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Research paper

One-pot synthesis of biomorphic Mg-Al mixed metal oxides with enhanced methyl orange adsorption properties

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ABSTRACT

Biomorphic Mg-Al mixed metal oxides with hierarchical structures were synthesized by a one-pot method employing cotton fibers as templates. The as-prepared samples were characterized by X-ray diffraction (XRD), field emission scanning electron microscopy (FESEM) and transmission electron microscopy (TEM). It was found that the as-prepared biomorphic Mg-Al mixed metal oxides retained the tubular morphology of cotton fibers. Adsorption of biomorphic Mg-Al mixed metal oxides for methyl orange was investigated in detail. Different conditions were evaluated, including adsorbent dosage, initial methyl orange concentration, adsorption time and temperature. The adsorption mechanism was also discussed according to the adsorption kinetics and thermodynamics. The results indicated that the adsorption process was well fit to Freundlich isotherm model and pseudo-second-order kinetic model.

1. Introduction

With the increasing stress on world resource shortages and eco-environment degradation, much attention has been focused on the method of preparing renewable resource and environmentally friendly material (Zhang et al., 2013). In recent decades, biomimetic synthesis has attracted increasing attention due to its high efficiency, low cost and environmental benignancy (Zhang et al., 2014b; Gao et al., 2015). Biomimetic synthesis is an important synthetic method which employing natural materials as templates to control the growth of inorganic materials with unique morphology and superior performance (Zhang et al., 2009; Mu et al., 2015). In the process of biomimetic synthesis, templates play an important role in controlling the morphology of materials. To date, a variety of natural materials such as butterfly wing scales (Zhang et al., 2006; Han et al., 2015), leaves (Zhang et al., 2015a), bamboo fibers (Zhao et al., 2013), rape pollen grains (Zhang et al., 2015b) and woods (Fan et al., 2008) were employed as templates to synthesize biomorphic materials including various oxides (Sun et al., 2005; He et al., 2014; Zhao et al., 2014).

Layered double hydroxides (LDHs), as a kind of hierarchically structured materials, have been widely studied in the last decades due to their versatile applications in adsorption, catalysis, electrochemistry and biomedicine (Iyi and Sasaki, 2008; Wang et al., 2014; Zhang et al., 2014a). LDHs can be readily transformed into the corresponding mixed metal oxides by heating to a certain temperature (Matei et al., 2011; Kameda et al., 2012; Wang et al., 2015a). Mixed oxides are an important class of materials due to their physicochemical properties and various applications. A prominent potential field for the use of such materials is in adsorption (Wei et al., 2011; Duan et al., 2015). Numerous studies have reported that the adsorption capacity of calcined LDHs is considerably higher than that of uncalcined LDHs (Zaghouane-Boudiaf et al., 2012). To date, a variety of mixed oxides have been reported, such as Mg-Al mixed metal oxides (Liu et al., 2013b; Wang et al., 2016), Ni-Al mixed metal oxides (Cherepanova et al., 2015; Manukyan et al., 2015), Zn-Al mixed metal oxides (Ni et al., 2007; Cheng et al., 2010) and so on. Unfortunately, few studies have focused on the synthesis of biomorphic mixed metal oxides with hierarchical structure, of which the morphology control remains a big challenge.

Removal of dye from industrial waste streams is very important for preventing environment pollution (Liu et al., 2013a; Allouche et al., 2015; Istratie et al., 2016). Nowadays, many treatment methods have been used to remove dye (Mekatel et al., 2015). Although every method has its own advantages and disadvantages, adsorption has been recognized to be one of the most promising and cost effective processes for treating dye wastewater (Wang et al., 2015b; Dalvand et al., 2016).

Herein, a simple and efficient method for fabricating biomorphic Mg-Al mixed metal oxides with tubular and hierarchical structure was developed. In this work, Mg-Al mixed metal oxides composites

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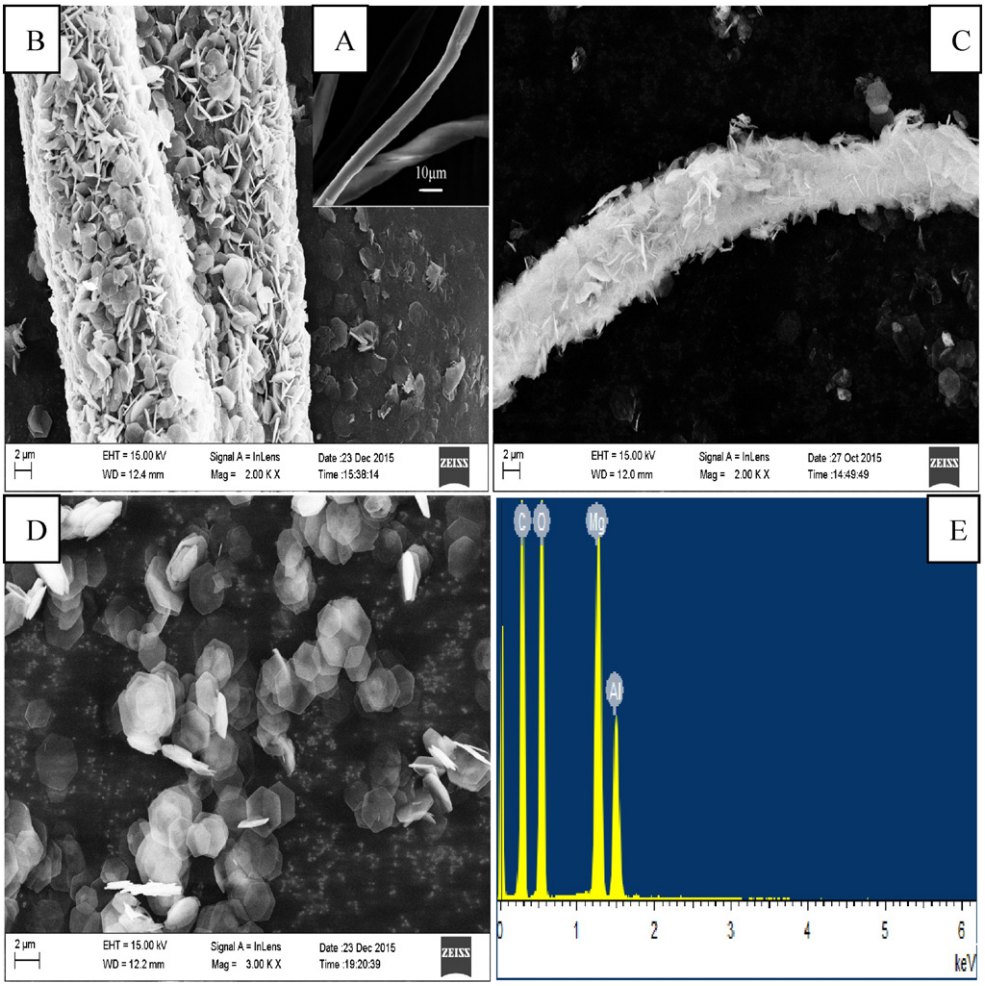

Fig. 1. SEM images of (A) cotton fiber, (B) biomorphic Mg-Al LDHs, (C) biomorphic Mg-Al mixed metal oxides, (D) Mg-Al mixed metal oxides without the template and EDX spectra of (E) biomorphic Mg-Al mixed metal oxides.

which were prepared by a one-pot and biotemplating method will have great promising applications in adsorption. Mg-Al mixed metal oxides with tubular and hierarchical structures was obtained by replicating the structures of cotton fibers and the self-assembly growth of metal oxides nanoplatelets. Furthermore, biomorphic Mg-Al mixed metal oxides was employed for the removal of methyl orange.

2. Materials and methods

2.1. Materials

The cotton was chosen as the template in this study, after being washed 3 times with deionized water and anhydrous ethanol, it was dried in the drying oven at 80 °C for 24 h. Other reagents (analytical

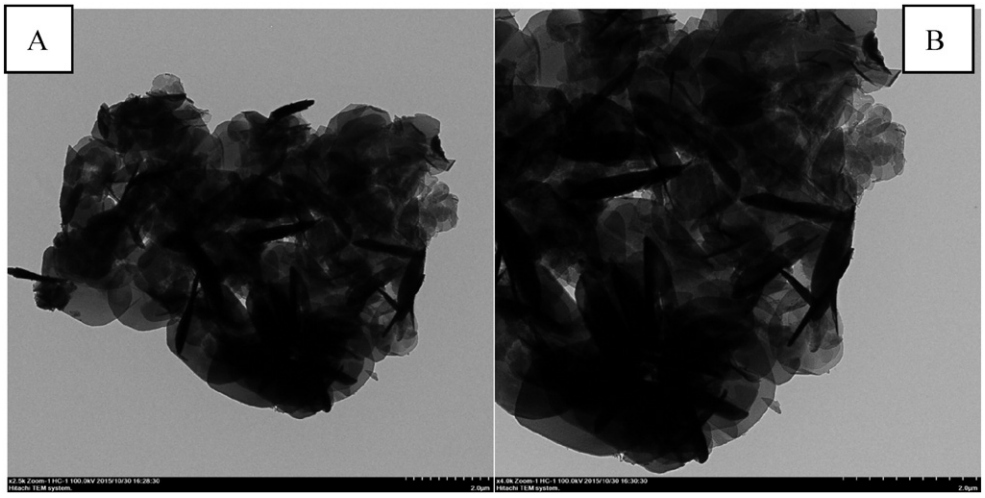

Fig. 2. TEM images of (A–B) biomorphic Mg-Al mixed metal oxides.