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Application of ultrasound-aided method for the synthesis of $NdVO_4$ nano-photocatalyst and investigation of eliminate dye in contaminant water

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ABSTRACT

This paper presents a new approach to preparation of neodymium vanadate nanostructures via facile sonochemical route. Several parameters were compared to reach optimum size and uniformity of as-made samples. These factors include sonication time, sonication power, solvent and using ethylenediamine as alkaline and capping agent, for the first time. Neodymium vanadate nano-photocatalyst applied in decolouration of dye as organic contaminant. Effect of type of dye, type of irradiation source, pH and catalyst loading was described on improving efficiency of catalyst function. Numerous techniques were specified in order to determine purity, morphology and optical properties of products consist XRD, FT-IR, EDX, SEM, TEM and DRS.

1. Introduction

Neodymium vanadate is a significant category of rare earth orthovanadate material which is play an important role in diverse fields such as: catalyst [1], photocatalyst [2], Photoluminescence optical attributes [3], phosphors [4], polarizer [5] and laser properties [6]. Previous researches have documented several morphology and shape for neodymium vanadate which synthesized by different methods. These include sol-gel [7], sonochemical [8], microwave [9], hydrothermal [10], solid state [11] and precipitation [12]. In addition to the rare earth vanadate, transition metal vanadate have a suitable potential for applying in various industrial fields. Vanadate of copper, cobalt, zinc, cadmium and iron[13–19] have been studied for use in lithium ion batteries [20], antibacterial additive [21], photocatalyst [22], water splitting [23], super capacitors [24], luminescence device [25] and gas sensors [26]. Among all applications for vanadate compound, much attention has been paid to photocatalytic ability in elimination of organic contaminant from waste water. Utilizing novel technology and material based on versatile, clean and renewable source is an essential task due to important crises such as environment pollutant and energy deficiency. Nowadays, Nano-photocatalyst material with convenient use available everywhere for water purification and recycling of contaminated water. A key factor in select a proper photacatalyst is a material with a narrow band gap which provides favorable condition to use all wavelengths (UV and visible) of sunlight. A series of compounds in terms of low band gap which have been employed as catalyst for water treatment are lanthanide vanadate [27]. So, Neodymium vanadate, as one of the most serious family of vanadate materials, have an appropriate feature in destruction of pollutant. The various types of photocatalysts are available that most famous of them can be noted TiO_2 [28,29]. But researches continue to replace or improve the properties of the photocatalyst materials [30–32]. TiO_2 as catalyst has favorable potential for decoloration of dyes as organic pollutant. Kansal et al. investigated Photocatalytic degradation of Eriochrome Black T dye using well-crystalline anatase TiO_2 nanoparticles and showed that photocatalytic efficiency for degradation of Eriochrome Black T by TiO_2 is about 83% [33]. Recently, several authors [12,34] have proposed ability of $NdVO_4$ nanoparticles for photocatalytic performance. In related references it was observed that $NdVO_4$ have proper photocatalytic activity which is competitive with TIO_2.

This paper takes a new look at ultrasound assisted synthesis of neat $NdVO_4$ by focusing on the impact of various factors and preparation condition such as solvent, power and time of sonication on size and homogeneity of as-prepared samples. Within the framework of these criteria, XRD, FT-IR, EDS, UV–Vis, SEM and TEM analysis were used to comparing and characterizing properties and structure of as-prepared products. Several parameters were performed to improve photocatalytic activity of catalyst on degradation of different organic dyes under UV and Visible light.

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Table 1
preparation condition for synthesis of neodymium vanadate nanoparticles.

No.	Method	Solvent	Sonication Time (min)	Power ultrasound (W/cm^2)	Crystallite Diameter (XRD)/nm	Particle Range Size (SEM)/ nm
1	Sonochemical	Water	30	60	13.89	26–62
2	Precipitation	Water	–	–	–	33–75
3	Sonochemical	Water	10	30	–	26–89
4	Sonochemical	Water	10	60	–	31–63
5	Sonochemical	Water	20	60	–	24–70
6	Sonochemical	MeOH	30	60	–	19–42
7	Sonochemical	PG	30	60	9.33	34–97

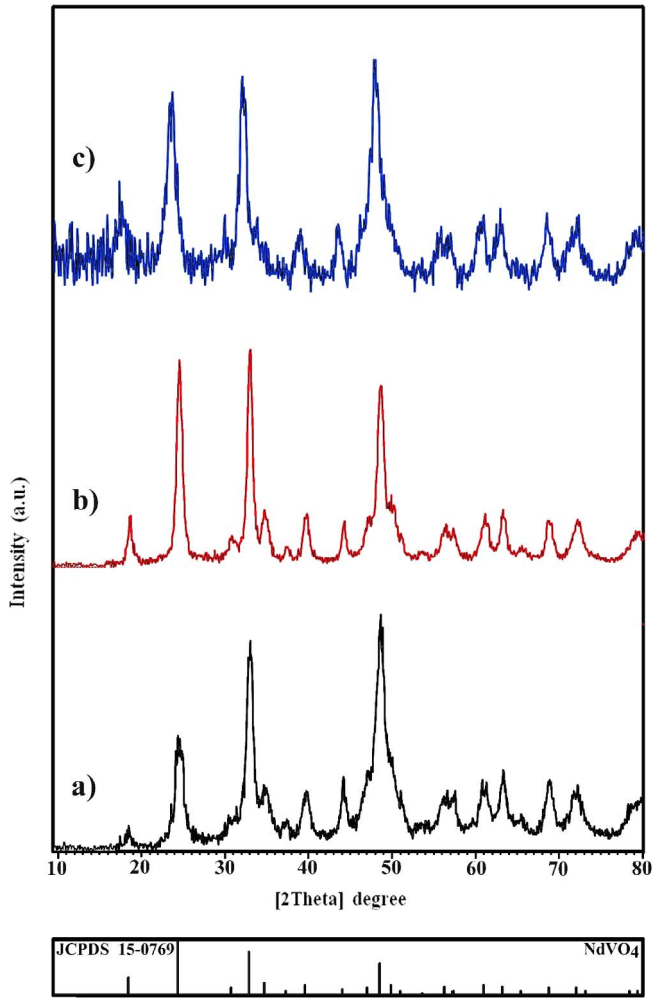

Fig. 1. XRD pattern for $NdVO_4$ a) (Sample No. 1) before calcination, (b): (Sample No. 1) after calcination at 500 °C, (c) (Sample No. 7) prepared in presence of PG.

2. Experimental

2.1. Materials and physical measurements

All of the chemicals used in synthesis of Neodymium Vanadate nanostructures including neodymium nitrate hexahydrate, ammonium metavanadate and ethylenediamine were purchased from Merck Company and didn't purify any more. GC-2550TG (Teif Gostar Faraz Company, Iran) were used for all chemical analyses. A multiwave ultrasonic generator (MPI Ultrasonics; welding, 1000 W, 20 kHz, Switzerland), immersed directly in the reaction solution. X-ray

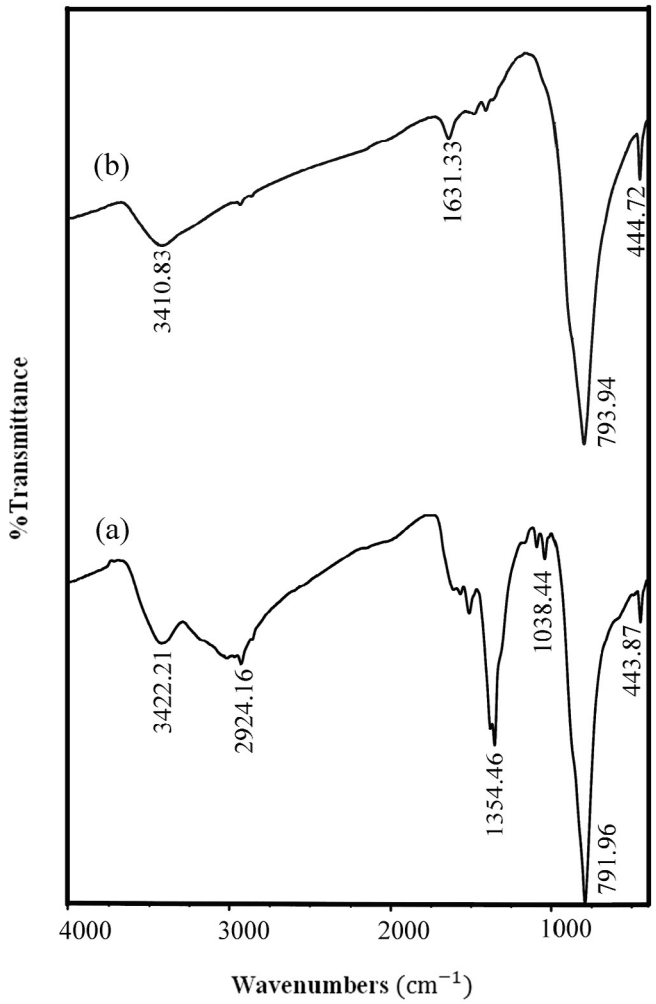

Fig. 2. FT-IR spectra for $NdVO_4$ a) before calcination and b) after calcination.

diffraction (XRD) patterns were recorded by a Philips-X'pertpro, X-ray diffractometer using Ni-filtered Cu Ka radiation. Fourier transform infrared (FT-IR) spectra were recorded on Nicolet Magna- 550 spectrometer in KBr pellets. The electronic spectrum of the sample was recorded on Perkin–Elmer LS-55 luminescence spectrometer. GC-2550TG (Teif Gostar Faraz Company, Iran) were used for all chemical analyses. Scanning electron microscopy (SEM) images were obtained on LEO-1455VP equipped with an energy dispersive X-ray spectroscopy. The EDX analysis with 20 kV accelerated voltage was administered. Transmission electron microscopy (TEM) image was found by a Philips EM208 transmission electron microscope with an accelerating voltage of 200 kV. The diffused reflectance UV–visible spectrum (DRS) of the sample was recorded by a V-670 UV–Vis–NIR Spectrophotometer (Jasco). The N_2 adsorption/desorption analysis (BET) was performed at −196 °C using an automated gas adsorption analyzer (Tristar 3000, Micromeritics). Pore size distribution was calculated by using desorption branch of the isotherm by the Barrett, Joyner and Halenda (BJH) method. Magnetic properties were measured using a vibrating sample magnetometer 60 (VSM, Meghnatis Kavir Kashan Co., Kashan, Iran).

2.2. Synthesis of pure $NdVO_4$

Neodymium Vanadate nanostructures were synthesized by simple sonochemical procedure in the presence of ethylenediamine. Initially, 0.25 g Nd $(NO_3)_3{\cdot}6H_2O$ dissolved in 40 ml deionized water. Then, 0.067 g NH_4VO_3 dissolved in 40 ml deionized water at 70 °C and added to the above solution. The stoichiometric ratio of Nd:V is 1:1 for each