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Fabrication of MoS_2 nanomaterials by ultrasonic vibration in the water

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Abstract
Molybdenum Disulfide (MoS_2) nanomaterial has been found in many applications in the industry. There have been many studies on the synthesis of MoS_2 nanomaterial using different ways; however, expensive chemicals, long reaction times, and specialized equipment are usually required. The work presents the synthesis process of MoS_2 nanomaterial by the ultrasonic vibration method in water, a simple method at room temperature. Morphology, structure, and properties of MoS_2 nanoparticles were determined by scanning electron microscopy (SEM) and transmission electron microscope (TEM), X-ray diffraction (XRD), and Raman spectroscopy. The obtained product has a hexagonal structure (2H-MoS_2) with a size of about 100-1500nm and a thickness of 2-15nm.

Keywords: *MoS_2 nanomaterial, nanoparticles, laminated structure, narrow bandgap.*

I. INTRODUCTION

Molybdenum disulfide (MoS_2), a laminated structure like graphene, is a semiconductor in the family of transition metal dichalcogenides MX_2 (M = Mo, W; X = S, Se, Te) [1-2]. It has many applications such as lubricants, scanning probe microscopes, catalysts, energy storage, thermoelectricity, photoelectric sensors [3-8], and so on. In particular, MoS_2 is often found in pure water photocatalytic applications or is a decomposition catalyst for organic pollutants in visible light due to its narrow bandgap energy (about 1.35 eV) and environmentally friendly character [7]. Besides, MoS_2 nanomaterial has been selected as the friction-reducing lubricant in mechanical applications due to its high mechanical strength and thermal stability up to 1100°C. These special properties have made MoS_2 nanomaterials a great research interest in scientific research, especially in machining and energy [1,2,10]. Typically, this material can be prepared from a hydrothermal reaction from some Molipdin-rich salts such as $(NH_4)_6Mo_7O_{24}.4H_2O$, $(NH_4)_2MoS_4$) [11,12] and so on or by the synthesis in a CVD furnace to form MoS_2 crystals having relatively high purity and relative size uniformity [13].

However, the limitation of the above methods is that they require expensive chemicals, long reaction times, and specialized equipment. Therefore, the synthesis of MoS_2 by simple methods at room temperature is still a challenge. This paper aims to present the fabrication of MoS_2 nanosheets from MoS_2 commercial powder by using the ultrasonic vibration technique in the water. The SEM, TEM, and Raman investigations showed that the obtained material has the nanostructure, suggesting potential solutions for different applications such as lubricants in metal cutting processes [18].

II. MATERIAL AND METHOD

A. Fabrication of nanomaterial

MoS_2 powder was purchased from Merck KGaA, Darmstadt, Germany. Nitrogen liquid and two-time distilled water were purchased in Vietnam. To prepare the fabrication, one gram of MoS_2 material was mixed with 500 mL of two-time distilled water using a magnetic stirrer to heat and maintain the temperature around 80°C for 1 hour. The mixture is then poured into the plastic jar containing liquid nitrogen, then cool to room temperature. The mixture is then mixed with 500 ml of distilled water and taken by ultrasonic vibration (Ultrasons HD, Selecta, 40kHz frequency, 400W capacity) for 3 hours. It is filtered out by filter paper, washed with alcohol, and dried at 80°C in a vacuum oven for 24 hours. The obtained material is denoted EMS, and the untreated material is denoted BMS.

B. Analytical methods

The microstructure and crystal phase composition of the material was analyzed by the X-ray diffraction method (XRD) using the D2 Advance machine (BRUKER, USA). The surface morphology was assessed by scanning electron microscopy (FESEM) using S4800 (Hitachi, Japan) and transmission electron microscopy (TEM) (JEOL 2100F, Japan). The Raman spectrum (Obin-Yvon LabRAM HR800, HORIBA) uses excitation lasers with a wavelength of 632 nm.

III. RESULTS AND DISCUSSION

Figure 1 shows the SEM image of the EMS, BMS. It can be seen that, after ultrasonic dissection of the material, the thick, blocky MoS_2 pieces turn into smaller and thinner sheets in scaly shape. Besides, TEM images reveal fragments with horizontal dimensions ranging from 100-1500nm, which are quite uniform (Figure 2).

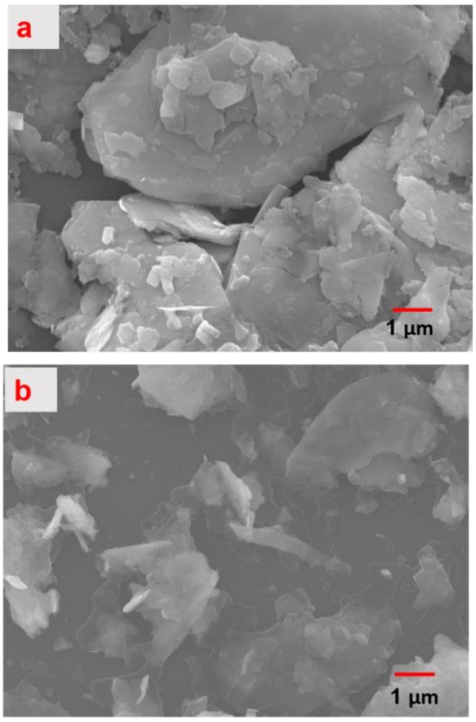


Figure 1. The SEM images: (a) EMS and (b) BMS

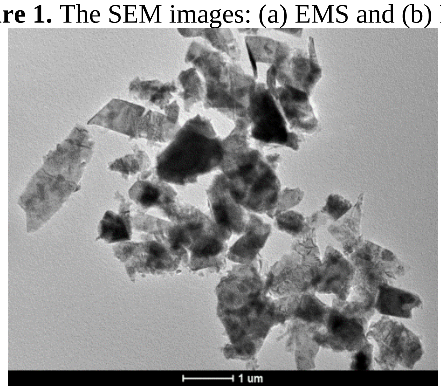
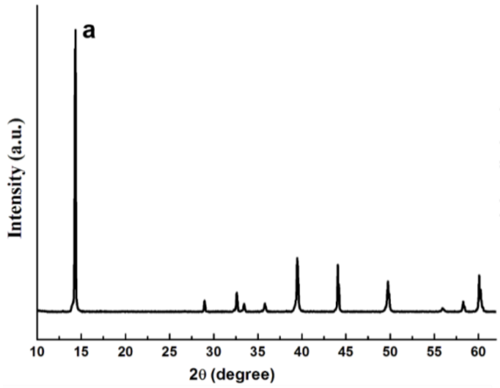


Figure 2. The TEM images of EMS



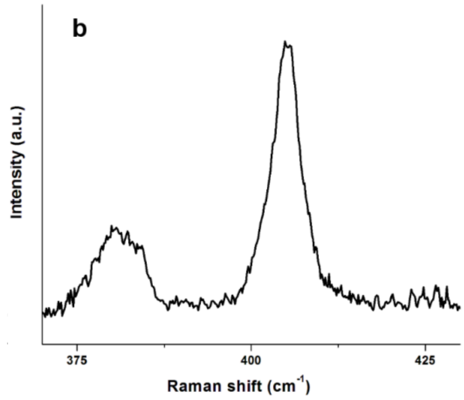


Figure 3. (a) The XRD and (b) Raman spectra of EMS

To confirm the material structure results obtained from the TEM image, the X-ray diffraction method and Raman spectroscopy are used to evaluate in detail. X-ray diffraction diagram (XRD) presented in Figure 3 shows that the product appears diffraction peaks characteristic of the 2H - MoS_2 (standard spectrum code 96– 900– 9145) (002), (100), (101), (103), (106), (105), (110), (008) related to at 2θ around $14{,}38^0$, $32{,}76^0$, $33{,}38^0$, $39{,}46^0$, $49{,}81^0$, $44{,}03^0$, $58{,}34^0$, respectively [14-17]. Besides, the Raman spectrum of the UMS sample also appeared peaks at a distance between the two peaks corresponding to the thin layer structure of MoS_2, about 2–15 nm [3,4]. Combined with SEM and TEM results, it showed that thin layer MoS_2 was fabricated from MoS_2 block samples. The mechanism of the process will be continued in the next studies.

IV. CONCLUSIONS

Nanometer-sized MoS_2 material has been successfully fabricated by ultrasonic vibration method in a water environment. A simple method at room temperature can be used to synthesize MoS_2 nanomaterial, which plays an important role in nanomaterial production and research. This obtained material has great potential for applications in the different fields of machining industries, photo electronics components, electrolytic electrodes, and sensors.

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