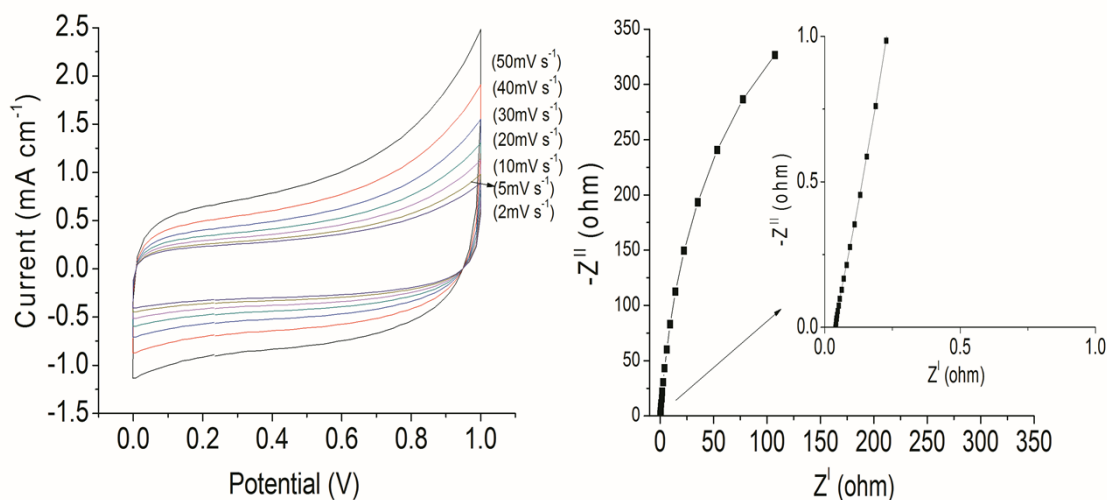
A short-term study for a period of 30 days has been conducted on the soil degradation behaviour of PVP- $\text{H}_3\text{PO}_4$  complex solid polymer electrolyte (SPE). Although long-term studies are more useful in characterizing the soil degradation of matrices (e.g., for a year or two), the short-term study does give an insight into the rapid evaluation of biodegradability of SPEs. The soil used was obtained from MIT garden. The soil was slightly acidic with a pH value of 6.7. The characteristics of the soil used were as follows: class, Ultisol (loamy type); electrical conductivity,  $0.08 \text{ dS m}^{-1}$ ; organic carbon,  $33 \text{ g kg}^{-1}$ ; CEC,  $16.2 \text{ cmol kg}^{-1}$ ; average nitrogen,  $151.4 \text{ mg kg}^{-1}$ ; average phosphorus,  $5 \text{ mg kg}^{-1}$ ; Ex. K:  $0.15 \text{ cmol kg}^{-1}$ ; Ex. Ca:  $4.6 \text{ cmol kg}^{-1}$ ; Ex. Mg:  $1.4 \text{ cmol kg}^{-1}$ ; Ex. Na:  $0.2 \text{ cmol kg}^{-1}$ . The preweighed SPE films were buried in soil in open desiccators. The soil was maintained at  $\sim 20\%$  moisture weight. The desiccators were kept at room temperature and the average temperature during the study period was  $30 \text{ }^\circ\text{C}$ . The films were taken out, washed with water, dried and weighed to know the degradation in the intervals of 10, 20 and 30 days.



**Fig. S4.** Degradation of SPEs having different acid concentrations.

In this study, the SPE films showed degradation of the order of about 2.2–10.02%. The film with higher acid concentration showed maximum degradation. This indicates that higher concentration of acid is able to break the intermolecular bonding of polymer chains and created more sight for degradation. The polymers exposed to soil might have initially undergone biodegradation, where microorganisms consume the oxygen component of PVP. Consequently, the oxygen can attack the newly generated surface with the formation of peroxides, hydro peroxides, oxides, etc., which promote the scission of polymeric chains into small fragments more susceptible to the attack of microorganisms. Soil bacteria and fungi might be responsible for the degradation.

## Supercapacitors studies



**Fig. S5** (left) CVs of supercapacitors fabricated using rGO obtained from commercial graphite at different scan rates, and (right) AC impedance plot of supercapacitors

The CV of supercapacitors fabricated using rGO obtained from commercial graphite showed almost rectangular shape, which is characteristic of ideal double layer capacitor. The stability and pattern was not altered significantly at different scan rates. The maximum specific capacitance was  $212 \text{ Fg}^{-1}$  at  $2 \text{ mV s}^{-1}$ . The specific capacitance value is comparative similar to that of rGO of battery based supercapacitors.

The AC impedance plot shows charge transfer resistance slightly lesser compared to that of rGO of battery based supercapacitors indicating that more uniform grain size and shape of rGO was obtained from commercial graphite. Moreover, the accessibility at the electrode/electrolyte interface has also been increased since the Warburg impedance (spike) is high compared to charge transfer resistance (semicircle). Equivalent circuit  $R1+Q2/(R2+W2)$  values of four elements are depicted in Table S1.

**Table S1:** Equivalent circuit values obtained by fitting AC impedance.

	R1 ( $\Omega$ )	Q2 ( $\text{F cm}^{-1}$ )	R2 ( $\Omega$ )
Battery graphite derived rGO supercapacitors	1.7	$1.1 \times 10^{-5}$	0.7
Commercial graphite derived rGO supercapacitors	1.2	$3.2 \times 10^{-5}$	0.3