

# Chapter 7

## **Summary and suggestions for future work**

*This chapter deals with the summary of thesis, issues and suggestions for future works.*

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## 7.1 Summary

There are number of researchers have been working on exfoliated and layered and/or porous and activated carbonous materials since the last few years. Offcourse, these type of materials are played vital role as a matrix in adverse conditions for different applications like sensors and biosensors, catalysis, charge storage and so forth. However, the defective and porous surface textures in such materials impede charge conduction particularly in these applications. Therefore, incorporation of conductive additives (metals, ceramics, polymers and modified macro and micromolecules) are one of the choices to resolve these issues. For instance, among these additives, the conductive layers of CPs particularly, over the external surface of carbon in its composite state not only minimize the active material loss or defects but also open a new charge transport path with shorter path length. In this way, the composites materials (CPs associated carbonaceous) shows a synergic improvement in electron conductivity and leading to better electrochemical performance as well as their kinetics for charge storage. This thesis describes some facile strategy to synthesize new hybrids materials with enormously improved electrochemical performance both in potentiostatic and potentiodynamic conditions. Surface modifications of carbonic materials *via* CPs were performed under *in-situ* chemical polymerizations and characterized by various tools. Herein, all case of polymerization, the concentration of monomers and oxidants are chosen as 1:2 molar ratio.

Various fraction of PIn grown to the functionalized g-C<sub>3</sub>N<sub>4</sub> surface by *in-situ* polymerization in presence of APS and used as active electrode material for supercapacitor. In the fraction 1:2 g-C<sub>3</sub>N<sub>4</sub>-PIn, the optimal coating of PIn over g-C<sub>3</sub>N<sub>4</sub>

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surface is able to reduce the conducting path length of defective g-C<sub>3</sub>N<sub>4</sub>. That is why, we observed improved electrochemical performance over its individual components, another g-C<sub>3</sub>N<sub>4</sub>/PIn fractions and few studied electrode materials. The estimated Cs value is 115.8 F/g at current density 2 A/g in 1.0 M H<sub>2</sub>SO<sub>4</sub> electrolyte. This electrode shows 95% retention in their performance over 250 cycles. Here, we suggested that g-C<sub>3</sub>N<sub>4</sub>-PIn nanohybrids might be one of the emerging candidates as a metal-free electrode material for electrochemical applications such as supercapacitor.

Similarly, in another frame work, ACs derived from bio-weeds e.g. *Eichhorniacrassipes* is synthesized successfully at various pyrolysis temperatures and optimized for high surface area having best capacitive performance. The as-optimized ECC 800 AC has a large specific surface area (780 m<sup>2</sup>g<sup>-1</sup>) and a random-mesoporous network structure having an excellent capacitance of 292.64 F/g at current density 0.78 A/g. Further, this material possesses excellent cycling stability, as electrochemical storage capacity has maintained after 250 cycles. Importantly, this works gives a new source for electroactive carbon which is cheap, eco-friendly, sustainable, and high electroactive material with additional significance for environmental pollution and wastage management. After this optimization, PANi is polymerized successfully in similar condition as adopted to PIn polymerization but over Ox-ECC nanoflakes. Herein, again random-mesoporous networked Ox-ECC/PAni with the expanse of PANi over Ox-ECC surface increases the specific capacitance from 569.4 F/g to 1542.84F/g due to the presence of conducting PANi that (a) shorten the conducting path length of defective Ox-ECC and (b) favours charge transfer behavior by the diffusion-controlled process. Thereafter, this as-

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synthesized Ox-ECC/PAni possesses excellent cycling stability for 1000 cycles and reveals 88% retention in its specific capacitances without changing its morphological textures. These works encouraged us to work with PIn functionalization by Fe inserted-octaethylporphyrin which gave a new and facile strategy to first Fe insertion in OEP central core surface, and as-synthesized hybrid material for improved electrode material towards charge storage application. The Csp for Fe-OEP/PIn hybrid is obtained as 338.42 F/g at 2.5 A/g current density. Further, a charge transport properties of this hybrid was investigated in Al/Fe-OEP/PIn/ITO junction and showed 0.21 cm<sup>2</sup>/Vs mobility ( $\mu_h$ ), 2.1 ideality ( $\eta$ ) factor, and 0.60eV barrier height ( $\Phi_B$ ). The hybrid material reveals significant enhancement in electro activity as well as conductivity as compared to pure PIn. In conclusion, it is hard to say that, any material can be used as active material for all applications; because for a particular application based on service condition, active material(s) should have atleast some dominating property and one can only modify it for improved multi-functionalities.

## 7.2 Suggestions for future work

- The issues related to electrode material for electrochemical application is still need more research and engineering.
- This thesis employs the bio-waste derived carbon ECC having good surface area, in supercapacitor application. So it also urges to explore other applications like sensor, catalysis, gas scavenger etc. because such applications directly depend upon the surface area and conductivity. Therefore, it might provide some interesting results.

- This thesis employs only *in-situ* chemical polymerization. So it is also urges to explore electrochemical method for polymerization over such carbon surface.
- The as-prepared Fe-OEP/PIn has high electro-active property. So, in order to achieving high processable electro-active hybrid, it is important to further research on various CPs so far. This materials could be applicable for solar cell, FET etc. which might have future scope of the presented scheme.