ABSTRACT

This thesis outlines the creation and description of a ternary composite with zirconium oxide (ZrO_2), graphitic carbon nitride ($g\text{-}C_3N_4$), and polyaniline (PANI). The composite was designed by combining the wide band gap and chemical stability of ZrO_2, the visible light activity of $g\text{-}C_3N_4$, and the high electrical conductivity of PANI. This was confirmed by optical studies using UV–Vis spectroscopy and Tauc plot analysis, where the band gap was 3.09 eV for the composite compared to 2.47 eV for pristine $g\text{-}C_3N_4$, indicating successful band gap tuning. Photoluminescence (PL) spectroscopy revealed an emission peak of about 2.8 eV, demonstrating suppressed recombination of photogenerated charge carriers due to interactions within the composite. Cyclic voltammetry (CV), galvanostatic charge–discharge (GCD), and electrochemical impedance spectroscopy (EIS) were also systematically studied. The redox peaks on CV curves obtained at scan rates of 10 to 50 mV/s showed a quasi-rectangular shape, indicating pseudocapacitance and good rate performance. GCD curves at current densities of 1 to 3 A/g exhibited symmetric charge–discharge profiles with minimal IR drop, confirming high Coulombic efficiency and reversibility. EIS analysis showed a small semicircle in the high-frequency range and a linear Warburg tail, indicating low charge transfer resistance and efficient ion diffusion. These improvements result from the synergistic nature of ZrO_2, $g\text{-}C_3N_4$, and PANI, which contribute high surface area, charge transport capabilities, and mechanical strength, respectively. Overall, $ZrO_2/g\text{-}C_3N_4$/PANI is a promising multifunctional compound suitable for supercapacitors, photocatalysis, and photoelectrochemical systems due to its custom optical and electrochemical activity.