

ABSTRACT

Plastic pollution has become a pressing global concern, necessitating innovative solutions for waste management. Among the various forms of plastic waste, Styrofoam® presents a particularly challenging concern due to its high volume, low value, and non-biodegradable nature. Efforts to address this problem have led to the exploration of conventional and advanced methods for converting plastic waste into valuable materials. In this study, conversion of Styrofoam waste into valorized nanomaterials i.e. graphene quantum dots (GQDs) have been carried out using microwave and hydrothermal pyrolysis and suitability of non-polar and polar GQDs thus synthesized is assessed for advanced applications. Simulation studies were first carried out in understanding and elucidating the mechanism involved in the conversion of Styrofoam to GQDs. Combining simulation methodologies with experimental techniques provided detailed insights for the conversion process of GQDs, facilitating optimization and functionalization strategies. Microwave and hydrothermal pyrolysis methods were selectively explored to synthesis nonpolar and polar GQDs, respectively, from the Styrofoam waste.

The synthesized GQDs from Styrofoam waste exhibited remarkable properties that enabled their suitability for application across diverse fields. The GQDs were utilized as coatings, imparting durable hydrophobicity and excellent self-cleaning properties to fabrics. Furthermore, GQDs served as crucial components in security ink formulations, offering a solution to combat counterfeit currencies, falsified documents, and tampered goods. In energy storage systems, such as supercapacitors, GQDs played a pivotal role in enhancing capacitance and energy density. When incorporated into electrode materials, GQDs facilitated efficient charge transfer and ion diffusion, resulting in improved electrochemical performance. Additionally, GQDs were employed as labeled sensors for metal ion detection, thereby offering selective and sensitive metal ion detection capabilities. A rapid and accurate detection of metal ions in various environments, including different water sources and industrial processes was thus enabled. Lastly, the development of an app for on-site detection of colorimetric elements enhanced the practical utility of the technology. A mobile phone based user-friendly platform provided cost-efficient alternative to conventional spectroscopic methodologies, thereby enabling real-time monitoring and analysis across a wide spectrum of materials and surfaces. The synthesis and applications of GQDs synthesized from Styrofoam waste presented a significant advancement not only for plastic waste management but also for the development of advanced nanomaterials for diverse advanced applications.