

# A new route to synthesize polyaniline-grafted carboxyl-functionalized graphene composite materials with excellent electrochemical performance

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**Abstract** A new route to synthesize polyaniline (PANI)-grafted carboxyl-functionalized graphene (PGCG) composite material is established. In this paper, PGCG is first prepared through a two-step carboxyl-functionalized process. PANI can be grafted and grown on the surface of graphene due to the covalent bonding existing between the carboxyl-functionalized graphene and polyaniline. This method cannot only improve the mechanical performance and adaptive performance of polyaniline effectively, but also reduce the production costs and environmental pollution during the synthetic process. Therefore, a green and industrial synthetic process is achieved. X-ray diffraction (XRD) patterns, X-ray photoelectron spectroscopy (XPS) and Fourier transformed infrared (FTIR) all confirm that composite materials have been prepared successfully. Scanning electron microscopy (SEM) and transmission electron microscopy (TEM) indicate that the as-prepared PGCG has regular structure. Thermogravimetric analysis (TGA) indicates that the addition of graphene nanosheets can significantly improve the thermostability of PANI. Moreover, the as-prepared material exhibits superior electrochemical performance. As an electrode material for supercapacitors, PGCG possesses high specific capacitance of 158 F g<sup>-1</sup> at a scan rate of 25 mV s<sup>-1</sup> and 147 F g<sup>-1</sup> at 50 mV s<sup>-1</sup> in 1 M H<sub>2</sub>SO<sub>4</sub>. The Nyquist

plot also confirms that the PGCG has low charge transfer resistance and good capacitive behavior. These great properties make PGCG a novel electrode material with potential applications in high-performance energy storage devices.

**Keywords** Graphene · Polyaniline · Composite · Nanoparticle · Carboxyl-functionalized

## Introduction

Graphene is a two-dimensional (2D) carbon atom material with the hexagonal lattice structure [1]. Since the direct investigation of Novoselov et al., who mechanically exfoliated graphene in 2004 [2], graphene has been considered as one of the most important materials in the current century due to its excellent physical [3], thermal [4], optical [5] and electrical properties [6] and so on. The thermal conductivity of graphene can reach 3000–5000 W m<sup>-1</sup> K<sup>-1</sup>, 10 times as much as copper [4]. The suspended graphene, on the other hand, exhibits a mobility approaching 200,000 cm<sup>2</sup> V<sup>-1</sup> s<sup>-1</sup> for the carrier density below 5 × 10<sup>9</sup> cm<sup>-2</sup> at low temperatures, far more than the single-crystal silicon and carbon nanotube conductivities [7]. In addition, the white light absorbance of a suspended graphene monolayer is about 2.3% (or transmittance of 97.7%) with a negligible reflectance of <0.1% [6]. Moreover, pristine graphene exhibits a high Young's modulus (≈1 TPa) [7] and large theoretical specific surface area (SSA, 2630 m<sup>2</sup> g<sup>-1</sup>) [8]. All these outstanding properties have thus aroused great research interest from the fundamental study to various applications of graphene.

However, everything has an opposite side: graphene with complete structure has high chemical stability [9], inert surface [10], high van der Waals forces within layers [11] and easy aggregation ability [12]. Moreover,

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