

Abstract 5 – Paper ID: 106**Engineered Graphene Quantum Dots for High-Temperature Supercapacitors: A Pathway Toward Sustainable and High-Performance Energy Storage**

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Abstract

In this study, advanced electrode materials based on graphene quantum dots (GQDs) and polyaniline (PANI) composites are developed to achieve high-performance supercapacitors for next-generation energy storage systems. GQDs were synthesized via a microwave-assisted hydrothermal (MAH) route, providing a rapid, energy-efficient, and scalable method. Pristine GQDs exhibited promising electrochemical behaviour when integrated with PANI through chemical oxidative polymerization performed at both room temperature and 4°C. The low-temperature synthesis induced distinct morphological transformations in the GQD/PANI composites, as confirmed through XRD and FESEM analyses, resulting in improved charge-storage capability.

Symmetrical supercapacitor devices fabricated using the optimized GQD/PANI electrodes delivered high specific capacitance along with superior energy and power densities. To ensure device operability under extreme conditions, room-temperature ionic liquid (RTIL) and bentonite-based gel electrolytes were employed. These electrolytes enabled stable performance at elevated temperatures up to 150°C, demonstrating excellent thermal stability, sustained energy density, and prolonged cycling durability under harsh operating environments.

Overall, the synergistic material architecture, combined with temperature-adaptive electrode engineering, highlights the potential of GQD-based hybrid electrodes as robust, high-energy, and high-temperature-resilient candidates for next-generation supercapacitor applications. This work positions GQD/PANI composites as a promising platform for advanced electrochemical energy storage technologies.

Keywords: Graphene quantum dots, Polyaniline composites, Supercapacitors, High-temperature energy storage, Ionic liquid gel electrolytes