Conjugated polymer nanocomposites for electrochemical hydrogen production and supercapacitor applications

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By

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Chapter 7

Conclusion

and

Future Scope

This chapter provides a summary of the thesis' findings and concludes with a proposal or prospective for the research work that can be done in this area in the future.

7.1 Summary

We found that the idea of nanostructuring and the synthesis of heterogeneously structured composite materials are effective techniques for increasing the surface area, stability, and active sites of composite materials. For instance, the incorporation of nanomaterials into the polymer matrix to form composites significantly alters the electrochemical performances because of the optimized synergistic effect. The polymer matrix (PCz, PPy) in the composites plays a vital role in the adhesion of nanoparticles and facilitates charge transfer by providing channeling during electrochemical activities. While the incorporation of the nanomaterials (WO_3, NFS, and Ni-doped NFS) into the composites exfoliates the polymer matrix and hence creates more electrochemical active sites and, consequently, better electrochemical performance. The composites discussed in this thesis for electrochemical applications are conjugated polymer-based, having electrochemical activity comparable to that of noble metal (Pt). These conjugated polymer composites have the advantage of being low-cost, environmentally friendly, noble metal-free, earth-abundant, easy to synthesize, and have high electrochemical activities. Therefore, they can be used as an alternative to replacing costly noble metals.

Chapter 1 presented an idea of the conjugated polymer, its historical background, classification, origin and mechanism of conductivity in conjugated polymers, properties, applications and limitations. This chapter also discussed the composites of the conjugated polymer, various techniques for composite formation, their improved properties and multiple applications. This chapter also discussed conjugated polymer composites' electrocatalytic and charge storage properties. This chapter also presented the basic principle and mechanism of electrocatalysis (FA oxidation and HER), charge storage, and their various important parameters. ***Chapter 2***

described the different tools and instruments used for characterizing the as-synthesized composite materials and electrochemical tools and terminology for application purposes. ***Chapter 3*** discussed the electro-oxidation of formic acid properties of polycarbazole/WO_3 composites (PCz/WO_3) prepared using various weight % of WO_3 incorporated into the fixed PCz matrix at the monomeric level. This investigation lightened on exploring low-cost, environmentally friendly electrocatalysts with high performance as an alternative for noble metals. ***Chapter 4*** discussed the HER properties of nanocomposites of polypyrrole and NASICON-structured NFS (PPy/NFS) synthesized using various weight % of NFS immobilized into a fixed amount of PPy matrix at the monomeric level. The optimized PPy/NFS composites ratio offers high catalytic activity and stability towards HER. ***Chapter 5*** further explored the enhanced catalytic activity towards HER of PPy/Ni-doped NFS composites via incorporating a varying amount of Ni doping into the NFS. The obtained results significantly highlight the role of Ni doping in NFS for enhancing the active sites and ease of charge transfer as well as ease of hydrogen adsorption resulting in excellent HER activity by PPy/NFS(Ni) composites. The improved HER catalytic activity of PPy/NFS(Ni) composites is comparable to that of noble metal Pt. It can be treated as an alternative to replacing the costly noble metal Pt catalyst for HER. ***Chapter 6*** discussed the charge storage property of PPy/NFS and PPy/Ni-doped NFS composites as a supercapacitor. The electrochemical results showed that the composites have good charge storage capacity and can be a promising candidate for supercapacitor application.

Future Scope

The investigation and exploration of electrochemical applications based on conjugated polymer composites in the research world using this thesis work are least but not limited. Although it covers promising candidates and efficient alternatives to the noble metals in the electrochemical application area, several significant spaces are available for exploration in other unreached major areas of applications as follows

1. Tuning the structure dimensions and properties of Conjugated polymer via incorporation with various fillers/nanomaterials opens a broader opportunity to work on enhancing its conductivity and activity as well as mass transfer to bring it for commercial electrochemical and electronic applications.
2. Since the catalytic oxygen evolution and reduction components have gotten less attention, there is still much room for research on electrochemical H_2 generation employing conjugated polymer-based catalytic active sites.
3. Since the electrocatalytic process occurs on complex composite structures, the reaction mechanism of redox processes involving conjugated polymer composites is unresolved and needs to be re-investigated precisely and thoroughly.
4. Electrochemical conversion and energy storage must be coupled with renewable energy sources to supply and fulfill energy demands continuously.
5. Research efforts should be given for conjugated polymer composites to improve the redox processes to meet the requirements of industrial applications with as high performance as noble metals.

An enormous opportunity is available to work on using conjugated polymer composites to address the global energy demand and environmental issues; it requires the concerted efforts of the research community. The work compiled in this thesis is a small but impactful effort in this direction and definitely will have more enormous implications.