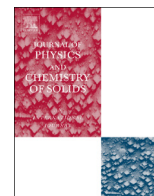




ELSEVIER

Contents lists available at ScienceDirect

Journal of Physics and Chemistry of Solids

journal homepage: www.elsevier.com/locate/jpcs

Catalytic behavior of graphene oxide for cement hydration process

Changqing Lin^{a,b}, Wei Wei^a, Yun Hang Hu^{a,*}^a Department of Materials Science and Engineering, Michigan Technological University, 1400 Townsend Drive, Houghton, MI 49931-1295, USA^b Department of electrical and Mechanical Engineering, Qiqihar Institute of Technology, Qiqihar, Heilongjiang, 161005, PR China

ARTICLE INFO

Article history:

Received 23 September 2015

Received in revised form

30 October 2015

Accepted 2 November 2015

Available online 10 November 2015

Keywords:

Graphene oxide

Concrete

Hydration

Catalysis

ABSTRACT

Hydration is a critical step that determines the performance of cement-based materials. In this paper, the effect of GO on the hydration of cement was evaluated by XRD and FTIR. It was found that GO can remarkably accelerate the hydration rate of cement due to its catalytic behavior. This happened because the oxygen-containing functional groups of GO provide adsorption sites for both water molecules and cement components.

© 2015 Elsevier Ltd. All rights reserved.

1. Introduction

Cement composites are the most important and most abundant building material [1,2]. Concrete is a composite material (primarily of cement, sand, and water) with nano-structures and multi-phases. As an important engineering material, concrete possesses an excellent compressive strength. However, it suffers several issues, such as brittle nature due to its poor resistance to crack formation, low tensile strength, and strain capacities. Many efforts have been made to enhance the performance of cement-based materials by manipulating their properties with admixtures [3–6], supplementary cementitious materials [7–10], and fibers [11,12]. Progress in nanomaterials created invaluable opportunities to enhance the performance of cementitious composites. The incorporation of nanomaterial additions as partial replacement for cement can improve the properties of the high-strength and especially ultrahigh-performance concrete with relatively high-cementitious binder content and high-lacking density, producing better dispersion and interaction of the reinforcement systems and achieving significantly higher mechanical strength and durability [13].

Carbon based materials have drawn attention and were incorporated in the cement matrix for strengthening. Carbon nanotubes and nanofibers were explored as promising promoters for reinforcements in cement-based materials at nanoscale [14]. Graphene, which consists of a one-atom-thick planar sheet

comprising a sp^2 -bonded carbon structure with exceptionally high crystal and electronic quality, is a novel material that has emerged as a rapidly rising star in the field of material science [15–18]. Graphene oxide (GO) has unique properties, such as a very high surface area [16], surface functionalization [16], and good dispersibility in aqueous solvents [17,18]. GO sheets bear various oxygen-containing groups, mainly epoxides and hydroxyls on their basal planes and carboxyls on the edges, which can facilitate the dispersion of GO in water [19,20]. Therefore, GO has been accepted as an efficient agent to improve the interfacial properties between fiber and matrix [21]. It was reported that small content (0.01–0.06%) of GO can remarkably improve compressive strength of concrete [22–24]. Recently, our group found that the mixture of graphene oxide (GO) sheets and single-walled carbon nanotubes (SWCNTs) exhibited an excellent co-effect, leading to 72.7% increase in bending strength of cement, which is much higher than the strength enhancements of 51.2% by GO and 26.3% by SWCNTs [25]. It is well-known that the structure and properties of concrete are strongly dependent on hydration reactions of major components (silicates and aluminates of calcium) in the cement [26–29], producing complex products, such as calcium hydroxide (CH), ettringite (Aft), and monosulfates (AFm). Furthermore, the contents and crystal shapes of those hydrates determine the final strength of concrete [30]. However, a little effort was made to explore the effect of GO on the cement hydration. In this paper, we report that GO can play a catalytic role for the hydration process of cement, which can remarkably accelerate the production of hydrates.

* Corresponding author.

E-mail address: yunhangh@mtu.edu (Y.H. Hu).

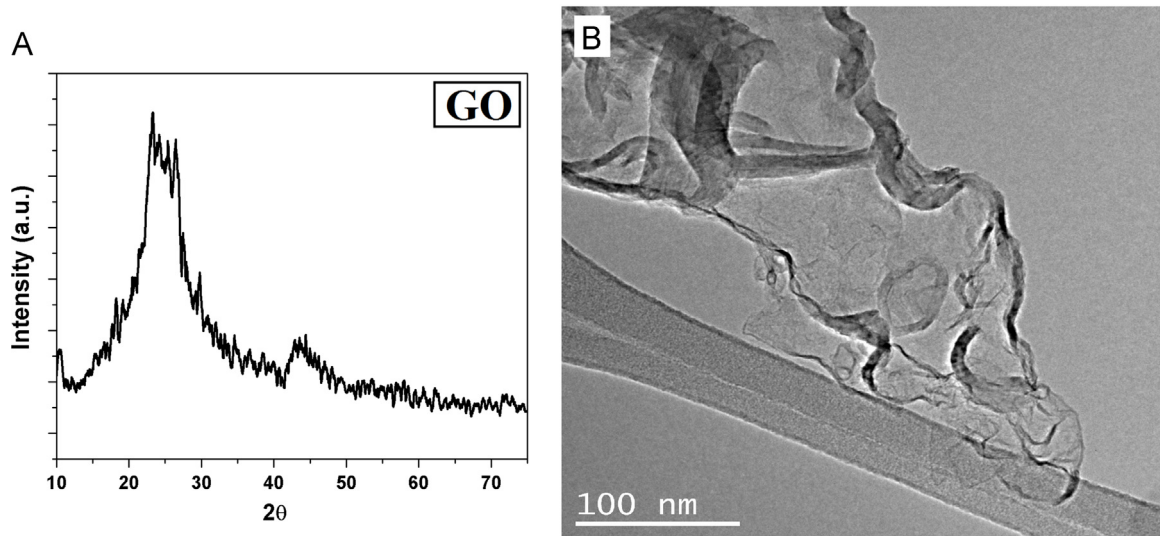


Fig. 1. (A) XRD pattern of graphene oxide and (B) TEM image of graphene oxide sheets.

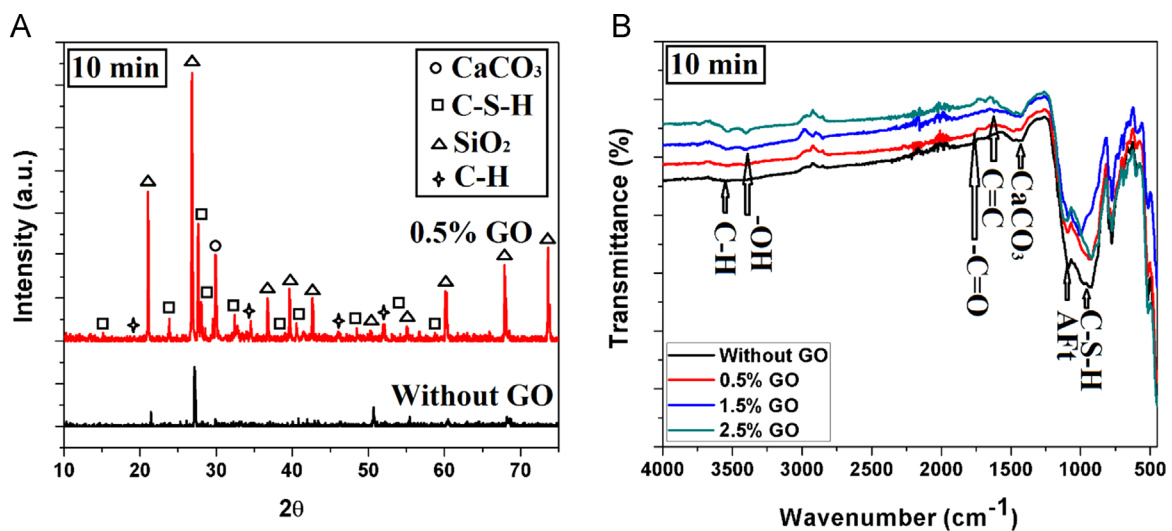


Fig. 2. (A) XRD patterns of concrete nanocomposites without GO and with 0.5 wt% GO at 10 min and (B) FTIR spectra of concrete nanocomposites without GO and with 0.5 wt%, 1.5 wt%, and 2.5 wt% GO at 10 min.

2. Experimental

2.1. Materials

Portland cement type II (No. 1124), which was used in this work, consists typically of 51% tricalcium silicate (C_3S), 24% dicalcium silicate (C_2S), 6% dicalcium aluminate (C_3A), 11% tetra-calcium aluminoferrite (C_4AF), 2.9% MgO, 2.5% SO_3 , 0.8% Ignition loss, and 1.0% CaO. Graphene oxide (GO) was synthesized from graphite powders (Sigma-Aldrich) with the modified Hummers method described as follows [31,32]: potassium permanganate (3 g) was added into the mixture of graphite (0.5 g), sodium nitrate (0.5 g), and sulfuric acid (25 mL) at room temperature, followed by heating to 35 °C with a water-bath and then stirring at 35 °C for 5 h to form a thick paste. Deionized water (40 mL) was added into the thick paste with stirring, followed by heating to 90 °C over 30 min, then adding more deionized water (100 mL), and finally gradually adding 10 mL of H_2O_2 (30%). The obtained sample was filtered and washed with 100 mL of deionized water. The filter sediment was dispersed in deionized water again, followed by

ultrasonic treatment for 24 h and then centrifugal treatment to separate the solid from the water. The obtained solid sample of graphite oxide was dried in a vacuum furnace at 50 °C. The as-prepared graphite oxide was re-dissolved in deionized water, followed by ultrasonic treatment (for 48 h) to achieve full exfoliation from graphite oxide to graphene oxide (GO).

2.2. Concrete sample preparation

Four concrete samples were prepared by mixing 40 g cement, 120 g stand sand, 12 g water, and 4 g polycarboxylate superplasticizer (PC) solution (that contains 0, 0.5, 1.5, and 2.5 wt% GO, respectively) as follows: GO was suspended in distilled water and sonicated for 3 h until the homogeneous solution was obtained. Then, polycarboxylate superplasticizer (PC), which is an indispensably admixture for a cement composite to reduce water consumption without losing fluidity of the cement paste, was added to the mixture. The water to cement ratio was kept the same. Finally, the cement and sand were added.

Download English Version:

<https://daneshyari.com/en/article/1515492>

Download Persian Version:

<https://daneshyari.com/article/1515492>

[Daneshyari.com](https://daneshyari.com)