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Well-dispersed chromium oxide decorated reduced graphene oxide hybrids and application in energy storage

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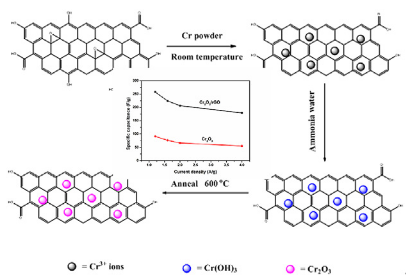
HIGHLIGHTS

- Cr powder can reduced graphene oxide (GO) to reduced GO (rGO).
- The one-pot reaction between GO and Cr powder to obtain the well dispersed Cr^{3+} ions decorated rGO.
- The Cr_2O_3/rGO hybrids show excellent electrochemical performances than the pure Cr_2O_3.

GRAPHICAL ABSTRACT



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ABSTRACT

This report describes an artful method to prepare Cr_2O_3/reduced graphene oxide (rGO) using Cr powder and graphene oxide (GO) as follows: the one-pot reaction between GO and Cr powder to obtain the well dispersed Cr^{3+} ions decorated rGO, followed by adding ammonia water and annealing to easily transform to Cr_2O_3/rGO hybrids. The introduction of rGO can improve the surface area and conductivity of the Cr_2O_3/rGO hybrids. Therefore, the Cr_2O_3/rGO hybrids show excellent electrochemical performances than pure Cr_2O_3, such as the three times as high specific capacitance of Cr_2O_3/rGO than pure Cr_2O_3. In addition, the Cr-based material could be also used as a class of electrode material of supercapacitors.

1. Introduction

With the progressive depletion of fossil fuels and ever increasing environmental problems, the new and green energy systems are being developed. Supercapacitors, solar cells and Li ion batteries are the potential energy storage devices and have attracted many researchers' attention. Due to their environmental friendliness and sustainability, supercapacitors have been broadly used as the energy storage devices in electric vehicles, digital communication devices like mobile phones, and solar cells [1,2]. Supercapacitive materials commonly store electrical energy based on either the formation of an electrical double layer or fast surface redox reactions [3,4]. Generally, the materials with Faradic redox reactions exhibit higher capacitance than electrical double layer capacitive materials [5].

Transition metal oxides have been intensively investigated as the electrode materials, owing to the multiple oxidation states,

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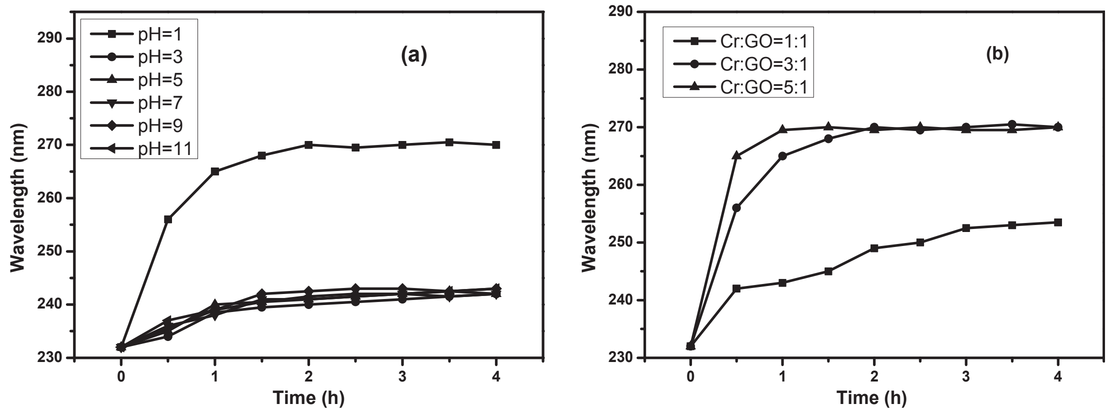
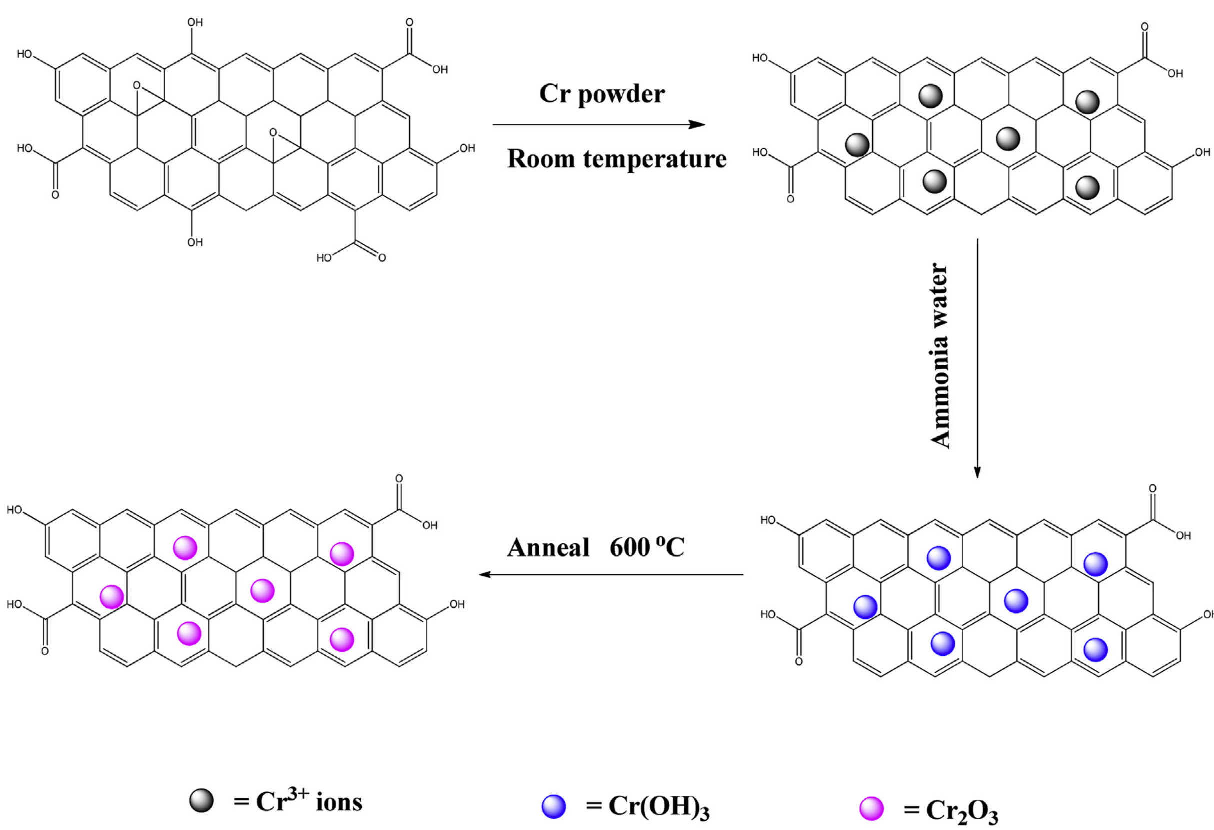


Fig. 1. Effect of GO suspension pH (a), and the Cr/GO ratio (b) on the reduction of GO by Cr powder. Cr/GO = 3:1, pH = 1, room temperature (unless otherwise state).

such as RuO_2 [6], NiO [7], Co_3O_4 [8], Fe_2O_3 [9], MnO_2 [10], MoO_3 [11], V_2O_5 [12] and so forth. The transition metal oxide Cr_2O_3 is also low-cost and easy-availability, making it a promising candidate for the supercapacitive materials. However, like other transition metal oxides, Cr_2O_3 has some problems that restrict its supercapacitive performances, including the poor dispersion and conductivity. The poor dispersion causes the low surface area and not obvious porous structure.

In order to avoid these limitations, the proper substrate could be selected for Cr_2O_3. Graphene, a two-dimensional (2D) carbon material, have prominent and inherent chemical and physical properties, such as good flexibility [13], high electrical conductivity (10^3~10^4 S/m) [14], large surface area (2675 m^2/g) [15] and ultra-high mechanical strength (130 GPa) [16]. Therefore, graphene is the very potential substrate for dispersing the metal oxides. In addition, the pure graphene is also an electrical double layer capacitive material and widely used in energy storage devices.

This report describes an artful method to prepare Cr_2O_3/reduced graphene oxide (rGO) using Cr powder and graphene oxide (GO) as follows: the one-pot reaction between GO and Cr powder to obtain the well dispersed Cr^{3+} ions decorated rGO (GO can be reduced by Cr powder, and simultaneously Cr^{3+} ions can be absorbed onto the rGO through the electrostatic attraction), followed by adding ammonia water and annealing to easily transform to the Cr_2O_3/rGO hybrids. The obtained Cr_2O_3/rGO hybrids were used as the electrode materials for supercapacitors and their electrochemical performances were analyzed by cyclic voltammetry (CV), galvanostatic charge/discharge (GCD) and electrochemical impedance



Scheme 1. The preparation procedure of the Cr_2O_3/rGO hybrid.