J Mater Sci (2015) 50:2113–2121
DOI 10.1007/s10853-014-8773-3

Highly efficient adsorption of heavy metals from wastewaters by graphene oxide-ordered mesoporous silica materials

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Received: 18 October 2014 / Accepted: 4 December 2014 / Published online: 11 December 2014

Abstract Novel graphene oxide-ordered mesoporous silica materials with two-dimensional mesoporous structure and large surface area were successfully fabricated through sol–gel and self-assembly methods. The synthesized materials were characterized by small-angle X-ray diffraction, scanning electron microscopy, transmission electron microscopy, and nitrogen adsorption–desorption. By taking advantage of the excellent properties, the hybrid materials were employed as the adsorbent for removal of heavy metals in environmental waters by adsorption separation—inductively coupled plasma mass spectrometry. The results showed that the materials exhibited superior adsorption capacity, the removal efficiencies for As, Cd, Cr, Hg, and Pb reached 97.7, 96.9, 96.0, 98.5, and 78.7 %, respectively. The facile, low-cost, and environmental friendly synthesis method as well as highly efficient adsorption ability made it become a promising adsorbents for the removal of toxic heavy metals at low or trace concentrations from wastewater.

Introduction

Heavy metals have caused various diseases and threaten ecosystem and public health seriously with the rapid development of the industry in recent years [1]. They can be distinguished from other toxic pollutants, since their bioaccumulation and high toxicity even at very low concentrations in water [2, 3]. Therefore, the removal of heavy metals have attracted increasing attention and become an extensive research subject. Conventional treatment techniques, such as ion exchange, chemical precipitation, solvent extraction, and adsorption have been widely applied [4–6]. Among them, the adsorption is considered to be the most facile and effective method [7, 8].

Traditional adsorbents, such as clays [9], nanosized metal oxides [10], polymer and polymer-based hybrids [11, 12] were of interest for wastewater treatment. However, these classical adsorbents had several problems such as unpredictable metal ions removal, toxic sludge production, and extra handling cost for sludge disposal [13]. Moreover, most of sorbents were only applied to high or moderate concentrations of heavy metals but not to low or trace [14]. Therefore, it is very urgent to develop novel adsorbents with low-cost, simple operating performance, and excellent adsorption efficiency to low or trace.

In recent years, with progresses in modern nano-science and technology, ordered hybrid porous materials have exhibited substantial performance in adsorption and separation applications because of regular, uniform, and interpenetrating mesopores, tunable pore sizes, high surface areas [15–18]. Numerous organic–inorganic porous hybrids have been developed for removing heavy metal ions from wastewater, such as Cd, Cu, Hg, and Pb [19–22]. In addition, as an attractive 2D material with remarkable physical and chemical properties, graphene oxide (GO) composites have been widely applied in this field [23–25].

In this study, in order to take good use the advantages of GO and porous materials, graphene oxide-ordered mesoporous silica materials (denoted as GO-OMS) with long

Electronic supplementary material The online version of this article (doi:10.1007/s10853-014-8773-3) contains supplementary material, which is available to authorized users.

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