Applied Surface Science 439 (2018) 364–370

Contents lists available at ScienceDirect

Applied Surface Science

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

Full Length Article

Fast adsorption kinetics of highly dispersed ultrafine nickel/carbon nanoparticles for organic dye removal

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ARTICLE INFO

Article history:
Received 11 September 2017
Revised 31 October 2017
Accepted 7 January 2018
Available online 8 January 2018

Keywords:
Ni nanoparticle
Ultrafine
Magnetism
Dye
Fast adsorption

ABSTRACT

Magnetic metal/carbon nano-materials are attractive for pollutant adsorption and removal. In this study, ultrafine nickel/carbon nanoparticles are successfully prepared via electrical wire explosion processing in ethanol media for the elimination of pollutant organic dyes such as Rhodamine B and methylene blue in aqueous solutions. High specific surface areas originating from both the nano-sized particles and the existence of carbon on the surface of Ni nanoparticles enhance dye adsorption capacity. In addition to this, the excellent dispersity of Ni/C nanoparticles in aqueous dye solutions leads to superior adsorption rates. The adsorption kinetics for the removal of organic dyes by Ni/C nanoparticles agree with a pseudo-second-order model and follow Freundlich adsorption isotherm behavior.

1. Introduction

Of the ~700,000 tons of organic dyes produced every year, as much as 200,000 tons are being released into wastewater during textile processing [1]. Rhodamine B (RhB) and methylene blue (MB) are organic dyes commonly used in the textile industry. However, they can irritate the skin, eyes, and respiratory system of humans and animals upon ingestion [2]. Additionally, these dyes can react with sunlight to form carcinogenic byproducts [3]. Removal of these toxic organic dyes from wastewater is therefore pivotal to improving public health and safety.

Currently, several conventional processes like coagulation, filtration, and chemical oxidation are used to remove organic dyes [4–6]. However, these conventional processes suffer from several major challenges such as low efficiency, environmental issues, and high cost. Adsorption, on the other hand, is considered a low-cost, energetically efficient, and highly effective process for the removal of organic dyes. Correspondingly, elemental metal and alloyed-based magnetic materials have been widely studied for their adsorption capabilities due to their facile separation from wastewater [7–9]. Moreover, the large specific surface areas of magnetic metal nanostructures enable them to adsorb wastewater pollutants more efficiently than bulk materials. However, preparing phase-pure nano-metals is relatively difficult as they are highly prone to oxidation during synthesis [10,11].

Metal nano-materials can be synthesized through either top-down or bottom-up processes. While bottom-up processes are more common, they typically have low yields and are synthesized via complicated, expensive, and ecologically unfriendly methods [11,12]. On the other hand, the electrical wire explosion (EWE) method is a facile top-down process, which can synthesize nano-sized compounds in a single-step at room temperature, thus making mass production feasible. The liquid media for EWE can easily be changed and used to synthesize a diverse range of metal nanostructures such as pure metal nanoparticles, metal oxide nanoparticles, metal/carbon nanocomposites, and metal/metal oxide nanocomposites [13–16].

In this study, we prepared ultrafine Ni nanoparticles with carbon (Ni/C NPs) using EWE in an ethanol media. Porous carbonaceous materials are commonly used as adsorbents due to their high specific surface areas, which increases the number of available active sites for adsorption [17,18]. We then evaluate the efficacy of Ni/C NPs for RhB and MB adsorption by studying their adsorption capacity, adsorption kinetics, and isotherm behavior.

2. Experimental details

2.1. Synthesis of Ni/C NPs

Ni/C NPs were prepared through a similar way using an electrical wire explosion, as observed in our previous study [15].

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https://doi.org/10.1016/j.apsusc.2018.01.061
0169-4332/