

Synthesis Of Al Doped PANI/TiO₂ Nanocomposite For Gas Sensing And Solar Applications

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Abstract

Aluminium (Al) doped PANI/TiO₂ nanocomposite was synthesized by adding TiO₂/Al nanopowder during oxidation polymerization method. TiO₂/Al nanopowder is prepared by using sol-gel method. PANI/TiO₂-Al nanocomposite was characterized by X-ray diffraction technique (XRD) and it was observed that TiO₂ exists in mixed anatase/rutile phase along with Al and PANI peaks. The crystallite size of PANI and TiO₂ was found to be 15±5 nm and 30±5 nm respectively. UV spectra exhibits that the value of energy band gap reduces significantly as 1.32 eV as compared to pure TiO₂. Scanning electron microscopy (SEM) suggests that TiO₂ exhibits cylindrical morphology in PANI matrix. Gas sensing of PANI/TiO₂-Al nanocomposite shows sensitivity towards H₂ gas at room temperature. Hence Al doped PANI/TiO₂ nanocomposite can play vital role in the development of gas sensing and solar applications.

Keywords: Polyaniline, Aluminum, Gas Sensing, Band Gap, Titanium Dioxide

1. Introduction

Titanium oxide TiO₂ is considered as the prominent semiconductor metal oxide material due to its wide use in fuel cell, paints, gas sensors, cosmetics and solar energy [1-3]. Anatase, rutile and brookite are the main phases of TiO₂. Rutile is the most stable phase as compared to anatase and brookite [4-5]. Anatase and brookite phase may transform to rutile phase after heat treatment. The wide energy bandgap of TiO₂ as 3.2 eV hinders its usage for various purposes. Therefore doping is the suitable method to create structural changes which may enhance its properties. The Al-doped TiO₂ layer was deposited on mesoporous TiO₂ film using chemical bath deposition (CBD) process as reported by Li et al. to improve the power conversion efficiency of the DSSCs. [6-7].

The addition of polymer with a semiconducting material also leads to enhancement of various properties [8-10]. Polyaniline (PANI) is the most extensively used polymer due to its high electrical conductivity, good stability, low cost and applications in batteries, solar devices and sensors. TiO₂ is an *n*-type semiconductor and PANI is considered as a *p*-type conducting polymer. Therefore it will be interesting to investigate the

effect of TiO₂/Al doping in PANI as it may change its structural, optical and gas sensing properties.

2. Materials & Method

Titanium isopropoxide and methanol are used for the preparation of TiO₂ nanopowder by sol-gel method. Aluminum powder (0.2g) is added during the formation of TiO₂. PANI/TiO₂-Al nanocomposite is prepared by adding 0.2 g of TiO₂/Al nanopowder annealed at 600^o C and 700^o C respectively during the formation of polyaniline. Polyaniline is prepared by using oxidative polymerization method. In this method the molar ratio of ammonium per sulphate and aniline is kept 1.2:1 in 3M HNO₃ aqueous medium. 0.2 g of TiO₂/Al nanopowder annealed at 600^o C and 700^o C is mixed in the solution of ammonium per sulphate [11]. The as prepared solution is added drop wise in aniline solution while stirring through magnetic stirrer at room temperature. The prepared sample is washed with deionized water and filtered. PANI/TiO₂-Al 600^o C and 700^o C nanocomposites are dried on hot plate.

3. Results

X-ray diffraction pattern (XRD) of PANI/0.2g TiO₂/(0.2g) Al-600^oC is recorded using CuK_α radiation as shown in Fig. 1. The crystallite size using Scherrer formula [1] is mentioned in Table 1.

It is observed that X-ray diffraction pattern (XRD) of PANI/(0.2g)TiO₂-(0.2g)Al -600^oC and PANI/(0.2g)TiO₂-(0.2g)Al-700^oC nanocomposite exhibits (Fig. 1) mixed anatase and rutile phase along with Al and PANI peaks.

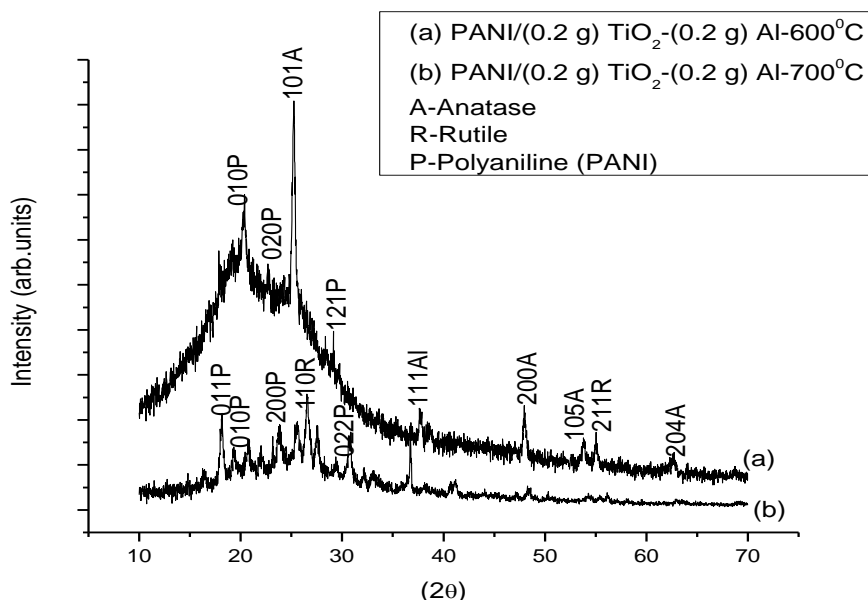


Fig. 1: X-ray diffraction pattern of (a) PANI/TiO₂-Al-600^oC and (b) PANI/TiO₂-Al-700^oC nanocomposite.

Table 1: Crystallite size and energy band gap value of PANI/TiO₂-Al specimen

Specimen	Crystallite Size	Energy band gap
PANI/(0.2g)TiO ₂ -(0.2g)Al-600 ^o C nanocomposite	PANI-15±5 nm TiO ₂ - 15±5 nm	1.78 eV
PANI/(0.2g)TiO ₂ -(0.2g)Al-700 ^o C nanocomposite	PANI-15±5 nm TiO ₂ - 30±5 nm	1.32 eV

Fig. 2 exhibits Tauc plots obtained by UV-spectra recorded at Shimadzu UV-1800. The energy band gap values calculated by extrapolating linear region to X-axis are shown in Table 1. Scanning electron microscopy (SEM) images of PANI/TiO₂-Al nanocomposites are shown in Fig. 3 (a) and Fig. 3 (b). It is observed that TiO₂ exhibits cylindrical morphology in polyaniline (PANI) matrix. Fig. 4

depict gas sensing response of Al doped PANI/(0.2g)TiO₂ nanocomposite towards H₂ gas at room temperature.

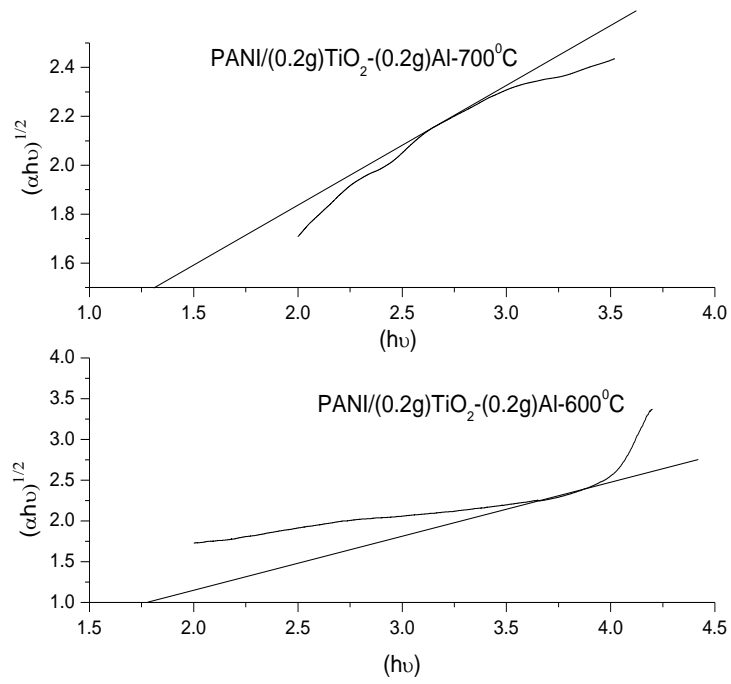


Fig. 2: Tauc plot for PANI/TiO₂-Al nanocomposite.

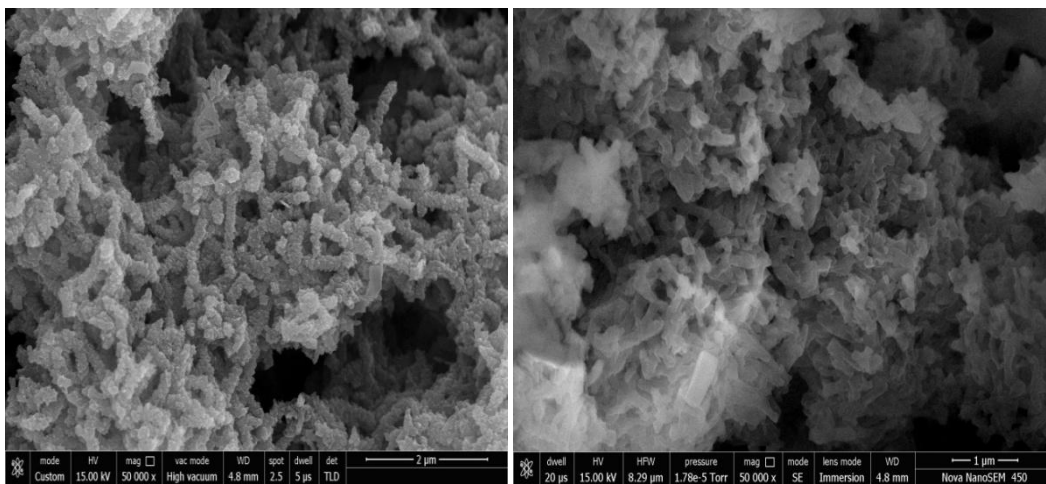


Fig. 3 (a)

Fig. 3 (b)

Fig. 3: Scanning electron microscopy images (a) PANI/TiO₂-Al-600⁰C and (b) PANI/TiO₂-Al-700⁰C nanocomposite.

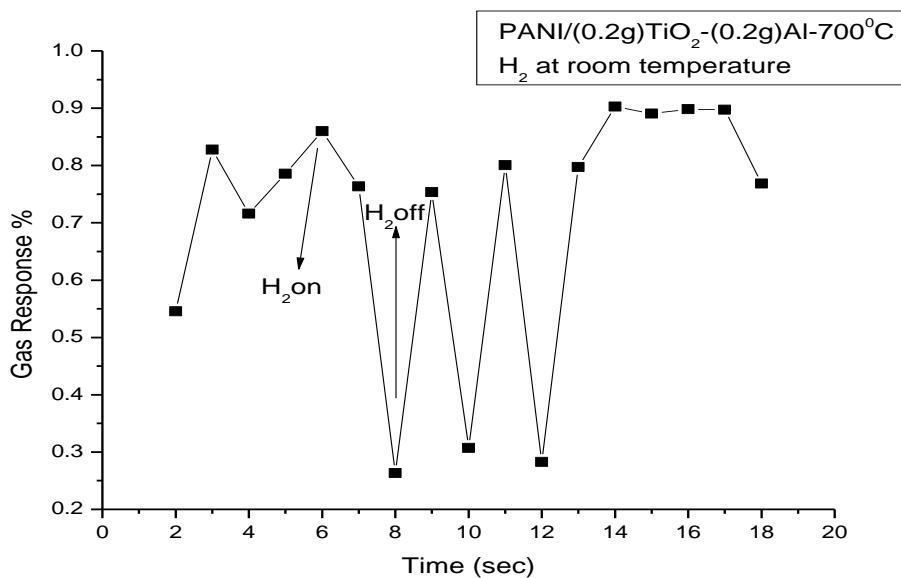


Fig. 4: Gas sensing response of PANI/TiO₂-Al nanocomposite at room temperature.

4. Discussion

The effect of polyaniline (PANI) and aluminium (Al) doping in TiO₂ is investigated. The doping of Al in PANI/TiO₂ nanocomposite reduces average crystallite size of TiO₂ and PANI (see Table 1) as compared to undoped PANI/(0.2g)TiO₂-600^oC (PANI- 25±5nm & TiO₂- 25±5nm) and PANI/(0.2g)TiO₂-700^oC (PANI- 25±5nm & TiO₂- 35±5nm) nanocomposite. It is observed from Table 1 that doping of Polyaniline and Al decreases energy band gap value as compared to pure commercially available TiO₂ (3.2 eV) [12, 13]. The energy band gap value decreases and average crystallite size of TiO₂ increases with increase in annealing temperature as shown in Table 1 [14]. Scanning electron microscopy (SEM) image (Fig. 3) suggests that TiO₂ exhibits cylindrical morphology in PANI matrix [11, 14].

The gas sensing behavior of PANI/(0.2g)TiO₂-700^oC nanocomposite doped with Al exhibits (Fig. 4) sensitivity towards H₂ gas at room temperature. The sensitivity of PANI/(0.2g)TiO₂ nanocomposite towards H₂ gas can be understood in terms of the fact that nanostructure PANI and TiO₂ nanopowder may create a semiconductor heterojunction which forms a positively charged depletion layer on the surface of TiO₂ nanopowder. It increases the inter-particle electron transition between PANI and TiO₂ [15, 16]. Scanning electron microscopy (SEM)

measurement indicates a porous open structure and high surface area of PANI/TiO₂ nanocomposite which may enhances its sensitivity towards H₂ gas because gas diffusion occurs more easily in the porous structure [16]. Therefore the observed sensitivity of PANI/TiO₂-Al nanocomposite towards H₂ gas and reduced energy band gap value may increases its suitability in the development of gas sensors and solar cells for commercial applications.

5. Conclusions

1. The doping of polyaniline (PANI) and aluminum (Al) in TiO₂ nanopowder reduces its band gap value significantly.
2. The nanocomposite PANI/TiO₂-Al shows sensitivity towards hydrogen (H₂) gas at room temperature.

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