Optik 127 (2016) 3299–3302

Contents lists available at ScienceDirect

Optik

journal homepage: www.elsevier.de/ijleo

Comparison of optical, structural, morphological, vibrational and thermal analysis of V_2O_5 nanobelts prepared with and without the application of constant current source from renewable energy

R.L. Josephine [a,*], S. Suja [a], A. Dhayal Raj [b]

[a] Department of Electrical and Electronics Engineering, Coimbatore Institute of Technology, Coimbatore 641 014, India
[b] PG and Research Department of Physics, Sacred Heart College, Tirupattur 635 601, India

ARTICLE INFO

Article history:
Received 30 July 2015
Accepted 8 December 2015

Keywords:
Optical band gap
V_2O_5 nanobelts
Constant current source
Renewable energy

ABSTRACT

Investigating the optical and vibrational properties of a material plays a vital role in the materials applicability. One dimensional nanostructures of V_2O_5 are used as applications in the field of desalination, microelectronics, optoelectronics, sensors, lithium batteries, etc. The synthesis parameters play a vital role on the properties of the prepared nanostructured materials. Especially the problem of power fluctuation during the synthesis has a very predominant effect in the synthesis of Nanomaterials. Hence a constant and continuous power from a renewable energy-constant current source incorporating solar and wind energy has been applied for the preparation of uniform and smooth surfaced V_2O_5 nanobelts by simple hydrothermal method. Therefore the resulting nanobelts proved to be successful outcome of material science and renewable technology. The prepared nanobelts were found to be uniform surfaced with narrow size distribution. The samples have been characterized by UV-vis, XRD, SEM, FTIR and TG/DTA in order to investigate the optical, structural, morphological, Vibrational and thermal properties.

1. Introduction

Optical properties of a material when tailored contribute much for the applicability of the material. The synthesis parameters and formation conditions affect the optical, structural and compositional properties of nanomaterials to a great extend. In this research an interdisciplinary work combining the engineering research outcome with the material scientists in nanomaterial synthesis to study the effect of constant current source with negligible variation in power supplied during the material synthesis has been reported. Among the abundant nanostructure metal oxide, vanadium oxide (V_2O_5), which is an important semiconductor material with a band gap of 2.4 eV, is of great interest because of its potential applications to cathode materials [1], solid field emitters [2,3], thermochromic [4], Photoconductivity [5], Cation-Induced Coiling [6], sensors [7–10], lithium batteries [11], microelectronics [12], optoelectronics [13], etc. It is seen that the optoelectronic properties and other properties of V_2O_5 are highly structure sensitive which in turn can severely influence the device performance. Especially, the optical properties of the nanomaterials get affected very much because of their morphology and structure. Despite numerous scientific works, new routes of fabrication and the fundamental understanding of these materials are much more essential so that they can be integrated into contemporary and emerging technologies. Therefore, an attempt has been made in our present investigations to prepare V_2O_5 nanobelts powders by simple hydrothermal method and to investigate their optical, vibrational and compositional properties.

2. Experimental procedure

2.1. Construction of constant energy source from renewable resource

Energy source is a hybrid renewable energy system deploying Photo Voltaic Array and Wind energy system incorporating with the battery backup. The typical configuration of the energy source integrates Variable Speed Wind Turbine (VSWT) based Permanent Magnet Synchronous Generator (PMSG) and Photo Voltaic (PV) array is shown in Fig. 1. PMSG of rating 2.7 kW wind turbine at 6 m/s wind speed is chosen. Solar PV array is installed for 6 kW. Hence the overall load Power that can be handled is 8.7 kW. Both the input powers are fed to the load through the inverter of rating 10 kV A. The energy utilization from these power sources varies

* Corresponding author. Tel.: +91 9750541213.
E-mail address: josephinedhayal@gmail.com (R.L. Josephine).

http://dx.doi.org/10.1016/j.ijleo.2015.12.026
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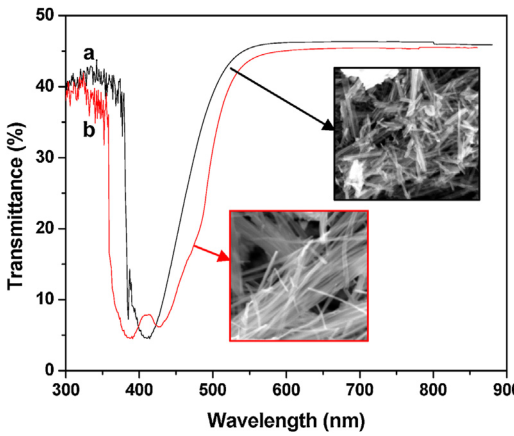

Fig. 1. UV–vis spectra of V_2O_5 nanobelts (a) sample A and (b) sample B.

with various instants of times along the entire day. The energy is saved in the battery and is used during the absence of the both renewable energy. In case of solar, wind and battery outages and when the battery discharges and reaches the lower limit, the grid supply is utilized to charge the battery and to handle the necessary loads.

2.2. Synthesis of V_2O_5 nanobelts

In a typical synthesis of V_2O_5 nanobelts, 0.1 mol of ammonium metavanadate was taken and adjusted to a pH value of 2 by adding Sulphuric acid (H_2SO_4) drop wise under constant stirring at room temperature. Now the entire reaction mixture was transferred to Teflon lined stainless steel autoclave of 50 ml capacity and ensured that it is packed well. The autoclave was then maintained at a temperature of about 200 °C for 24 h. The precipitate formed at the end of the reaction was separated and washed repeatedly with double distilled water and ethanol to remove the traces of unreacted starting compounds. Finally the precipitate was separated by centrifuging and dried in hot air oven at a temperature of 75 °C for 5 h. The same procedure has been adopted to prepare two samples. Sample A was prepared by applying the constant current source obtained from the renewable energy, by avoiding the fluctuations in the power supply. Sample B was prepared with ordinary current supply with fluctuations and variations. Both the samples have been characterized in order to investigate the importance of constant current source and to study the effect on the optical, vibrational and thermal properties of preparing the samples with and without current fluctuations.

3. Results and discussion

3.1. Optical analysis

To evaluate the optical properties of the obtained V_2O_5 nanobelts prepared with and without Constant current source, the UV–vis spectroscopic technique has been used. The UV–vis absorption spectra in Fig. 1a and b correspond to V_2O_5 nanobelts prepared with and without constant current source. The inset pictures in Fig. 1 correspond to the respective SEM images indicating the surface morphology of the nanobelts. The surface area of the sample plays a vital role in the UV–vis absorption as is evident from the spectra presented in Fig. 1. The uniform smooth surfaced nanobelts with large length shows more absorption which may be accounted with increased surface to volume ratio of the sample. From earlier reports the absorption band for bulk V_2O_5 powders appear at about 470 nm [14]. However, the absorption edge of both the V_2O_5 nanobelts prepared with and without constant current source from renewable energy is blue-shifted compared to that of bulk V_2O_5 powders. The origin of the blue shift in the absorption edge is suggested to be the contribution of a quantum size effect in V_2O_5 nanorings and microloops [15,16]. The V_2O_5 nanobelts prepared with constant current source from renewable energy shows two broad prominent peaks around 380 nm and 430 nm respectively.

3.2. Structural analysis

Powder X-ray diffraction patterns were recorded by employing a Bruker AXS D8 X-ray diffractometer (Cu-$K\alpha$, $\lambda \sim 1.5406$ Å). X-ray diffraction patterns were recorded to evaluate the phase purity and structural confirmation of the samples obtained. The diffraction patterns were recorded in the range $10^\circ < 2\theta < 60^\circ$ scanning with steps of 0.1° min^{-1}. Fig. 2a and b shows the XRD pattern of the samples A and B respectively. The well resolved peaks in the pattern match with JCPDS # 09-0387, confirming the formation of V_2O_5 with a orthorhombic structure. The lattice parameter values of the prepared samples were a = 11.51, b = 3.559, c = 4.371 Å. The insert images in Fig. 1a clearly show that even when the intensity of the peaks are very high the peaks are broad indicating the formation of fine nanostructures. The average crystallite size as calculated by Scherrer's formula is approximately 40 nm and 23 nm for sample A and sample B respectively.

3.3. Morphological analysis

The surface morphology of the grown nanobelts was examined using Hitachi model S-3000H scanning electron microscope. The scanning electron microscope was used to examine the shape of the prepared samples. Fig. 3a corresponds to the SEM image of the sample (sample A) prepared by applying the constant current source

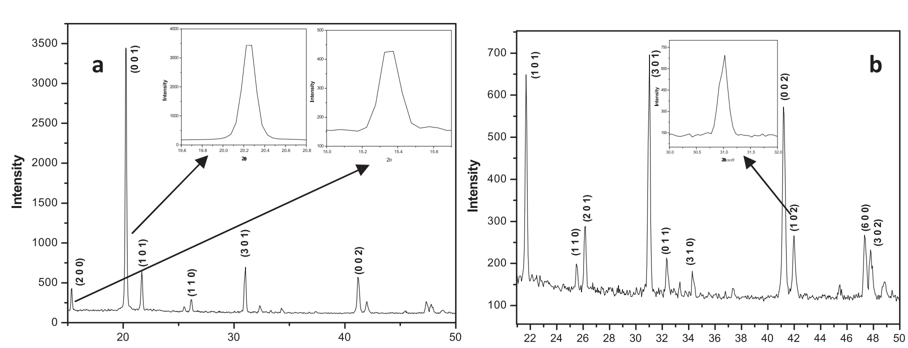

Fig. 2. XRD pattern of V_2O_5 nanobelts (a) sample A and (b) sample B.