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A facile synthesis of boron nitride nanosheets and their potential application in dye adsorption

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ABSTRACT

A facile approach was developed to prepare boron nitride nanosheets (BNNSs) by directly exfoliating hexagonal boron nitride (h-BN) intercalated with concentrated H_2SO_4, subsequently the rapid heating effect of H_2SO_4 mixing with water. The obtained BNNSs were characterized. It was demonstrated that bulk h-BN powder was successfully exfoliated by this new method. Transmission electron microscopy and atomic force microscopy confirmed that the obtained BNNSs mainly consisted of few-layer sheets with a thickness range 1–2 nm, corresponding to 3–6 layers. X-ray photoelectron spectroscopy and Fourier transform infrared spectroscopy revealed that the oxidation did not occur in BNNSs during the concentrated H_2SO_4-intercalated exfoliation process. It was directly observed that the resultant BNNSs could be well dispersed in water. The adsorption performance of the BNNSs for Rhodamine B were then studied. Compared with the bulk BN, BNNSs showed superiority in adsorption ability. And the adsorption capacity of BNNSs was about 2 times that of h-BN.

1. Introduction

Since the successful preparation of graphene in 2004 [1], layered two-dimensional (2D) nanomaterials have attracted great attention because of their remarkable physicochemical properties. Many excellent properties such as specific surface area, electrical performance, thermal conductivity, mechanical strength, can be dramatically enhanced when layered materials are exfoliated to nanosheets [2,3,4]. As a process, exfoliation of layered solids have become a popular concept and method for modification of materials. Many new graphene analogues with a single atomic layer have been successfully obtained (e.g. molybdenum sulfide, graphitic carbon nitride and boron nitride nanosheets) [5,6,7].

As representative of graphite-like structure, hexagonal boron nitride (h-BN) have become a hot research topic due to its unmatched properties, such as intrinsic electrical insulation, high thermal stability and chemical stability [8,9]. These unique features make h-BN as a promising material in a large amount of potential applications such as sensors, catalysts, dielectric substrates, far-ultraviolet light-emitting and high performance electronic devices [10,11,12]. As mentioned, researchers have found that boron nitride nanosheets (BNNSs) also outperform their bulk counterpart in various application areas.

Differed from graphite, weak van der Waals force and ionic character of the B—N bonding, coexist in the layer of h-BN [13]. Therefore, it is more difficult for the exfoliation of h-BN. Nevertheless, a number of experimental studies still have tried to prepare the nanosheet form of h-BN to fully explore the potential of h-BN. Among these methods, the most popular approaches are mechanical method, chemical vapour deposition (CVD) and liquid-phase exfoliation (LPE). Streletskii et al. [14] investigated the processes of mechanical activation of h-BN. And the prepared BN nanosheets were less than 5 nm in thickness. However, the yield of mechanical method was very low for real applications and more defect was present in BNNS. CVD almost fabricates a perfect, single atomic sheet of h-BN through controlling the growth process. Song et al. [15] successfully synthesized large area h-BN films with 2–5 atomic layers by CVD. But CVD often require extreme environmental conditions such as high vacuum or high temperature or rather expensive templates. LPE is a relatively facile, scalable and easy-handling approach to prepare BNNSs. Generally, h-BN powder is dispersed reasonably in an appropriate solvent (i.e., isopropyl alcohol (IPA), *N,N*-dimethylformamide (DMF), dimethyl sulfoxide (DMSO), and *N*-methylpyrrolidone (NMP)), along with ultrasonic or microwave-assistant or heat treatment [4]. Zhi et al. [2] prepared the BNNSs with thicknesses about 1.2 nm in DMF, accompanying with ultrasonication for

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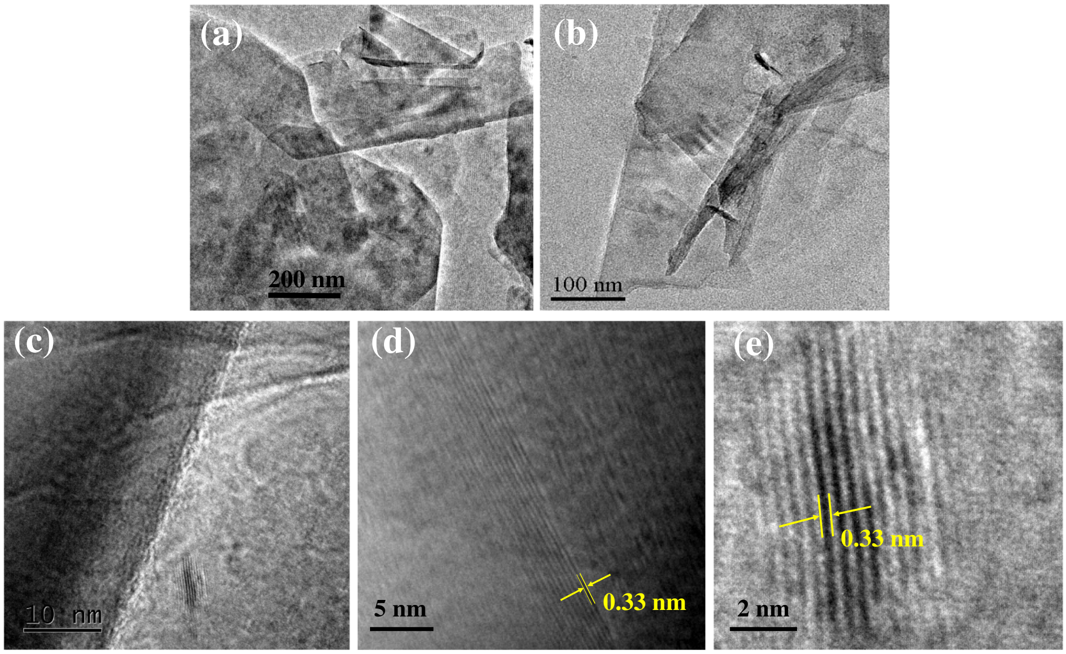

Fig. 1. (a, b) Low-magnification TEM and (c, d, e) high resolution TEM images of BNNSs.

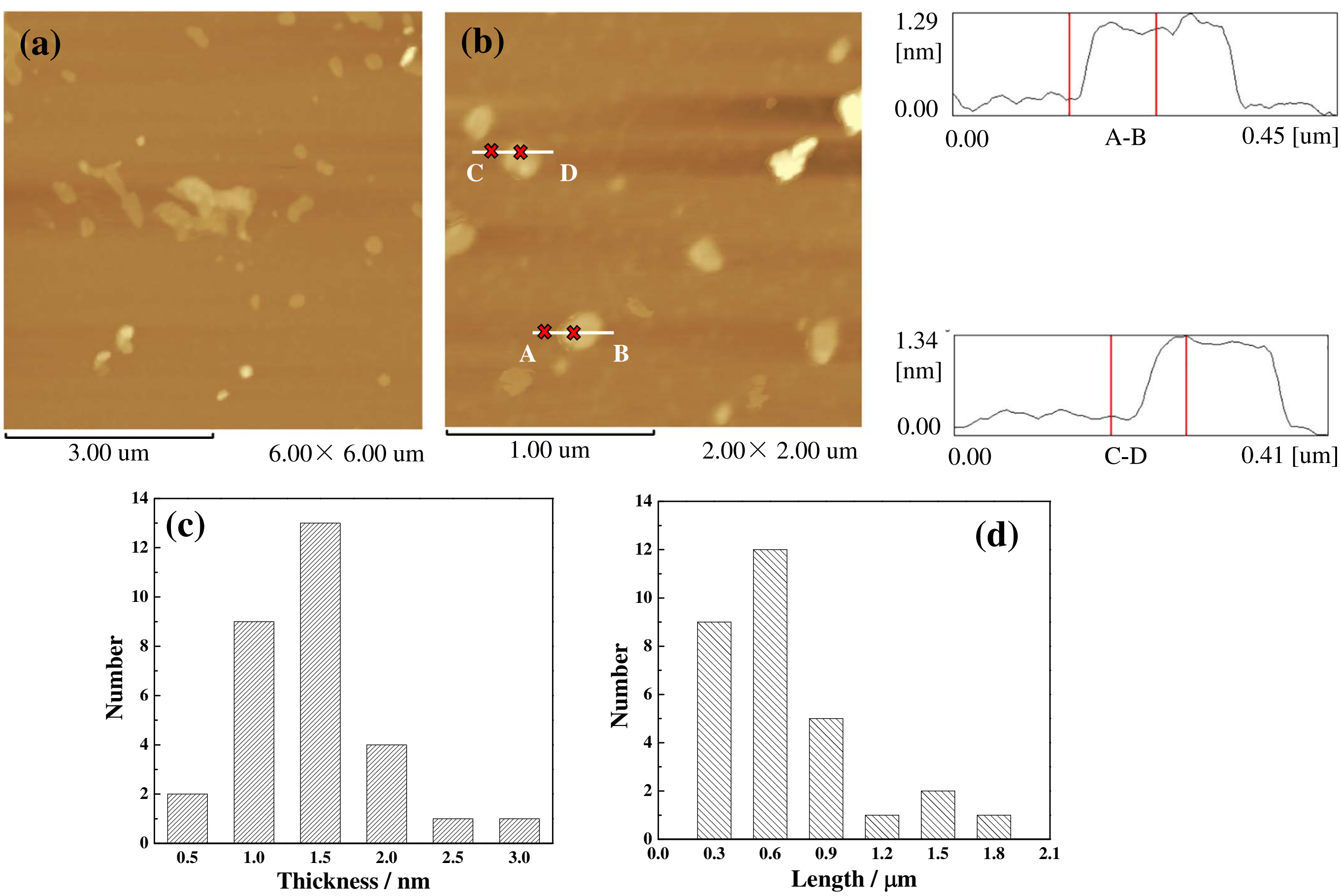

Fig. 2. (a) Tapping mode (6 × 6 μm) and (b) (2 × 2 μm) AFM image and (c, d) statistical analysis of the AFM images of 30 flakes BNNSs.

10 h. Warner et al. [16] successfully exfoliated h-BN powder in 1,2-dichloroethane using an ultrasonic bath for 3 h. The obtained BNNSs contained few-layer and monolayer. It was obviously noted that the used solvents in the methods were toxic and harmful to the environment. Furthermore, they consumed large amount of time and energy. The concentration and yields of the obtained BNNSs remained low. Thus, it is still a great challenge to develop a facile method for the purpose of producing largescale and high quality BNNSs.