Progress in Physics of Applied Materials 3 (2023) 29–33

Semnan University

Progress in Physics of Applied Materials

journal homepage: https://ppam.semnan.ac.ir/

Fabrication and Investigation on Luminescence Properties of Bi_2WO_6 Microfibers via Stretching Process

M. Mansourian[1,2], S. Almadari[1,*]

[1]*Department of Nanotechnology, Faculty of New Sciences and Technologies, Semnan University, Semnan 35131-19111, Iran*
[2]*Faculty of Engineering, Payame Noor University, P.O. Box: 35351-13111, Semnan, Iran*

ARTICLE INFO

Article history:
Received: 24 December 2022
Revised: 10 March 2023
Accepted: 23 March 2023

Keywords:
Fiber
PVA
luminescence
Bi_2WO_6

ABSTRACT

In the fields of science and engineering, photoluminescent fibers have been employed for a variety of purposes, including optical storage, biological labeling, noninvasive imaging, solid-state lasers, light-emitting diodes, spectrum modifiers, and temperature sensors. Here, polyvinyl alcohol (PVA)-based microfibers comprising Bi_2WO_6 nanoparticles were fabricated via a simple stretching method as a highly luminescent and flexible material. The structural and optical features of the prepared Bi_2WO_6 microfibers were investigated using X-ray Diffraction (XRD), field emission scanning emission microscopy (FESEM) image, and ion beam induced luminescence (IBIL) techniques. Utilizing XRD analysis, related tetragonal phase of Bi_2WO_6 and polymer based PVA peaks were found in the prepared microfibers. Prepared Bi_2WO_6 microfiber exhibited strong blue-green emission upon excitation of 2.2 MeV proton beam and under a UV lamp at room temperature. Furthermore, microfiber diameter was obtained in the range of 8-33 μm. This highly luminescent microfiber is believed to be a good candidate for optical sensor and wearable optoelectronic applications.

1. Introduction

Many traditional materials have been replaced by nanostructured materials in the never-ending quest for superior qualities and performances since the latter surpass the former because of their structure and characteristics, which fall somewhere between those of atoms and materials in bulk. Due to the anisotropy in their length, high-aspect-ratio nano and microfibers are favored over nanoparticles and thin films. Comparing the ultra-elongated nanostructures to bulk materials or two-dimensional systems, they perform better in terms of charge and energy transmission. As a result, the creation of nanoscale light-emitting devices with high efficiency, extremely sensitive optical sensors, optical filters, waveguides, and innovative laser designs is becoming more and more in demand [1,2]. They can take on a variety of morphologies, including hollow fibers, hierarchical and core-shell nanofibers, micro- or mesoporous fibers, nanobelts, nanowires, nanoflowers, nanorods, and nanotubes. These morphologies lead to an increase in the nanofibers' specific surface area, which subsequently dictates improvements to their attributes, particularly in terms of their sensing performance [3]. By proper design and manipulation of the nanowire assembly, they can be utilized in complementary to photonic band-gap structures and plasmonic-primarily based gadgets in nanophotonic. On the other side, among tungstate family, Bi_2WO_6 is an extremely desirable material for optical devices due to its ideal luminescence characteristics, acceptable bandgap (2.75 eV), high exaction bonding energy, good density, and capability to detect ionizing radiations [4-8]. In another study PVA based nanofiber film comprising surface carboxylated CdSe/$Cd_xZn_{1-x}S$ quantum dots exhibited good photoluminescence-humidity and stretchability [9].

Recently, flexible perovskite luminescent textiles woven based polymer@perovskite@cyclodextrin@silane composite fibers have been reported; They have bright, narrow-band photoluminescence and good stability against immersion in water, UV radiation, elevated temperatures and overpressure [10]. Fiber optic sensors incorporating luminescent matter are useful in detecting physical parameters and biochemical species. Fluorescent

* Corresponding author. Tel.: +982331535431
E-mail address: s.alamdari@semnan.ac.ir

DOI: 10.22075/ppam.2023.29403.1050

materials embedded in fiber optic tips, for example, provide a way to perform fluorescence thermometry while monitoring the intensity or spectral variations of the fluorescence signal [11-13]. Stretching is a frequently used process to efficiently and economically manufacture bulk-scale micro sized materials. By using this technique, a polymer solution or melt is exposed to a mechanical and electrostatic forces outweighs the surface tension, the droplet is stretched to create fibers [14]. The feedstock consists of polymer solutions or melts with a high level of molecular cohesion brought on by interactions among molecules. This study presents an optical and structural investigation of luminescent Bi_2WO_6 microfibers obtained through stretching technique.

2. Experimental

Using our prior reports, Bi2WO6 nanoparticles were synthesized [4-11]. First, 50 ml of DI water was combined with 0.01 M of Bi(NO3)3 and Na2WO4 (99.9% Merck). The Na-containing solution was then added to the Bi-containing solution drop by drop. The produced precipitate centrifuged, dried and finally calcined at 600 ℃ for 2h. Synthesized nanopowders were mixed together according to the stoichiometry of 20-80 to PVA polymer in a larger beaker to obtain a completely homogeneous solution. Fig. 1 shows the experimental design for stretching and drying using an aluminum profile frame. In order to produce fibers, PVA powder was gradually added to the Bi2WO6 and deionized water solution by a magnetic stirrer, and after the solution reached a certain viscosity, it was ready to prepare nanofibers by stretching method. To produce fibers, first, some viscose solution was poured between two small flexible metal plates and fibers were formed by moving the two plates. An XRD analyzer (PAN analytical PW3050/60 diffractometer) was used to study the crystallography patterns of the thin films. Field scanning electron microscopy (FESEM-TESCAN) was used to study the shape and size of the samples. The ion beam induced luminescence (IBIL) was performed at the room temperature. Proton beam of 2.2 MeV energy and a current of ~5 nA was employed in the IBIL experiments.

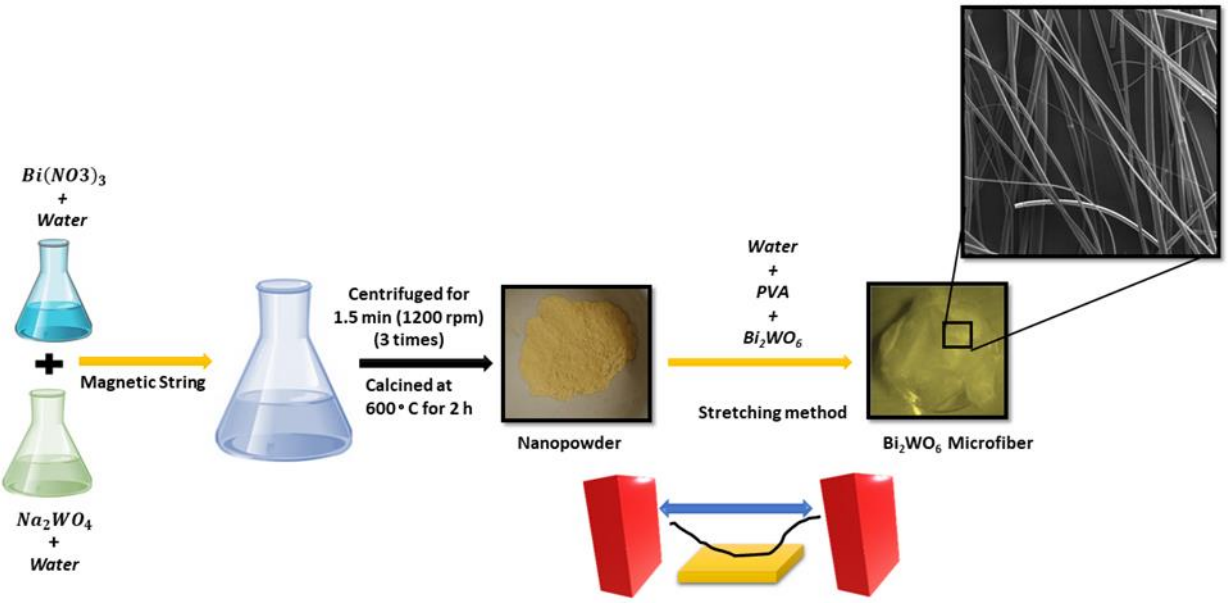

Fig. 1. Brief schematic photo of experimental works for microfiber preparation

3. Results and discussion

Figure 2 shows the XRD patterns for pure PVA, Bi_2WO_6 nanopowder, and prepared microfiber. It can be seen from Fig. 1 that the XRD pattern shows sharp and broad peaks around 2θ = 15° and 35° corresponding to semicrystalline nature of pure PVA [15]. The diffraction peaks for synthesized Bi_2WO_6 powder agree well with JCPDS card no.73-1126 of tetragonal phase of Bi_2WO_6 [4]. Two strong Bi_2WO_6 peaks and related PVA broad peaks are observed in XRD patterns of the prepared microfiber, this suggesting that the addition of the PVA doesn't change the crystalline structure of Bi_2WO_6.

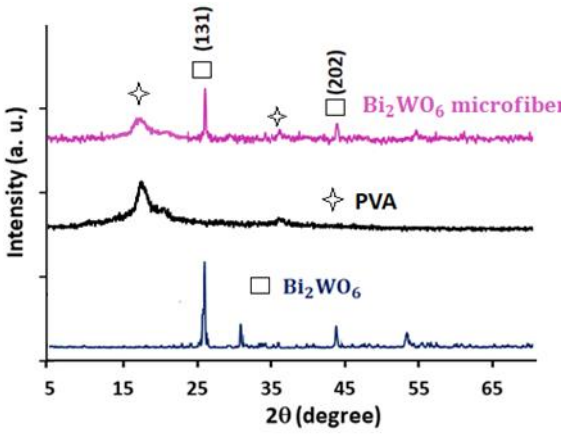

Fig.2. XRD patterns of the prepared samples

The surface morphology of the prepared Bi_2WO_6 microfiber and Bi_2WO_6 NPs was investigated by FESEM and TEM images (Fig.3). According to Fig.3(a-c) and its inset, Bi_2WO_6 particles are decorated on the PVA fibers with the average diameter of 8-13 µm. Cubic-like particles with an average diameter size of ~ 150 nm for Bi_2WO_6 NPs were observed in the TEM image (Fig.3c).

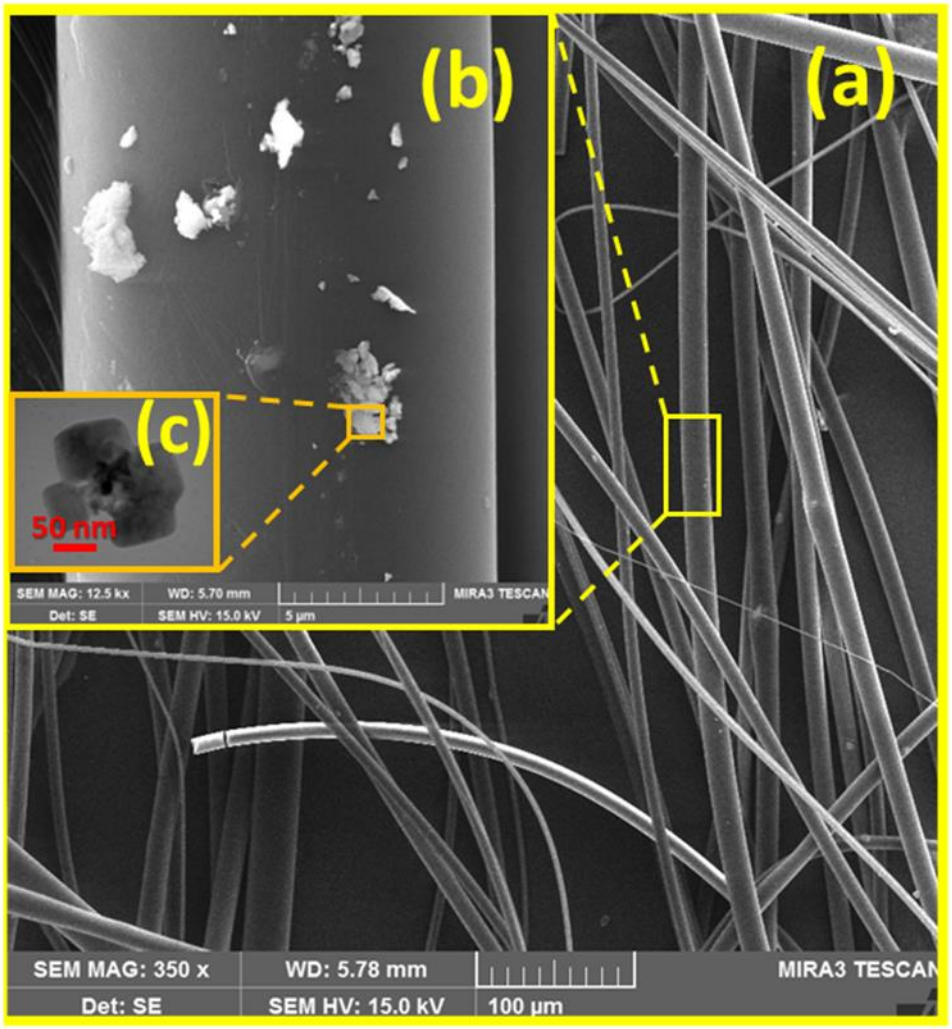

Fig.3. (a)FESEM image of the prepared Bi_2WO_6 microfiber with (b)inset FESEM image in different scale, and (c)TEM image of the pure Bi_2WO_6 nanopowders.

Figure 4(a) shows the photos of the prepared microfibers under day light and UV lamp. It is obvious that under UV irradiation fabricated Bi_2WO_6 microfiber shows strong blue-green luminescence for optical applications. As shown in Figs. 4(b, c) under concentrated proton beam irradiation, fabricated microfiber displayed strong green peak in the visible region which is related to the radiative recombination of excitons in WO_3 and WO_4^{-2} and groups. In similar study, NiO–ZnO ceramic nanofibers exhibited strong emissions at UV and visible region [16]. Also, La^{3+}: ZnO ceramic nanofibers displayed strong visible emissions at 400–600 nm under UV excitations [15]. Photoluminescence spectrum of the prepared pure Bi_2WO_6 nanopowder under 270 nm excitation wavelength at room temperature is displayed in the Fig.4(d). As is observed, green emission peak is appeared at about 530 nm. That is because of the recombination photo-induced charge transporters. Also, oxygen vacancies in Bi_2WO_6 crystals are thought to be the reason for the green emission [17].

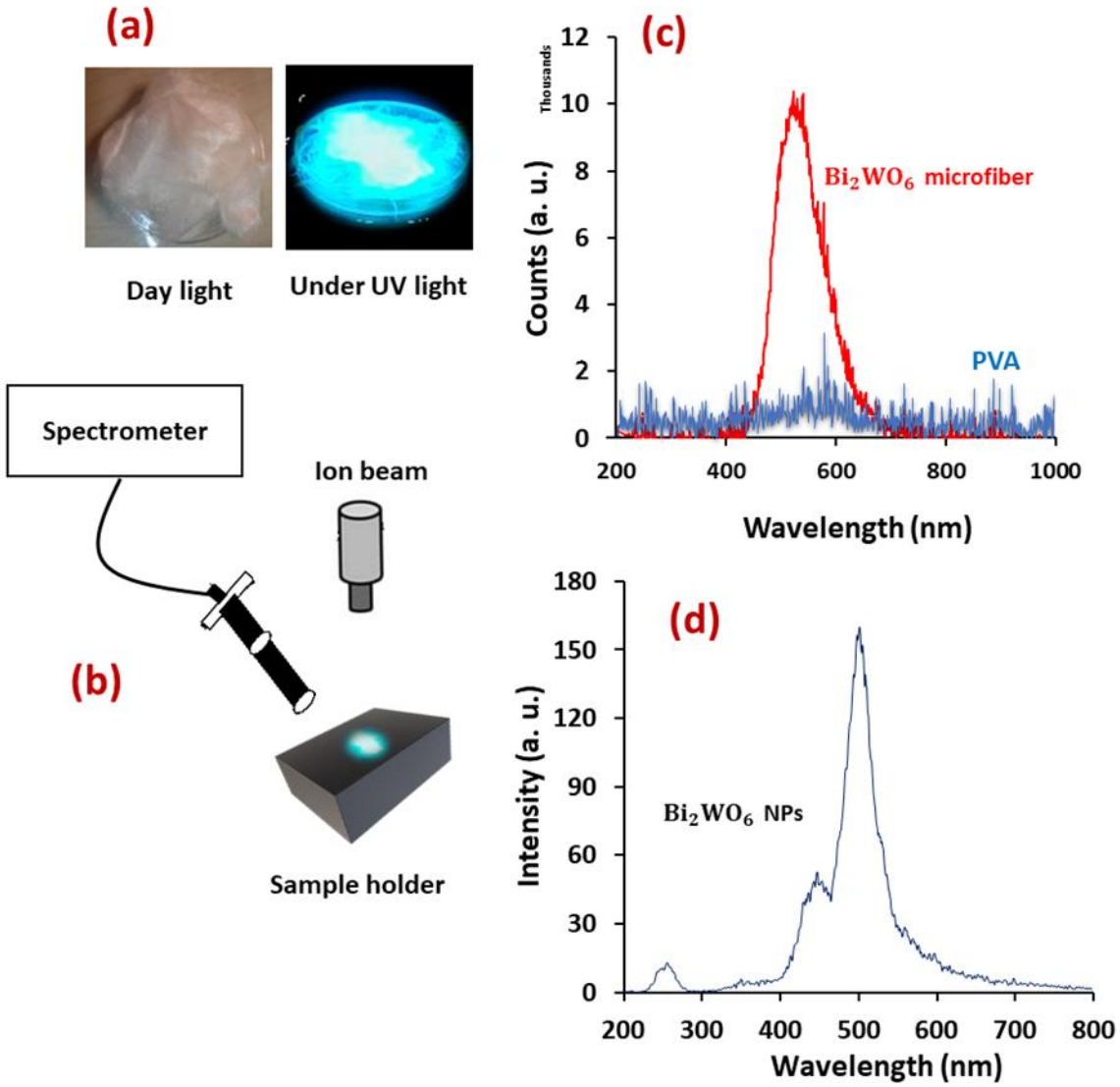

Fig.4.(a) Photos of luminescence properties of the prepared sample under UV light, (b)IBIL measurement setup, (c)IBIL spectrum of the neat PVA as background and prepared Bi_2WO_6 microfiber, and (d)PL spectrum of the pure Bi_2WO_6 NPs under 270 nm excitation wavelength at room temperature.

4. Conclusion

In conclusion, we developed a PVA-based microfiber comprising Bi2WO6 NPs to obtain a luminescent flexible material. First by applying a simple co-precipitation process Bi2WO6 NPs were synthesized then, using stretching method Bi2WO6 microfiber was prepared. The resulting fibers with the average diameter of 8-33 μm exhibited strong green emission under proton beam excitations. Utilizing XRD analysis, related tetragonal phase of Bi2WO6 and PVA peaks were found in the prepared microfibers. Obtained results showed that this new idea affords a technical reference for the construction of heterojunction phosphor with unique interface touch and its utility in optical fields.

Compliance with ethical standards

All the authors declare that they have no conflict of interest.

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