Rational Design of Nanocarbon- Nanoparticles Heterostructures for Catalytic Reduction of 4-nitrophenol to 4-aminophenol

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Abstract

In the past decades, nanocarbons (NCs) including carbon nanotube (CNTs), graphene, graphene nanoribbon (GNR), and graphene quantum dot (GQD) have spurred intensive interests due to their exceptional physical and chemical properties. Recent theoretical and experimental works demonstrated that NCs are promising materials for many applications such as energy generation and storage, chemical and biosensors, catalysis, nanocomposites, and nanoelectronics. To further boost the advantages of NCs, metal nanoparticles (NPs) were selected to form various types of NC-NP heterostructures for applications including, energy storage, photocatalyst, electrochemical sensors, and especially catalysis. The unique nature of NC-NP composite materials with high surface area and exceptional materials properties can assist the chemical reaction to lower the activation energies and increase reaction rates of reactions.

Here we report a rational design of NC-NP composites for catalysis. We used the catalytic reduction of 4-nitrophenol (4-NP) to 4-aminophenol (4-AP) as a testing platform to exam the catalysis properties of NC-NP heterostructures. 4-NP has been a persistent wastewater constituent from various industries. Consequently, a catalytic method is sought-after in reducing 4-NP to less toxic and commercially important4-AP. In our work, we comprehensively prepared various NC-NP heterosctrutures. The NCs were including multi-walled CNT, singled-walled CNT, graphene, graphene oxide, GNR, GQD, and the NPs were including different metal NPs including Pt, Ag, and Au. Detailed materials characterizations and systematic catalysis study indicates that GNR-PtNP heterostructures showed exceptional catalytic performance with a normalized reaction rate constant (k_n) of 120 x 10^{-3} $mmol.s^{-1}g^{-1}$ for 4-NP reduction. Our work suggests that nanoengineering of NC-NP composites can open a new venue to develop an effective and stable catalyst for environmental protection.