Synthesis and Characterization of Vanadium Pentoxide (V_2O_5) Nanoparticles

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ABSTRACT

Vanadium Pentoxide (V_2O_5) nanoparticles have been prepared using a Hydrothermal method by Ammonium metavanadate as a precursor and Cetyl trimethyl ammonium bromide (CTAB) as surfactant. They are characterized using P-XRD, UV-Vis spectroscopy, FESEM, EDAX and Antimicrobial investigations. As there are many forms of vanadium oxides produced during this process, X-ray diffraction (XRD) technique was used to identify V_2O_5 phases. The size of as- prepared nanoparticles was around 45 nm. UV spectra indicate that the samples exhibit absorption bands below 400 nm which shows that there is a blue shift due to the quantum confinement of developed nanoparticles. The morphological properties of the V_2O_5 were investigated by FESEM.

Keywords: *Hydrothermal, Surfactant, Morphological, FESEM, Structural*

1. Introduction

V_2O_5 has been gained significant interest in the applied research to range of applications [1]. V_2O_5 is the most stable among all vanadium oxides and has high oxidation state [2, 3]. The outstanding properties such as a direct band gap in the visible-light region (Eg = 2.2 to 2.7 eV) [4], multi-valance, good chemical and thermal stability, excellent thermoelectric property make V_2O_5 nanostructure is a suitable material for solar cells [5], gas sensor [6], optical-electrical switches [7], chemical sensing [8], electrochromic devices [9], and optoelectronic devices [10,11]. Therefore, one dimensional (1D) nanostructures of V_2O_5 are considered to be more appropriate for the device applications as compared with its other forms. V_2O_5 nanostructures have been prepared by different techniques including chemical vapor deposition [12], magnetron sputtering [13], sol-gel method [14], pulsed laser deposition [15], electron beam evaporation [16], electro spinning [17], spray pyrolysis [18] and hydrothermal synthesis [19].

Transition metal oxides have been a subject of research in recent years in view of their fundamental and technological aspects. Among these, vanadium creates many compounds with oxygen; these have different structural, optical and chemical properties. Meaningful differences between the properties of different phases of vanadium oxides like VO, VO_2, V_2O_3 and V_2O_5 depend on their structure, which determines other properties [20, 21].

Vanadium pentoxide (V_2O_5) is a thermodynamically stable form which exhibits electrochromic properties. In this article, vanadium pentoxide nanoparticles are fabricated by using hydrothermal method. Structural and surface morphological properties have been studied.

2. Experimental Detail

The synthesis of V_2O_5 nanoparticles have been carried out by a surfactant assisted hydro thermal method. V_2O_5 was prepared by mixing of 3.52gm of Ammonium meta vanadate (NH_4VO_3) along with 0.01 mol of CTAB which dissolved in ethanol and mixed with distilled water. The 5ml of nitric acid has been added slowly in the above mixture for about 1 hour at 70°c with continuous stirring to reach the pH level '2'. The resulting solution was kept inside the hot air oven around 2 hours at 180°C for precipitation. After two hours, the precipitate was washed with distilled water for 10 times and then washed with ethanol. Finally, the sample was dried at room temperature and then calcinated at 400°C and 600°C for about 2 hours. After the completion of the above procedure the prepared nanoparticles are characterized using XRD, UV, FESEM with EDAX.

3. Result and Discussion

3.1. XRD Analysis of Pure V_2O_5 Nanoparticle

The average grain size of V_2O_5 nanoparticles has been estimated from full width at half maximum (FWHM) and the crystalline size was calculated with the help of Debye-Sherrer formula, which is given as

$$D = 0.9\lambda/\beta \cos\theta$$

Where, D is the crystalline size, β is the full width at half maximum (FWHM) of the most intense diffraction peak in radiance, θ the diffraction angle and λ the wavelength of X–ray radiation.

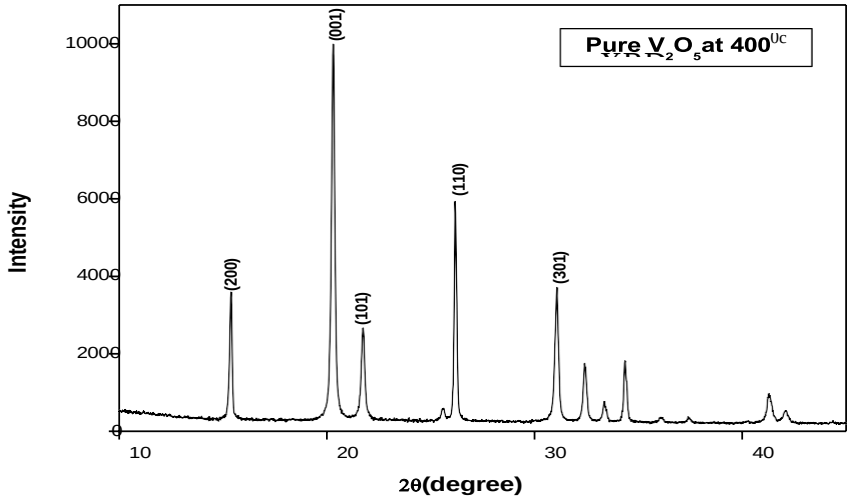

Fig 1. XRD spectrum of V_2O_5 nanoparticles at 400°C

The observed d-spacings and the relevant prominent peaks for the V_2O_5 nanoparticles correspond to reflections of (200), (001), (101), (110) and (301) planes and are in good agreement with the standard data (JCPDS card no: 77.2418; a = 11.51Å, b=3.564Å,c=4.368Å) and the PXRD peaks of V_2O_5 are at $2\theta = 15.414^0$, 20.329^0,21.764^0, 26.196^0 and 31.078^0 respectively. No other impurities are observed. XRD spectrum shows orthorhombic structure of V_2O_5 annealed at 400°C. The mean size of the annealed V_2O_5 nanoparticles was found to be around 45nm from Debye-Sherrer equation.

Table 1. Comparison of JCPDS and observed d-spacing values of V_2O_5 nanoparticles at 400°C

Position 2θ (Degree)	FWHM (β) (Degree)	Observed d-spacing (Å)	JCPDS d-spacing (Å)	(hkl) Values	Relative Intensity (%)
31.078	0.115	2.87542	2.8780	(301)	37.3
26.196	0.100	3.39918	3.4045	(110)	67.2
21.764	0.113	4.08028	4.0839	(101)	24.6
20.329	0.106	4.36488	4.3680	(001)	100.0
15.414	0.100	5.74385	5.7560	(200)	34.3

3.2 UV-Vis Absorbance Spectroscopy

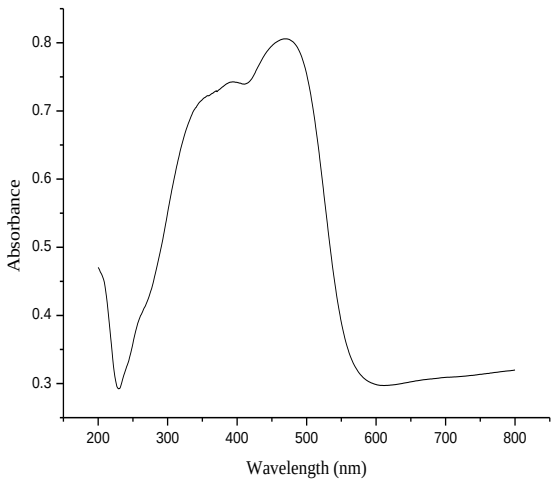

Fig 2. UV-Vis Absorbance Spectroscopy of V_2O_5 nanoparticles

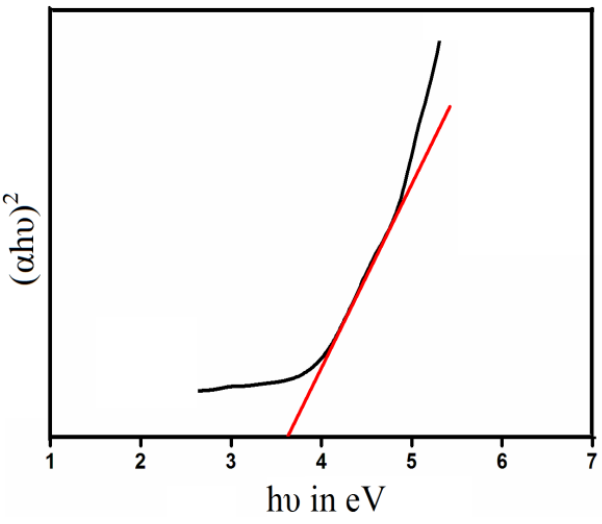

Fig 3. UV Bandgap energy of V_2O_5 nanoparticles

The UV-Vis absorption spectra were used to record 0.001 M of V_2O_5 which dissolved in ethanol. UV–Vis optical properties in the range (200–800) nm at temperature (400°C) showed temperature-dependent absorbance as given in Fig. It can be seen that the absorption peaks of V_2O_5 nanoparticles appear around 350 nm and the bandgap energy calculated from Tauc plot is found to be around 3.6 eV.

3.3 FESEM and EDAX of V_2O_5 Nanoparticles

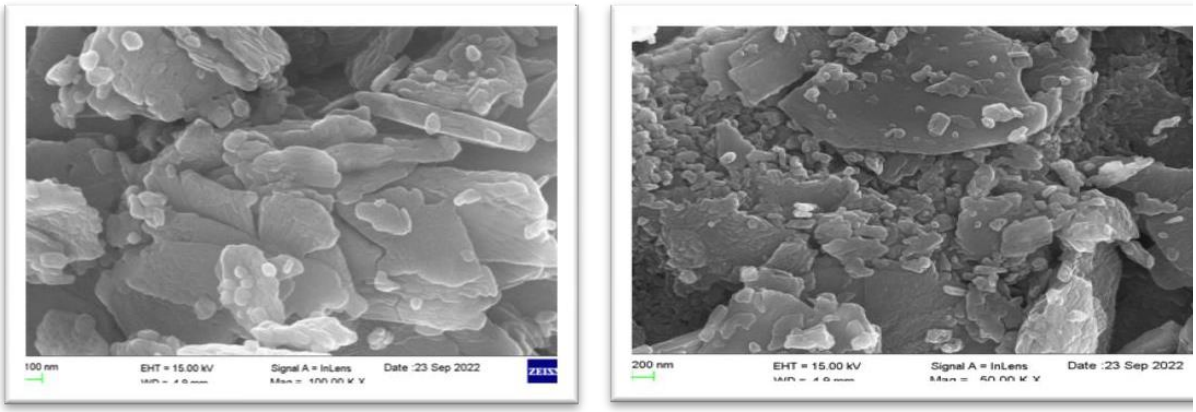

Fig 4. FESEM images of V_2O_5 nanoparticles at 400°C

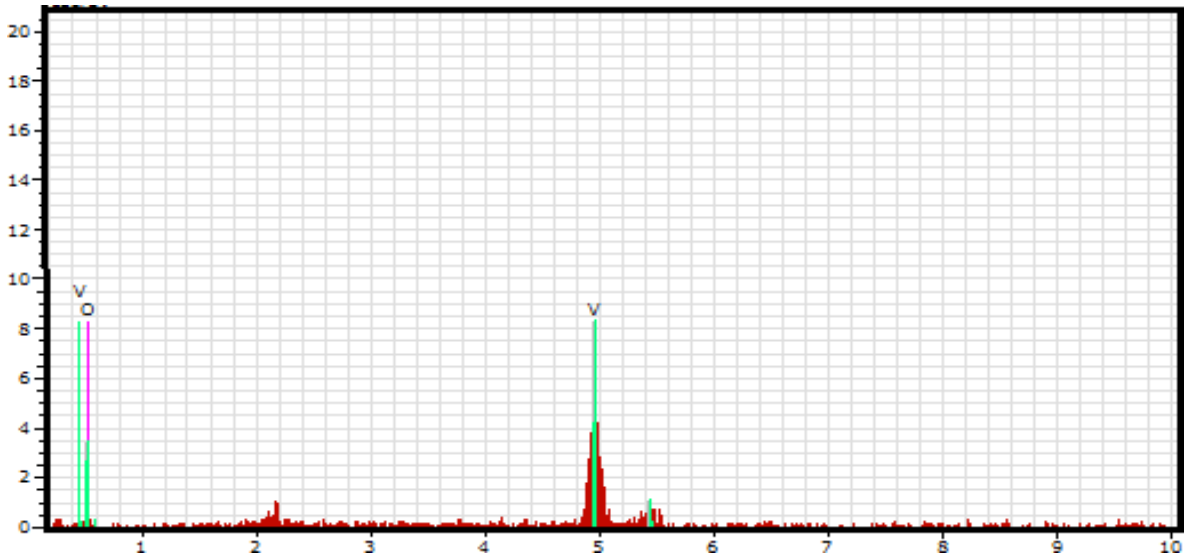

Fig 5. EDAX spectrum of V_2O_5 nanoparticles at 400°C

The surface morphology of the V_2O_5 nanoparticle is characterized by FESEM analysis and suggested rod like morphology. The elemental analysis (qualitative and quantitative) of the prepared sample was analyzed by EDAX spectrum. The EDAX spectrum confirms the elements present in the sintered sample are V and O ratio 23:1.

Conclusion

Vanadium oxide nanoparticles were successfully prepared using simple hydrothermal method by ammonium metavanadate as precursor and CTAB as surfactant. XRD spectrum shows orthorhombic structure of V_2O_5 annealed at 400^oC. The morphological properties of the V_2O_5 were investigated by FESEM. From FESEM images, it is clear that with increasing temperature the morphology of the particles changes to nanoparticle shaped and the size of particles decrese to 10 nm. UV-Visible spectra of V_2O_5 nanoparticles with surfactant exhibited absorption at 350 nm and the bandgap energy calculated from Tauc plot is found to be around 3.6eV.

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