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Structural, Optical and Electrical Properties of ATO Nanoparticles Synthesized by Combustion Method

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Abstract

Antimony doped tin oxide (ATO) nanoparticles (1,2 and 3 wt%) were green synthesized by combustion method using Terminalia bellirica (T. Bellirica) seed extract as a fuel, stannous chloride and antimony trichloride as precursor. The microstructural, optical and electrical properties of synthesized ATO nanoparticles were investigated using XRD, SEM, FTIR, UV–Vis and computer-controlled impedance analyser. XRD analysis of green synthesized ATO nanoparticles exhibit tetragonal structure. SEM investigation shows granular structure of nanoparticles. FTIR studies confirm the formation of ATO nanoparticles. The optical band gap was found using diffused reflectance spectral studies. AC conductivity is studied as function of frequency using impedance analyzer. The improved microstructural, optical and electrical properties of 2 wt% ATO nanoparticles was used for SO_2 gas sensing application by pellet technique. SO_2 gas sensing studies were carried out using pellet of 2 wt% ATO nanoparticles and sensing response of 16% was obtained for 3.2 ppm of SO_2 gas concentration.

Keywords: *Green synthesis, antimony doped tin oxide (ATO), nanoparticles, combustion method*

1.0 Introduction

Air pollution is one of the global problems with the development of technology and industry. Detecting toxic gases is the basis for controlling air pollution. SO_2 is one such toxic gas and is harmful to the environment and human health. Inhalation of low concentration of SO_2 gas causes respiratory diseases [1]. Hence there is a need for detection of SO_2 gas.

Metal oxides semiconductor sensors are widely used in the detection of flammable and toxic gases. The basic principle of these sensors exhibits a resistance change due to the adsorption of the oxidizing or reducing gases. Metal oxide nanostructures are employed in biomaterials, pharmaceuticals, cosmetics medical diagnostics, batteries, optical, magnetic and electronic devices. The available chemiresistive SO_2 sensor is based on metal oxides such as SnO_2, TiO_2, ZnO in the form of thick/thin films. Tin oxide is most widely used in the applications such as gas sensors, organic light emitting diodes, solar cells and optoelectronics devices. Due to its non-toxicity, low cost, suitability, high chemical stability and abundance in nature, tin oxide is used in gas sensor applications [2]. Synthesis of SnO_2 nanostructures has been carried out using various methods. Also several SnO_2 nanostructures are synthesized by green chemistry approach [3,4]. Many doped or mixed metal oxides are used to improve the sensing performance.

This paper reports the structural, optical and electrical properties of green synthesized ATO nanoparticles. 2 wt% ATO nanoparticles were used for

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detection of low concentration of SO_2 gas by pellet form. SO_2 gas sensing studies were carried out in the concentration range of 1 to 3.2 ppm.

2.0 Experimentation

The procedure for synthesis of ATO nanoparticles using T.bellirica seed extract is reported in our work [5]. Suitable weight of $SbCl_3$ was added during synthesis to obtain 1, 2 and 3 wt% of ATO nanoparticles.

The characterization was carried out to study the structural, optical and electrical properties of ATO nanoparticles. The structural properties of ATO nanoparticles were investigated using XRD (Rigaku model) and SEM (Zeiss model). The optical properties were investigated using FTIR (Bruker Alpha model) and UV-Vis DRS (UV 3092 model). The electrical properties were investigated using impedance analyser (IM-3536 model).

After the conductivity analysis, the 2 wt% nanoparticles were found to be better than 1 and 3 wt% ATO nanoparticles. Hence it was used for the SO_2 gas sensing application. The synthesized nanoparticles were compressed into pellet of 2 mm thickness. The sensing response (S) of pellet towards SO_2 gas is given by the equation1.

$$S(\%) = \frac{I_g - I_a}{I_n} \times 1000 \quad \ldots (1)$$

The response of pellet was recorded at operating temperature of 250°C for 3.2, 3, 2 and 1 ppm of SO_2 gas concentration.

3.0 Results and Discussion

3.1 Structural Properties

XRD pattern of 1, 2 and 3 wt% ATO nanoparticles is shown in Figure 1. The pattern matches with JCPDS card no. 01-088-2348 and exhibits tetragonal structure. The three major crystal planes are (110), (101) and (211). It was found that the obtained diffraction peaks indicates the good crystallinity nature of the synthesized nanoparticles.

SEM images in Figure 2 shows that the ATO nanoparticles are of granular shape. The average grain size of 1, 2 and 3 wt% ATO nanoparticles were found to be around 400, 200 and 220 nm respectively using ImageJ software. The obtained results were good match with the literature [6].

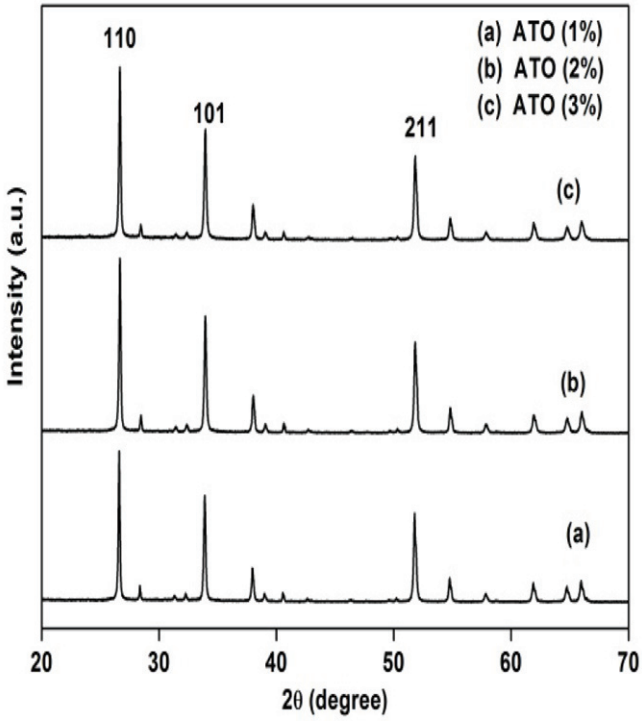

Figure 1: XRD pattern of green synthesized ATO nanoparticles

3.2 Optical Properties

The characteristic peaks of the ATO nanoparticles are found at 528 and 1023 cm^{-1} as shown in FTIR spectra in Figure 3. The result indicates the formation of ATO nanoparticles and is in good agreement with the literature [7].

Using Tauc plot as shown in Figure 4, the optical band gap of 1, 2 and 3wt % ATO nanoparticles was 3.63, 3.47 and 3.45 eV respectively. It was found that bandgap reduces with the increasing doping concentration.

3.3 Electrical Properties

The investigation of electrical properties was carried out using computer controlled impedance analyser by preparation of circular pellet of 2 mm thickness and 1 cm diameter. The measurement is made for the frequency range from 10Hz to 8MHz at 250°C temperature. The plot of AC conductivity for increasing frequency is shown in Figure 5. From the plot, it was observed that at low frequency AC conductivity is independent and as frequency increases it also increases gradually. It was noticed that the better conductivity was obtained for 2 wt% ATO nanoparticles.

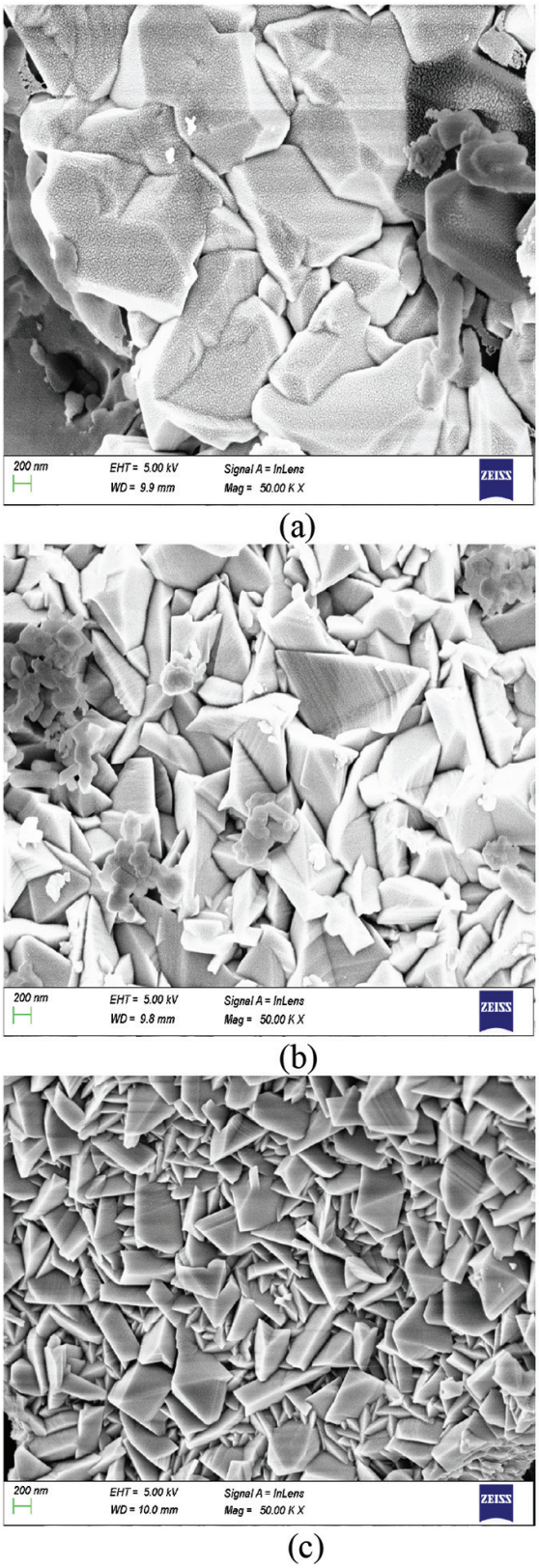

Figure 2: SEM images of green synthesized ATO nanoparticles (a) 1% (b) 2% (c) 3%

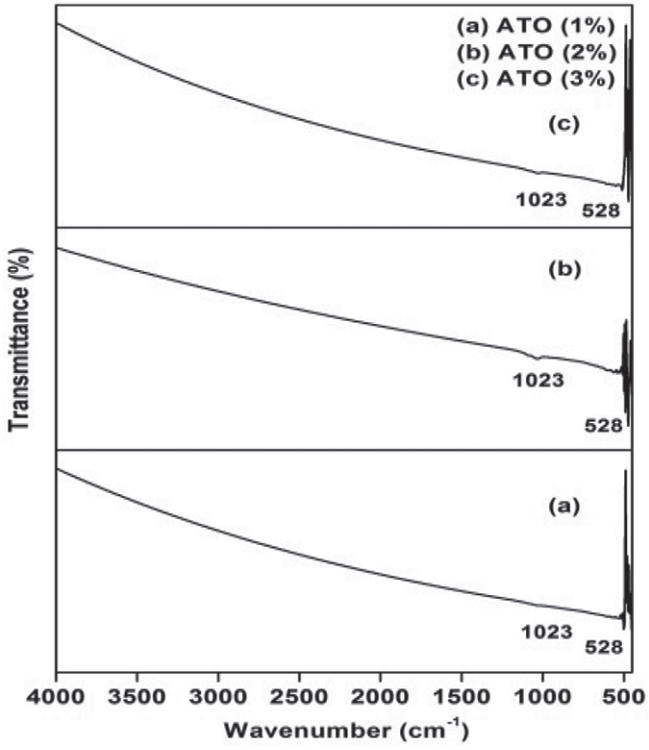

Figure 3. FTIR spectra of green synthesized ATO nanoparticles

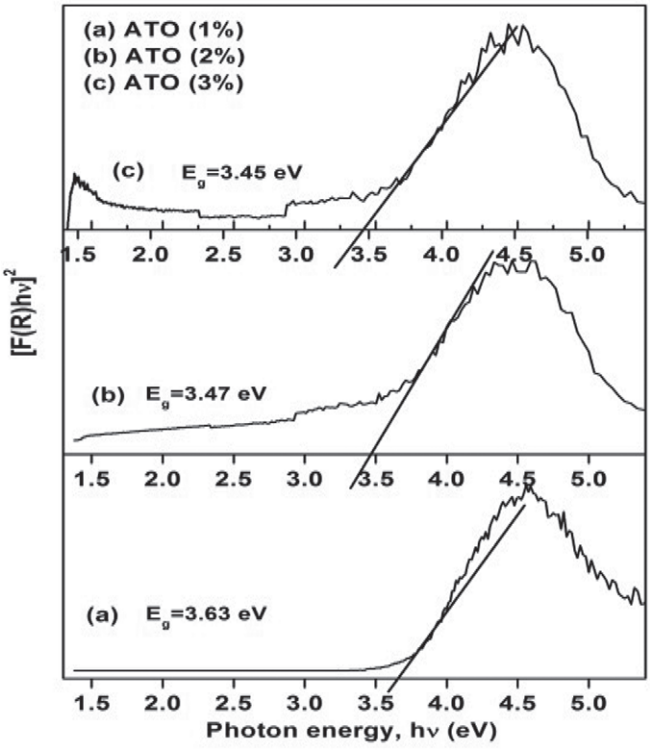

Figure 4: Tauc plot of green synthesized ATO nanoparticles

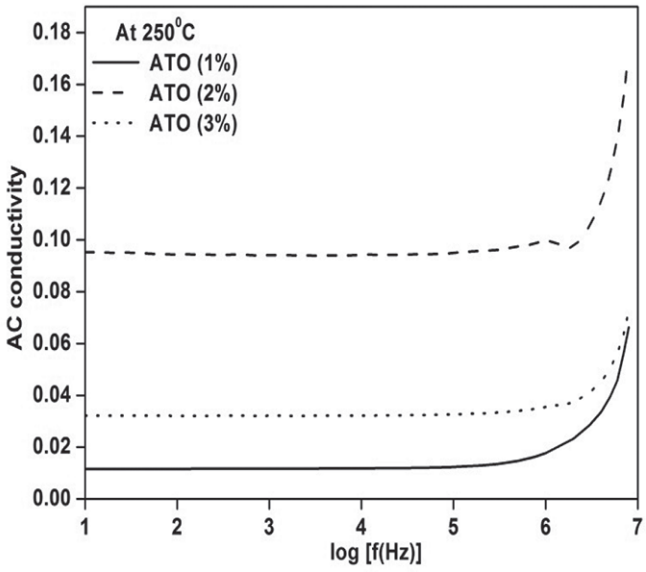

Figure 5: Variation of AC conductivity with frequency of green synthesized ATO nanoparticles

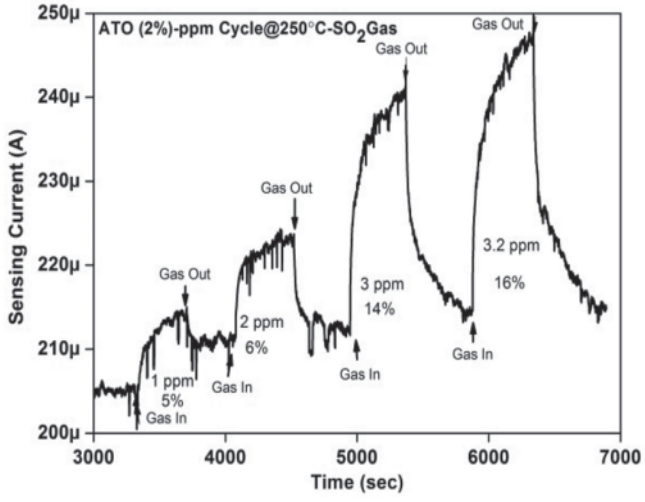

Figure 6: Sensing response of 2 wt% green synthesized ATO nanoparticles

3.4 Gas Sensing Measurements

In this section, gas sensing measurements for the prepared pellet using 2 wt% ATO nanoparticles for SO_2 gas sensing application is discussed.

The pellet of 2 wt% ATO nanoparticles exhibited sensing response of 16%, 14%, 6%, 5% for 3.2, 3, 2, 1 ppm concentration of SO_2 gas respectively at operating temperature of 250°C. Furthermore, the improved sensing response was obtained towards low concentration of SO_2 gas.

4. Conclusion

The ATO nanoparticles were successfully synthesized by green chemistry approach using combustion method. The structural, morphological and optical properties of green synthesized nanoparticles were investigated using XRD, SEM, FTIR, UV-Vis and impedance analyser. The synthesized 2 wt% ATO nanoparticles exhibited improved sensing response towards various low concentration of SO_2 gas at 250ºC operating temperature.

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Disclosure Statement

No potential conflict of interest was reported by the authors.

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