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Graphene-guided growth of rare earth-doped $Bi_2Mo_2O_9$ nano self-assembly for enhanced asymmetric supercapacitor device performance†

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Abstract

Nanoparticle self-assembly optimizes super-capacitive behaviour with sustainable life and ascertains the most optimal active material for electrodes. A nano self-assembly consisting of rare earth (RE = Ce and Gd)-doped $Bi_2Mo_2O_9$ ($Bi_{2-x}RE_xMo_2O_9$) and reduced graphene oxide (rGO)-modified $Bi_{2-x}RE_xMo_2O_9$ (GM-$Bi_{2-x}RE_xMo_2O_9$; RE = Ce and Gd) was synthesized using a gel combustion method. The phase formation of the as-synthesized nano self-assembly was confirmed using X-ray diffraction. Raman spectroscopy and XPS analysis confirmed the optical properties and chemical composition of the prepared materials. The morphology of the synthesized nano self-assemblies and their effect on the rare earth doping and rGO modification were explored using SEM and TEM. Brunauer–Emmett–Teller analysis confirmed the surface area and pore volume. Through CV, GCD, and EIS analysis, the electrochemical performance of the nano self-assembly was examined. GM-$Bi_{2-x}RE_xMo_2O_9$ (RE = Ce and Gd) exhibited high specific capacitance in a three-electrode configuration along with feasible cyclic stability. The fabricated asymmetric supercapacitor device of GM-$Bi_{1.9}Ce_{0.1}Mo_2O_9$ and GM-$Bi_{1.9}Gd_{0.1}Mo_2O_9$ exhibited an extraordinary energy density of 58.96 W h kg^{-1} and 56.67 W h kg^{-1}, respectively, with an equivalent power density of 750 W kg^{-1}. However, GM-$Bi_{1.9}Gd_{0.1}Mo_2O_9$ exhibited a higher cyclic stability of 86.55%, with the fabricated GM-$Bi_{1.9}Ce_{0.1}Mo_2O_9$ asymmetric device providing a superior super-capacitive performance. We improved the electrochemical performance of bismuth molybdate by rare earth doping and rGO modification, and it can potentially be a desirable electrode material.