Lightweight graphene oxide-based sponges with high compressibility and durability for dye adsorption

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Development of lightweight porous structure with high compressibility and mechanical durability is in great demand to promote graphene-based materials from fundamental research to engineering applications. In this study, graphene oxide (GO)-based sponges with hierarchical porous structures were synthesized by a simple freeze-drying method. By controlling and optimizing their structures, the lightweight GO-based sponges can offer excellent structural integrity even after being compressed at 95% strain, indicating the extremely high compressibility. The outstanding mechanical durability were also demonstrated by cyclic compression testing at 50% strain for 10,000 cycles. Considering the severe dye pollution problem, the sponges were investigated for methylene blue adsorption. It was found that the sponges with high selectivity during adsorption can have the maximum adsorption capacity up to 476 mg g\(^{-1}\). More importantly, the sponges were demonstrated with extraordinary recyclability along with a very simple recycling process and also high recycling efficiency (above 86% after the 10th cycle). It was experimentally demonstrated that if their morphological structures are carefully designed and optimized, the GO-based porous structures can exhibit the ensemble of outstanding compressibility and durability, and equally importantly the excellent adsorption performance. Therefore, it could show great promise of such nanomaterial-based sponges as excellent adsorbents for wastewater purification.

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1. Introduction

Graphene has been attracting much attention for around two decades due to its extraordinary blend of electrical property (high intrinsic mobility at 200,000 cm\(^2\) V\(^{-1}\) s\(^{-1}\)) [1], thermal conductivity (~5,000 W m\(^{-1}\) K\(^{-1}\)) [2], optical transmittance (~97.7%) [3], and high Young’s modulus (~1.0 TPa) [4]. This two-dimensional (2D) material has been investigated for the potential to use in a wide range of applications including energy storage [5], sensors [6], touch screen [7], toxic material removal [8] and so on. As one derivative of graphene, graphene oxide (GO) has abundant oxygen-containing functional groups including carboxylic groups, phenolic hydroxyl groups and epoxide groups on its surface. They can also offer a good dispersion feature in aqueous solutions and an ample chance to develop chemical modification on their surface by simple employing hydrothermal treatment. However, although they have been extensively investigated due to their great potential, it has been rarely realized in real-world applications. This can indicate that special efforts should be made particularly on the promotion of such a 2D nanolayered material to commercialization in various engineering applications.

The transformation of 2D nanoscale graphene/GO into a three-dimensional (3D) macroscopic porous structure might be one of the feasible ways to promote their practical applications, which can result from their light weight, high specific surface area, and