



# Efficient removal of heavy metal ions by thiol-functionalized superparamagnetic carbon nanotubes

Cheng Zhang, Jiehe Sui\*, Jing Li, Yilun Tang, Wei Cai

School of Materials Science and Engineering, Harbin Institute of Technology, P.O. Box 405, Harbin 150001, PR China

## HIGHLIGHTS

- ▶ Thiol-groups are successfully grafted on the surface of CNTs/Fe<sub>3</sub>O<sub>4</sub> nanocomposites.
- ▶ Thiol-functionalized CNTs/Fe<sub>3</sub>O<sub>4</sub> nanocomposites exhibit superparamagnetic property.
- ▶ A synthetic procedure for thiol-functionalized CNTs/Fe<sub>3</sub>O<sub>4</sub> nanocomposites is proposed.
- ▶ The adsorption kinetics can be best described using pseudo-first-order kinetic equation.
- ▶ The adsorption isotherms match well with Langmuir model.

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## ABSTRACT

Thiol-functionalized multiwall carbon nanotube/magnetite nanocomposites (CNTs/Fe<sub>3</sub>O<sub>4</sub>) were synthesized, and were investigated by power X-ray diffraction, transmission electron microscopy, energy-dispersive X-ray spectrometer, Fourier transform infrared spectroscopy, thermogravimetric analyses, BET analysis and physical properties measurement system. The results showed that the 3-mercaptopropyltriethoxysilane (MPTS) was successfully grafted on the surface of CNTs/Fe<sub>3</sub>O<sub>4</sub> nanocomposites. The as-synthesized thiol-functionalized CNTs/Fe<sub>3</sub>O<sub>4</sub> (MPTS-CNTs/Fe<sub>3</sub>O<sub>4</sub>) nanocomposites exhibited superparamagnetic property and higher specific surface area than that of CNTs/Fe<sub>3</sub>O<sub>4</sub> nanocomposites at room temperature. The adsorption properties of Hg<sup>2+</sup> and Pb<sup>2+</sup> as a function of contact time, pH value and initial metal concentration were characterized by an inductively coupled plasma optical emission spectroscopy (ICP-OES). The pseudo-first-order kinetic equation could better than that of pseudo-second-order kinetic equation to describe the adsorption kinetics of the before and after thiol-functionalized nanocomposites. The removal efficiency of CNTs/Fe<sub>3</sub>O<sub>4</sub> nanocomposites and MPTS-CNTs/Fe<sub>3</sub>O<sub>4</sub> nanocomposites was highly pH dependent and the optimal pH value for adsorption was 6.5. The adsorption isotherms of Hg<sup>2+</sup> and Pb<sup>2+</sup> by MPTS-CNTs/Fe<sub>3</sub>O<sub>4</sub> nanocomposites matched well with the Langmuir model with the maximum adsorption capacities of 65.52 and 65.40 mg/g, respectively.

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## 1. Introduction

In recent years, the presence of heavy metal ions in groundwater and seawater systems has attracted much attention due to their adverse effects on public health and ecological systems [1,2]. Therefore, it is necessary to develop various efficient technologies for heavy metal ions removal. Recent researches focused on the development of novel adsorbents with enhanced adsorption rate, capacity, and selectivity for the target heavy metal ions.

Carbon nanotubes (CNTs) have attracted much attention in the field of heavy metal ions removal, such as lead [3], copper [4], chromium [5], nickel [6,7] and zinc [8,9], because of their large specific

surface area, small size, and hollow and layered structures [7]. Although the CNTs have high adsorption capacity for heavy metal ions removal, it is difficult to separate from aqueous solutions due to their small size. Traditional centrifugation separation method needs high price and the filtration method may cause the blockage of filter. Compared with the centrifugation and filtration methods, magnetic separation is a rapid and convenient method to collect magnetic adsorbents from aqueous solutions [10]. Given all of this, combination CNTs with magnetic nanoparticles was studied and had been proved as an efficient method for the retrieve of CNTs from aqueous solutions [10–15]. In our group, nearly monodisperse and superparamagnetic Fe<sub>3</sub>O<sub>4</sub> nanoparticles with sizes less than 10 nm have been successfully in situ deposited on CNTs without any surface modification [16]. Therefore, CNTs/Fe<sub>3</sub>O<sub>4</sub> nanocomposites as efficient and easily recycling adsorbents are very worth to expect.

\* Corresponding author. Tel.: +86 451 86412505; fax: +86 451 86418649.

E-mail address: [suijiehe@hit.edu.cn](mailto:suijiehe@hit.edu.cn) (J. Sui).