Leveraging Electrochemistry to Uncover the Role of Nitrogen in the Biological Reactivity of Nitrogen-Doped Graphene

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The introduction of dopants, particularly nitrogen, into the conjugated 2D carbon structure of graphene offers an effective approach to tailor electronic structure and chemical reactivity of graphene. This chemical doping approach has led to advancements in (bio)electronics, (bio)sensors, electrocatalysts, and energy storage and conversion. However, to date, very little is known about the influence of the nitrogen (N) heteroatom on the biological activity of graphene. Given the growing evidence from our previous research that supports the importance of reactive sites, electron exchange, and electron transport, this work aims to elucidate the bioelectrochemical properties of N-doped graphene. We prepared a suite of systematically modified N-doped graphene materials using the hydrothermal method. The degree of N-doping and types of N in doped graphene is tailored by using two different nitrogen precursors (urea and uric acid) and thermal annealing under different temperatures. The electrochemical activity for the oxygen reduction and oxygen evolution reactions confirms the different electron transfer properties between the N-types. The bioactivity of the prepared materials is evaluated as the inactivation of a bacterial model organism, *Escherichia coli,* and the propensity to oxidize the intracellular antioxidant, glutathione. Given the importance of oxygen and electron transfer in mechanisms of biological activities, the results from electrochemical experiments further our goal of connecting the electronic behavior and the mechanism underlying differential biological activities of 2D carbon nanomaterials. Additionally, this work explores the potential to tailor functional performance (electrochemical reactions) and hazard outcomes (the biological implications) through advancement towards global rational material design guidelines.