Energy Storage using Graphene-Polymer nanocomposite thin film

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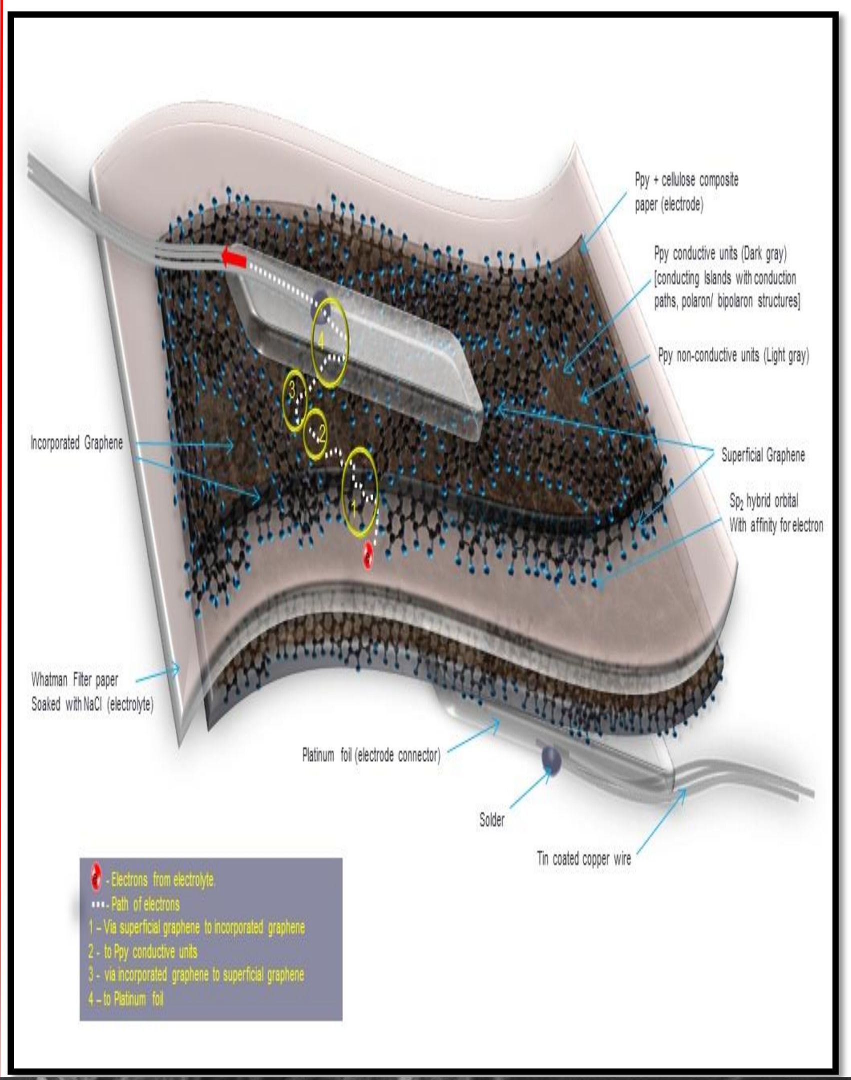
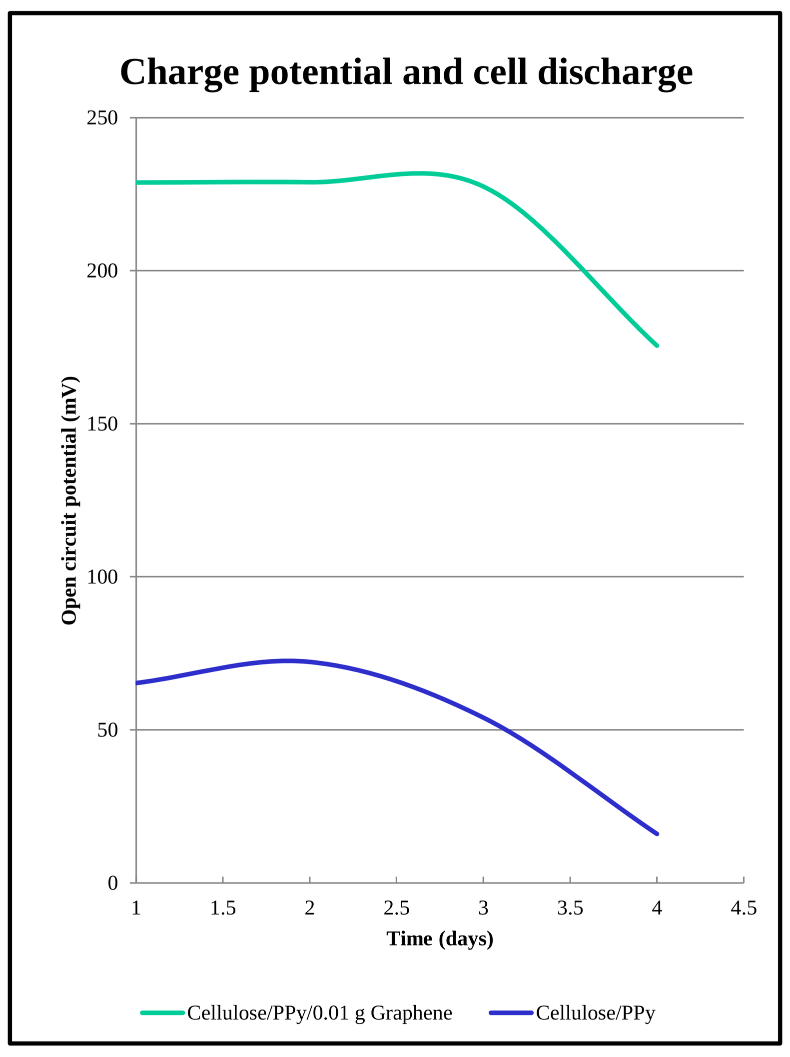
Abstract

There is an unmet need for efficient and environmentally-friendly ultrathin energy storage devices. Here we report a thin and flexible energy storage mechanism using electrically conductive polymer (ECPs) polypyrrole and atomically thin material and a highly conductive allotrope of carbon graphene which is coated on thin paper substrate made from *cladophora aegagropila* algae cellulose. The cyclic voltammetry data exhibits a capacitive behavior of the device, as do the multimeter readings of the voltage while charging and discharging exhibit a battery performance. The device demonstrated hybrid characteristics in which graphene behaved as an electrochemical double layer capacitance (EDLC) and PPy behaved as a pseudo-capacitor. With significant mechanical strength and flexibility, the device shows good power density, higher charge discharge cycles, and lower self discharge rates. TEM and SEM images show well dispersion of graphene on the surface of cellulose fibers. In order to decrease the effective weight of the insulating material and to achieve a controlled thickness of the electrode in few microns to nm range we propose the fabrication of the thin film using electrodeposition technique. Preliminary experiments show that using a small electrode of $1cm^2$ area we can achieve up to 1.5 V of potential across the terminal.

Method

We extracted the cellulose from C. *aegargrophilla* algae using a modified protocol. Cellulose is considered to be a suitable substrate for coating with the conductive polymers. Because of its high specific surface area, it has excellent wetting properties and individual cellulosic fibers can be mixed with conductive polymers. After the cellulose was extracted from the algae, it was coated with PPy using the polymerization process of pyrrole (Py). The final product after the polymerization was dried and was given a thin rectangular shape with approximate thickness of 100µm as shown in figure1**.** Graphene has gained much interest in recently because of its ballistic conductivity, mechanical strength and very high specific area. We used graphene dispersion with different concentration to observe the effect on the energy storage device





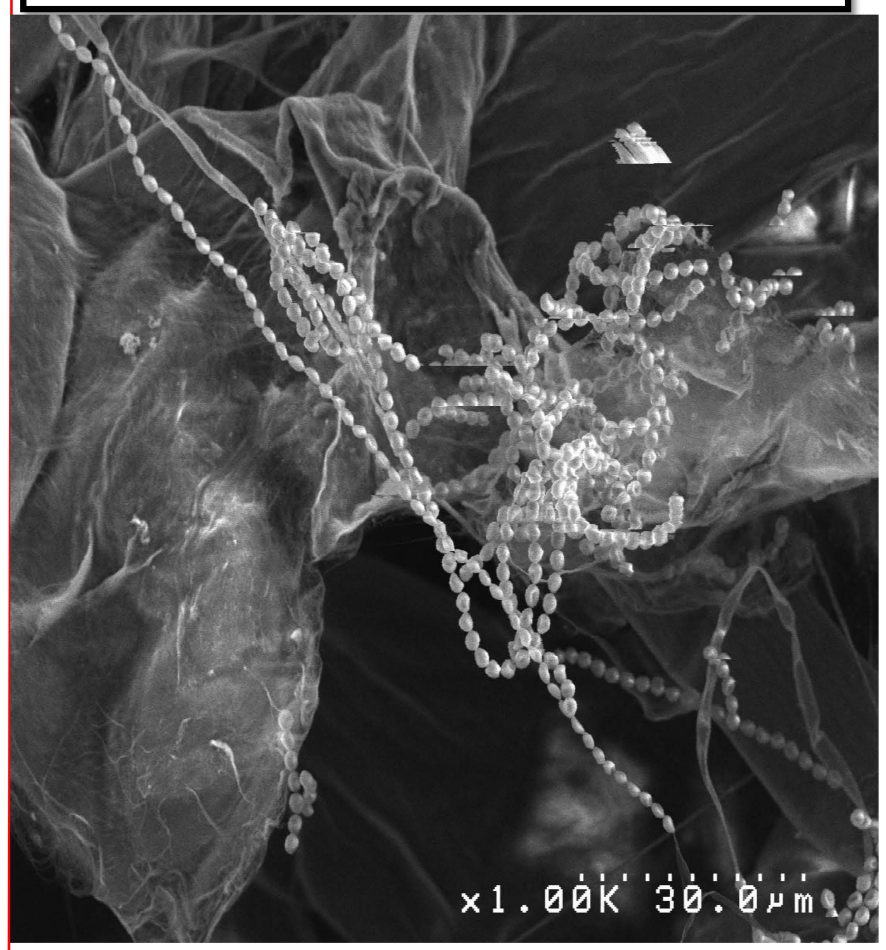


Figure 1: A) Schematic of final assembled device ,B) Charge potential and cell discharge, C) SEM image of the graphene dispersed in cellulose

Polypyrrole Film formation

We used cyclic voltammetry to deposit PPy film on the graphite electrode.

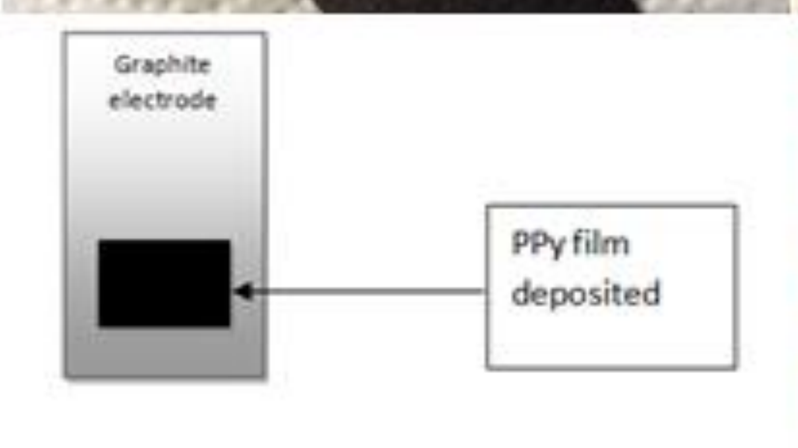
✓200ml of deionized and added to it 6.982ml of Py with 2.84 g of sodium sulphate.

✓We used three electrode setup to perform electrodeposition of PPy where CE was Pt, RE was Ag/AgCl and WE was graphite plate.

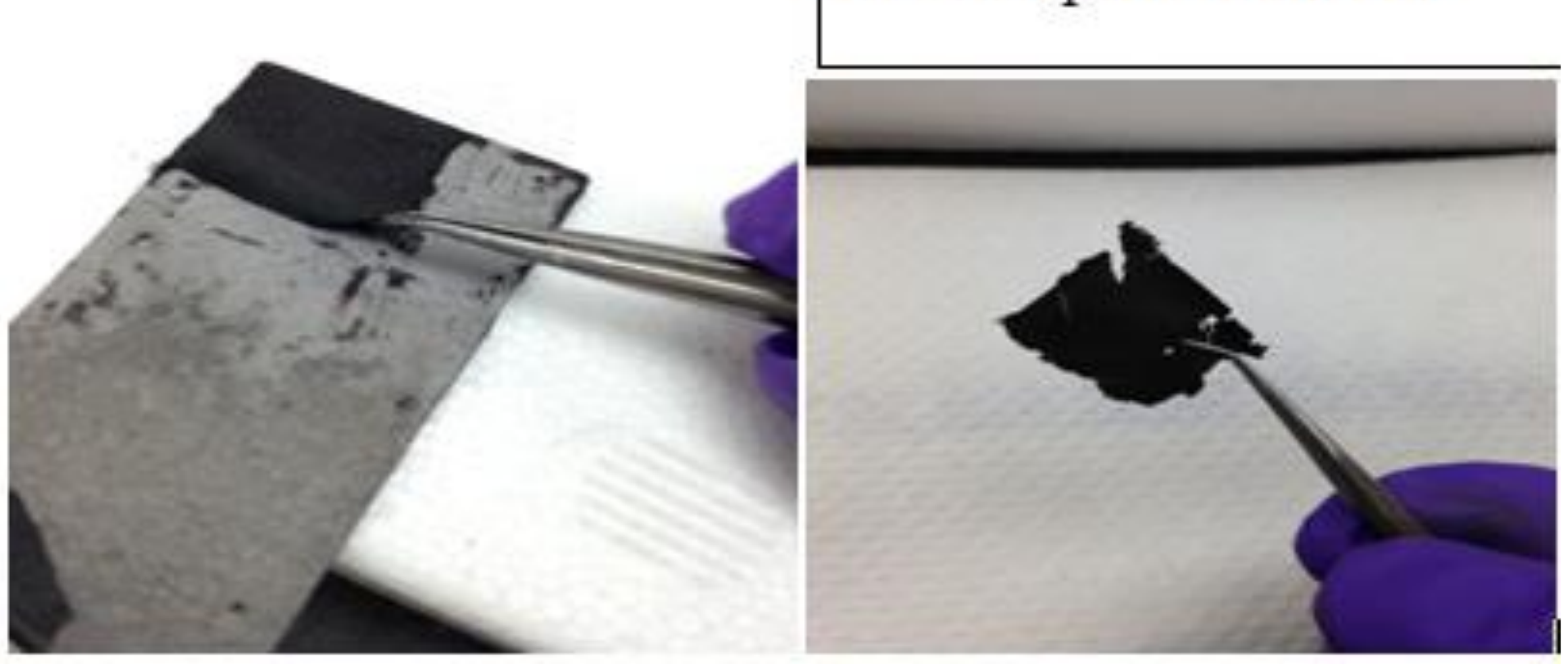
✓CV parameters: Vup = 900mV, Vdown = 800mV, scan rate 20 mV/s

✓PPy film deposited on Graphite electrode

# of cycles =100



[A, B] Images of the PPy film made using electrodeposition method, [C] Scheme showing the electrodepostion method, [D, E] images of the PPy-graphene film using electrodeposition method



Polypyrrole Film formation

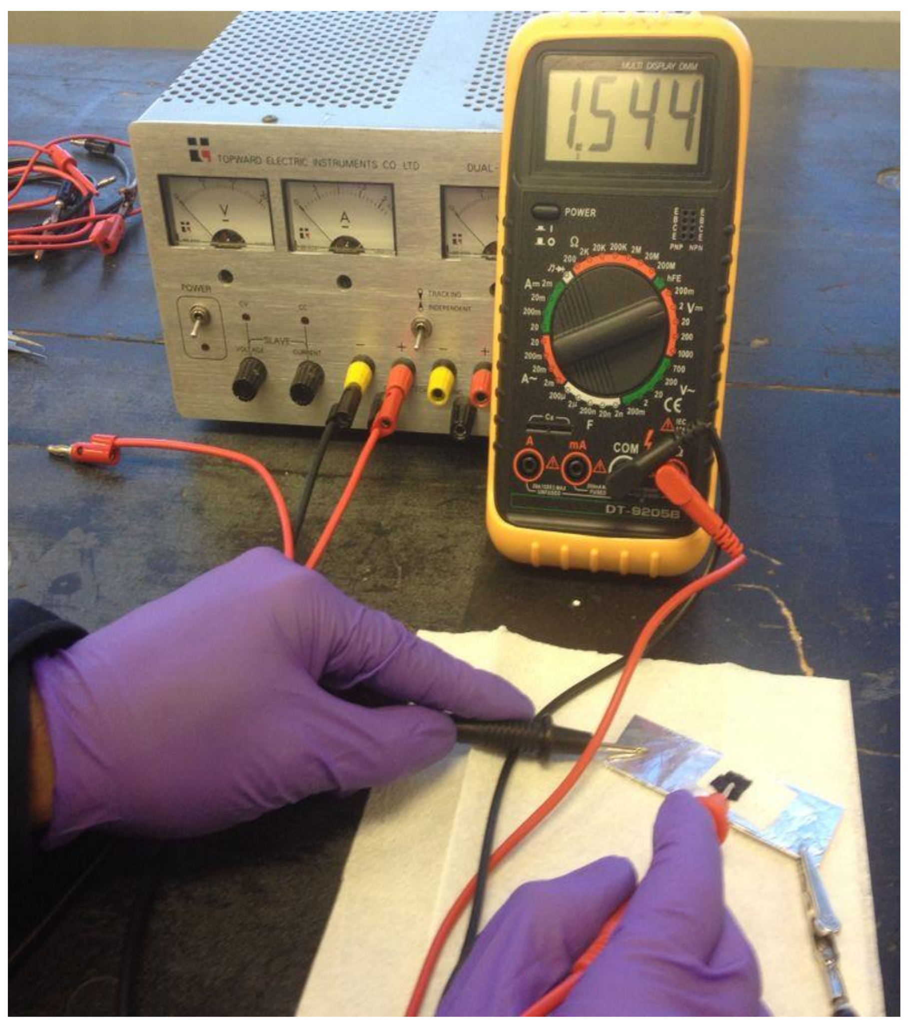
Concentration: 0.004g graphene/ 80ml Py solution (0.05g/ml)

CV parameters: Vup = 900mV, Vdown = 800mV, scan rate 10 mV/s

Ppy+graphene film deposited Graphite electrode

# of cycles =100

Upon connecting to the multimeter and charging the device for 5s the voltage across terminal reaches 1.5V



Hybrid System

The developed energy storage device is a hybrid system that stores charges based on electrochemical double layer capacitance (EDLC) principles as well as those of a pseudo capacitor. EDLCs store charge electrostatically using reversible adsorption of electrolytic ions on active material with high specific surface areas. Previously, other carbon-family substances, such as nanotubes, carbide-derived carbons, and nanohorns, have been successfully tested for EDLC applications. Graphene is an atomically thin layer of carbon atoms that stores charge electrostatically. PPy stores charges by the virtue of a reversible redox reaction between the PPy and electrolyte, which is a pseudo capacitive behavior. This hybrid system offers a better performance because it combines the properties of pseudo-capacitors and EDLCs.

Conclusion

The energy storage device exhibits a hybrid systems and hence we get the benefit of the high energy density as well as high power density. This device is mechanically flexible, strong and very efficient with a very low self discharge rate.