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Ni nanoparticle-carbonized bacterial cellulose composites for the catalytic reduction of highly toxic aqueous Cr(VI)

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Abstract
In this work, we report a facile technique to prepare Ni nanoparticle-carbonized bacterial cellulose (Ni@CBC) composites by pyrolysis bacterial cellulose adsorbing corresponding nickel(II) nitrates. The introduction of carbonized bacterial cellulose served as a reductant for the conversion of Ni(II) to Ni as well as a support for Ni NPs to prevent the agglomeration. The synthesized composite material was tested as a catalyst to reduce toxic Cr(VI) to Cr(III) at room temperature, and UV–Vis spectrophotometry was employed to monitor the reduction process. According to the results, the Ni@CBC material showed good stability and highly catalytic activity at room temperature.

1 Introduction

Rapid civilization and industrialization have caused serious environmental issues throughout the globe during last few decades. Chromium generally exists in two forms such as hexavalent [Cr(VI)] and trivalent [Cr(III)] of which hexavalent chromium is highly toxic, carcinogenic, mutagenic and results in several health issues such as liver damage, pulmonary problems, vomiting, and diarrhea [1]. Hexavalent Chromium [Cr(VI)] is mainly generated during the electrochrome plating, pigments manufacturing and also by tannery industries, and has been listed as toxic environmental pollutant by the U.S. Environmental Protection Agency [2–4]. However, with respect to compared to Cr(VI), Cr(III) is relatively inert, non-toxic, and an essential element to the human metabolism. Therefore, the reduction of Cr(VI) to Cr(III) is considered as an important technique to remove the toxicity of Cr(VI). In addition, the reduction reactions are gaining more attention due to their simple operation, high selectivity and rapidness. Reduction of Cr(VI) to Cr(III) using formic acid as the reducing agent in the presence of catalyst has been reported in the literature [5, 6]. Recently, metal nanoparticle (N Ps)-based materials have been received significant attention towards catalytic reduction of Cr(VI). Palladium (Pd) NPs supported mesoporous γ-Al_2O_3 film can be utilized as a catalyst for the reduction of Cr(VI) with an extraordinary activity [7]. Veerakumar et al. reported an effective method to reduce Cr(VI) by formic acid using Pd@GAC as a catalyst [4]. Although Pd-based composites are the most effective catalysts, but their high cost and the requirement of high temperature as a catalyst impeded the large-scale applications [8]. Nickel NPs was inexpensive and has also an important applications in catalysts and magnetic materials [9]. Qin et al. prepared a novel Ni@C-dots hybrid material as a catalyst to reduce Cr(VI) to Cr(III) [10]. Bhowmik et al. reported a very rapid reduction of Cr(VI) to Cr(III) using formic acid as a reducing agent in the presence of Ni NPs embedded in reduced graphene oxide (Ni-RGO). In addition, Ni-RGO is also found to be very active materials to enhance the rate of reduction of other metal ions at room temperature as reported in the literature [11]. Nevertheless, in the aforementioned both methods, the fabrication process of Ni support is complex, and an additional reductant is necessary for the conversion of Ni(II) to Ni in the introduction of Ni, which leads to the high cost of the catalyst.

Bacterial cellulose (BC) is a linear polysaccharide synthesized using bacteria (ie. *Acetobacter xylinum*). It has become the substrate of attraction for researchers due to its 3-dimensional network structure, ease of availability, high porosity, biocompatibility, non-toxic nature [12]. The carbonized

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