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Microwave Assisted Synthesis Polyaniline-Vanadium Oxide Nanocomposites and their Electrochemical Studies

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ABSTRACT

In this article, we reported microwave assisted processing of vanadium oxide-polyaniline nanocomposite (PANI/V_2O_5). Firstly, polyaniline (PANI) is synthesized by oxidative polymerization method and vanadium pentoxide nanoparticles. In the second step, intercalation of PANI in V_2O_5 framework are carried out in the microwave at 80 ºC for 30 min in Teflon crucibles. The XRD exhibited a set of well-defined peak support the crystal nature of nanocomposites. FTIR studies of the composite supported the intercalation of PANI with V_2O_5. The peaks obtained by cyclic voltammetry shows marginal separation between anodic peaks at 3.6 and 3.7 V for polyaniline and shifted to the higher potential for PANI/V_2O_5 nanocomposite. Also, the electrical conductivity is found to be 10^{-6} S cm^{-1} for PANI and higher electrical conductivity, 10^{-4} S cm^{-1} for nanocomposites.

KEYWORDS

Vanadium oxide, Polyaniline, Nanocomposite, Cyclic voltammetry, Electrochemical properties.

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INTRODUCTION

The amalgamation of conducting nanoparticles and conducting polymers is a novel area of research [1]. Due to unusual properties such as tunability, electrical conductivity, decent eco-friendly steadiness, *etc*. make this nanocomposites as the prospective entrant for the extensive assortment of solicitations such as gas sensors [2], light emitting diodes (LEDs) [3], photovoltaic devices [4], corrosion inhibitors [5], storage devices [4], *etc*. By modifying the morphology of nanostructures their new set physico-chemical properties can be developed. In this lieu, many prominent researchers tried to synthesis one dimensional (1-D) nanostructure of conducting polymers [6]. One dimensional (1-D) nanostructure of conducting polymers a unique advantage for field emission practical applications due to high aspect ratio [8]. Several scientific groups [7-11] have carried out field emission investigation of various conducting polymers and nanocomposites. Among other conducting polymers, polyaniline (PANI) has been extensively used in the energy storage and conversion devices due to high specific capacitance, processability and cost-effectiveness [12]. It alone can be used in fabricating an electrode. However, the unstable nature of PANI restricts its application. Polyaniline nanocomposites can be used in super capacitors, sensing platforms, fuel cells, electrochemical devices, solar cells, lithium-ion batteries, *etc*. [13]. Polyaniline nanofibril synthesized and its field emission investigation is reported and observed threshold field of 5-6 V/μm corresponding to emission current density of 0.01 mA/cm^2 by Wang *et al*. [7].

Kim and his co-workers [8,9] reported electrical conductivity studies of nanowire and nanotubes of doped and de-doped PANI, polypyrrole, *etc*. Electrochemical properties of carbon nanotube-polyaniline composites have been reported by many researchers [13]. It has been perceiving that the functionality of the conducting polymers nanocomposites also improve their emission characteristics. In this perspective, Rakhi *et al*. [13] and Nair *et al*. [14] have investigated the electrochemical properties studies of different conducting polymers. Patil *et al*. [15] reported the field emission investigation of CdS-PANI nanocomposites.

V_2O_5 in arrears to its small band gap of 2.6 eV make it more convincing promise with stately photoemission and optical properties [16]. If we doped V_2O_5 with conducting materials which effectively increase electrons density give rise to change in fermi energy from the top of the valence band to the bottom the conduction band. The band gap was almost identical to the bulk structure band gap with a value of 1.66 eV [17]. Optical properties of this oxide is reported by Sieradzka *et al*. [18]. The V_2O_5 nanowires show morphology dependent optical properties and conductivity measurements display a minor turn-on field voltage ~8.3 V/μm at 1.8 mA/cm^2 [19]. $V_2O_5{\cdot}nH_2O$ nanotube array a novel material for energy storage reported by Zhou *et al*. [20]. Due to the structure stability amalgam of inorganic semiconductors-conducting polymers and favourable low bandgap make these materials as promising candidates for diversified applications in vacuum microelectronics [21], biosensors [22], photovoltaic and light emitting diodes [23].

Present main aim focused on simple synthesis and characterization of V_2O_5 nanotubes and vanadium oxide-polyaniline nanocomposite (PANI/V_2O_5) nanocomposite by microwave assisted chemical synthesis. This method of synthesis is fast, simple and eco-friendly in which microwave radiation was employed as a heating source for nanoparticle synthesizing. Compare to the conventional method of synthesis, microwaves directly react to the material by means of numerous possible mechanisms and the chemical react quickly [24]. Also, we reported the conductivity of PANI/V_2O_5 nanocomposite. The obtained value is higher than the individual counterparts' *i.e.* V_2O_5 and PANI nanostructures. The results obtained are encouraging with excellent morphological stability and outstanding physico-chemical properties.

EXPERIMENTAL

The precursors, aniline monomer, acetic acid, ammonium persulphate, ammonium metavanadate and nitric acid were procured from Sigma Aldrich (Merck) and used as received.

Synthesis of PANI: The polyaniline was synthesized by the oxidative polymerization method. Ammonium persulphate (0.2 M) was slowly added in the homogenous mixture of 0.1 M aniline monomer and 0.5 M acetic acid. The reaction proceeds with constant stirring for 5 minutes by the appearance of dark brown colour which turn green and finally into dark green. The mixture was kept undisturbed for next 24 h followed by filtration and washing 2 to 3 times with distilled water and ethanol and drying in the air by using IR lamp [25-27].

Synthesis of V_2O_5 hollow nanotubes: Vanadium oxide hollow nanotubes were synthesized by using 0.1 M solution of ammonium metavanadate mixed in 0.1 M nitric acid with constant stirring for 0.5 h in the acidic medium. The solution appears to dark red colour. The solution was kept at rest for 45 min to form the precipitate. The precipitate was collected and repeatedly washed by double distilled water. The precipitate was then taken into Teflon crucible and placed microwave oven for 30 min. After that the product is kept in the muffle furnace at 200 ºC for 2 h for drying [28-30].

Synthesis of PANI/V_2O_5 Nanocomposite: Polyaniline-vanadium oxide nanocomposite was synthesized by mixing synthesized PANI powder with a small amount of vanadium oxide nanotubes. The amalgam is then placed in a microwave oven for 30 min at 80 ºC. After that the product was kept undisturbed for the next 24 h. The procedure further proceeds with filtration, washing serval times with double distilled water and ethanol and drying by IR lamp [31-35].

RESULTS AND DISCUSSION

The characterization of synthesized materials is conducted at UGC-DAE Consortium for Scientific Research, Indore, India. X-ray diffraction scattering (XRD) study is carried out by using Bruker D8 Advance XRD diffractometer. This diffractometer is equipped with a sealed tube of Cu-Kα X-ray source. Scanning electron microscopy (SEM) images were captured using F model-JEOL JSM 5600. Cyclic voltammetry study is carried on CH Instruments (USA), CHI620D DAVV, Indore. FTIR study is also carried out to reveal the presence of PANI. The growth of nanocomposite and their morphology is revealed by SEM (Fig. 1). The aggregation PANI Nanoparticle of 5-10 nm in size over 1-D hollow nanotubes of V_2O_5 of a micron in length.

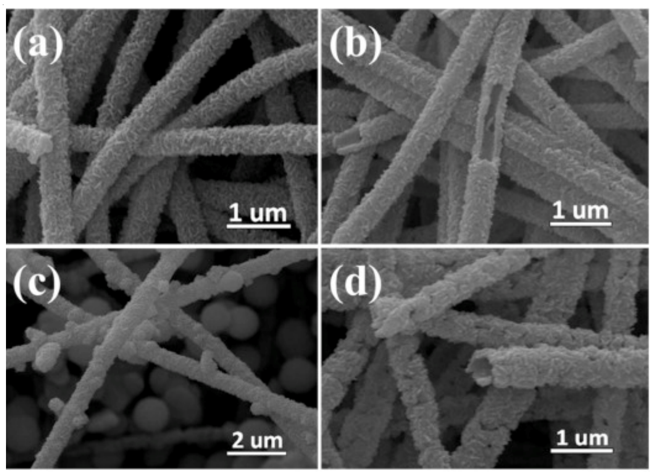

Fig. 1. SEM imag of PANI/ V_2O_5 nanocomposite

A set of well-defined peaks observed which is in good agreement for the crystallinity of PANI/V_2O_5 nanocomposite. The diffraction peaks (Fig. 2) observed at 2θ values 34.9º, 39.3º,

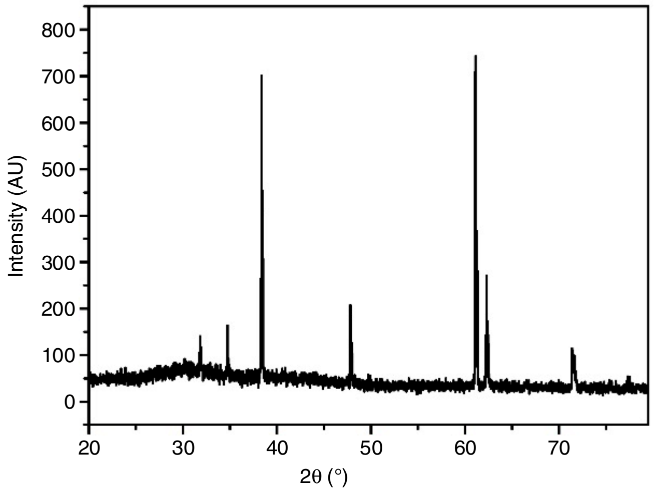

Fig. 2. XRD peaks of V_2O_5-PANI nanocomposite

47.4°, 62.3° and 72.4° are indexed to (134), (685), (205), (735), (248), and (101) planes of crystalline V_2O_5 phase, respectively.

Apparently, a change in cyclic voltammogram (Fig. 3) is observed indicating there is no change in the structure of Bayer

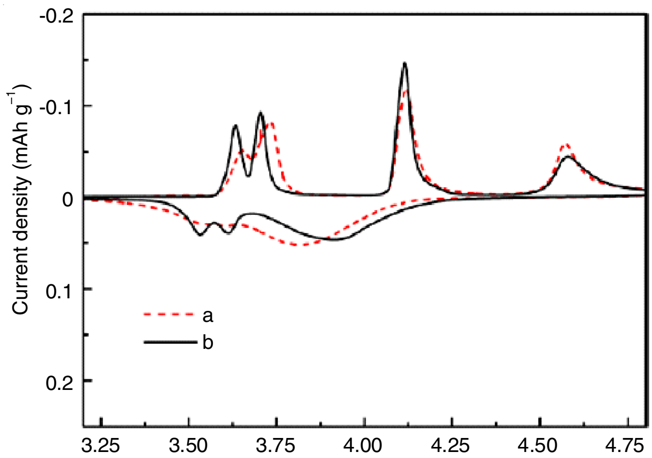

Fig. 3. Cyclic voltammetry curve of PANI/V_2O_5 nanocomposite

V_2O_5 and the remarkable shift is observed when the intercalation of PANI in the framework of V_2O_5 is taken place. The electrical conductivity is found to be 10^{-6} S cm^{-1} for PANI which get enhance for PANI/V_2O_5 nanocomposite. Tupper peak at 4.13 V indicates oxidation of V^{4+} to V^{5+}.

The characteristics bands at 1617, 1597, 1492, 1311, 1279, 1173-1131 cm^{-1} are assigned as the characteristics bands of PANI in turn also confirming the presence of PANI within the composite. The corresponding bands of V_2O_5 have been obtained in the region 1000-500 cm^{-1} (Fig. 4). There are some small shifts in the band positions in the as-synthesized PANI/V_2O_5 composite with that from PANI and V_2O_5 individually, indicating some interaction between PANI and V_2O_5 in the composite.

Conclusion

The PANI nanoparticle is successfully synthesized by the oxidative polymerization method. Also, we carried out the successful microwave-assisted synthesis of vanadium oxide-polyaniline nanocomposite (PANI/V_2O_5) at 80 ºC. The XRD peaks are in good agreement of the crystallinity of nanocomposites. Electrode reaction reversibility gets enhanced for nanocomposites which is supported by the obtained cyclic voltammogram. The results support that the synthesized material is the promising material for various application in the field of energy storage.

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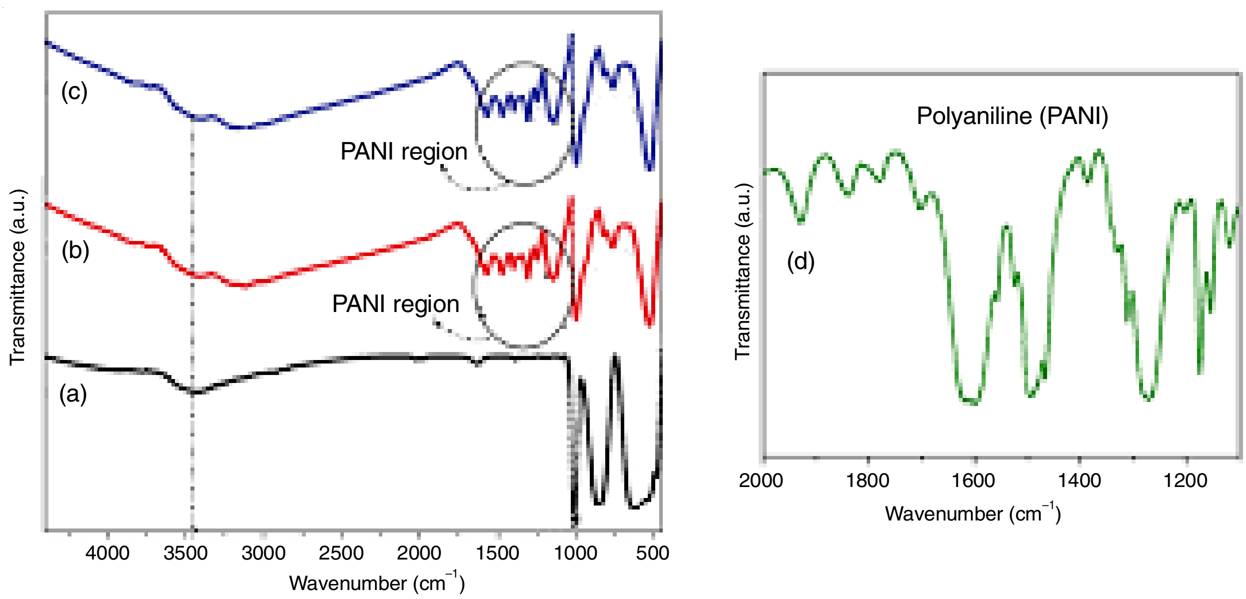

Fig. 4. FTIR graph of PANI/V_2O_5 and PANI

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