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Short communication

BCNO nanoparticles: A novel highly efficient fluorosensor for ultrarapid detection of Cu^{2+}

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ABSTRACT

In this paper, we demonstrate the first use of BCNO nanoparticles (BCNO NPs) as a novel highly efficient fluorosensor for Cu^{2+} detection with high selectivity. The detection process is ultrafast and can be completed within 2 min, and the detection limit is 0.1 μM. We also show the practical use of this sensor for Cu^{2+} determination in real water samples.

1. Introduction

It is of particular significance to develop sensitive chemosensors capable of selective recognition of cations, especially for metal ions with biological interest, due to their potential application in chemistry, biomedicine, and environmental studies [1]. Copper plays important roles in either environmental or biological systems. It is also an essential trace element for humans and other animals. Copper is required by proteins like cytochrome oxidase, zinc-copper superoxide dismutase, lysyl oxidase and several transcription factors for their activities. Copper is widely used in industry and copper ions (Cu^{2+}) can accumulate in human and animal livers through bioaccumulation. However, overloading of Cu^{2+} is high toxic to humans [2]. Indeed, disruption of copper homeostasis in cells may cause oxidative stress and severe disorders such as Menkes syndrome, Wilson's disease, amyotrophic lateral sclerosis and Alzheimer's disease [3–5]. As such, it is highly desired to develop simple and rapid method for Cu^{2+} detection.

Ion-induced fluorescence change-based Cu^{2+} sensors appear to be particularly attractive because of the simplicity and high sensitivity of fluorescence technique. The fluorescent probes can monitor Cu^{2+} both in solution and in living cells by fluorescent microscopy [6]. So far, a wide variety of fluorescent probes have been developed, including small organic molecules [7,8], noble metal nanoclusters [9,10], and metal-based quantum dots (MQDs) [10–12], etc. Such fluorescent probes, however, suffer from photobleaching of fluorescent dye, expensive cost of noble metals, or toxicity of MQDs, limiting their widespread applications. More recently, we have pioneered the use of nitrogen-doped, carbon-rich, photoluminescent polymer nanodots [13] and carbon nitride nanosheet [14] as highly efficient fluorosensors for Cu^{2+} detection.

BCNO is a kind of multi-color oxynitride phosphor, which is composed of B, C, N, and O atoms [15,16]. BCNO can be facilely synthesized from inexpensive and environmentally friendly raw materials with tunable color emission, high quantum efficiency, and long-duration afterglow [17]. Although BCNO exhibits excellent fluorescence properties, its sensing application has not yet been demonstrated so far. In the present study, we demonstrate

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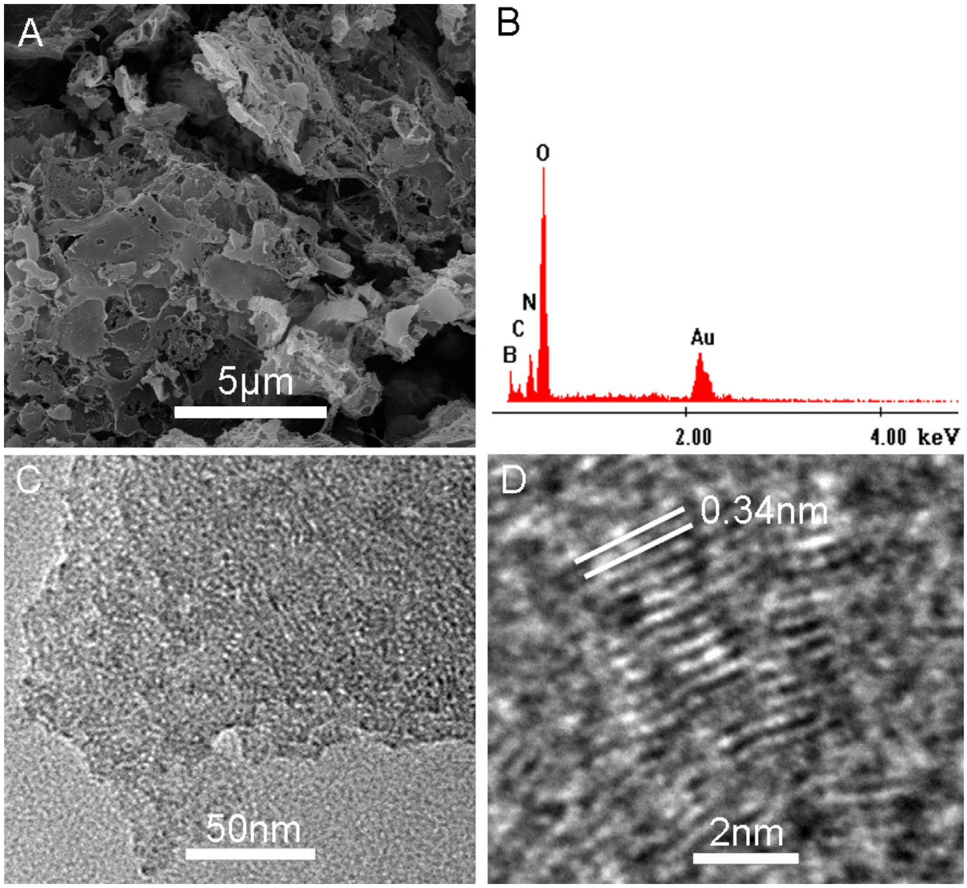

Fig. 1. (A) SEM image and (B) the corresponding EDS of bulk BCNO, (C) TEM and (D) HRTEM image of BCNO NPs.

the proof of concept that BCNO NPs can serve as a novel highly efficient fluorosensor for Cu^{2+} detection with high selectivity. The detection process can be completed within 2 min, and the detection limit of 0.1 μM. This sensor was also applied successfully for Cu^{2+} determination in lake water samples.

2. Experimental

2.1. Reagents and materials

Urea (Aladdin Reagent Co. Ltd.), polyethylene glycol (PEG, MW: 10000, Tianjin Fuyu Ltd.), and H_3BO_3 (Beijing Chem. Ltd.) were used as received.

2.2. Preparation of BCNO NPs

Bulk BCNO phosphors were synthesized according to reported method with minor modification [18]. In brief, H_3BO_3, urea, and PEG were used as the sources for boron, nitrogen and carbon, respectively. The precursors were mixed and heated to 800 °C and held for 30 min in air atmosphere at a heating rate of 5 °C/min. The obtained bulk BCNO (180 mg) was dispersed into deionized water (30 mL) to form a white dispersion, and then the dispersion was sonicated by a sonic tip at nominal power output of 95 W (10% × 950 W) for 60 min.

2.3. Instruments

Scanning electron microscopy (SEM) measurements were made on a XL30 ESEM FEG scanning electron microscope at an accelerating voltage of 20 kV. Transmission electron microscopy (TEM) measurements were made on a HITACHI H-8100 EM (Hitachi, Tokyo, Japan) with an accelerating voltage of 200 kV. UV–vis spectra were obtained on a UV-5800 spectrophotometer. Fluorescent emission spectra were recorded on a RF-5301PC spectrofluorometer (Shimadzu, Japan). The atomic emission spectrometry of measurement was performed on inductively coupled plasma-atomic emission spectrometry (ICP-AES). The water used throughout all experiments was purified through a Millipore system.

3. Results and discussion

3.1. Characterization of BCNO NPs

Fig. 1A shows the SEM image of the resulting bulk BCNO phosphors, indicating the formation of a large amount of solid agglomerates with a size of several micrometers. The corresponding energy-dispersed spectrum (EDS) (Fig. 1B) shows that microstructure consisted of B, C, N, and O elements, indicating the formation of BCNO (Au peak originated from the conductive coating layer for SEM characterization). Fig. 1C presents the TEM image of the products obtained by ultrasonication treatment of bulk BCNO, confirming the formation of small nanoparticles about 3 nm in diameter. The high-resolution TEM (HRTEM) image shown in Fig. 1D reveals clear lattice fringes with an interplane distance of 0.34 nm, which is in agreement with the work reported before [17]. All these observations indicate that the formation of BCNO NPs.

Fig. 2 shows UV–vis absorption and PL emission spectra of BCNO NPs dispersed in water. The UV–vis spectrum shows a weak absorption peak at 315 nm. It is of importance to mention that the dispersion shows a strong PL emission peak centered at 328 nm