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Zn_2SnO_4 : A Suitable Material for Liquid Petroleum Gas(LPG) Detection

G.Sarala Devi and H.Z. R Hamoon*
Inorganic Chemistry Division
Indian Institute of Chemical Technology
Habsiguda, Hyderabad – 500 607, INDIA
Telefax +91 040-27160921, Ph. +91-040-27191532
E-mail sarala@iict.res.in   sarala.ipc@gmail.com

Abstract:

Semiconducting Zincstannate (Zn_2SnO_4, ZTO) having face – centred cubic spinel structure with band gap of (*E*g =3.6eV) have been successfully synthesized by Sol-gel protocol. The effect of thermal treatment on the phase formation, microstructure and optical properties of Zincoxide-Tinoxide ceramics were investigated, starting powder of Zincoxide and Tinoxide were taken in the molar ratio of 2:1. The appearance of Zincstannate in the final product is demonstrated by X-Ray Diffraction, Energy Dispersive X-Ray analysis, Ultraviolet-visible and Raman spectral characterizations.The XRD pattern show that the highly – crystalline Zincstannate (ZTO) nanostructures could be formed in a well dispersed manner for 1000°C sample at a crystallite size of 29 nm. The Raman data confirmed presence of three different Zincoxide, Tinoxide and Zincstannate phases at 700°C. Whereas at 1000°C a sharp Raman shift can be seen at 669 cm^{-1} corresponding Zincstannate vibration modes. Furthermore, Gas sensing characteristics towards Liquid petroleum gas (LPG) was tested. The sensor demonstrated excellent Sensitivity and Selectivity towards 1000ppm of Liquid petroleum gas.

Key words: Zincoxide -Tinoxide ceramic, Zincstannate (Zn_2SnO_4), X-Ray Diffraction,

Energy Dispersive X-Ray analysis, Ultraviolet-visible

1. Introduction:

Zinc Stannate (Zn_2SnO_4) as a ternary wide band gap semiconductor (*E*g = 3.6eV) is a promising material with high electron mobility, high electrical conductivity and low visible absorptions [1]. These specific properties lead to several applications in pioneer technologies including: gas sensor [2]. Various processing routes of synthesising zinc stannate were reported such as hydrothermal method [3], thermal evaporation [4], high temperature calcination [5], spray pyrolysis [6] etc. In this study formation and properties of Zn_2SnO_4 nano crystallites synthesized via sol-gel protocol were investigated. Effect of calcination temperature on the formation of different phases of SnO_2, ZnO and Zn_2SnO_4 nano particles was completely studied. In addition, LPG sensing property of the synthesized Zn_2SnO_4 nanopowders has been tested at different temperatures as well as various concentrations in our quest for developing high quality and economical chemical sensors

2. Experimental:

Synthesis of Zinc Stannate Nano Particles

In the present Sol-gel synthesis procedure Zinc chloride and Stannous chloride taken in 2:1 molar ratio was dissolved in 25ml deionized water, to which 1 ml ethylene glycol was added and obtained solution neutralized with 25% aqueous ammonia. Resulting materials was filtered, washed and dried overnight at 80°C.

3. Results and Discussion:

3.1 Characteristics of Nanostructured Zincstannate powder

The XRD pattern of synthesized nano crystallites calcined at different temperatures from 400°C to 1000°C are as shown in Fig1. At 400°C tin oxide nano crystallites phase can be observed and with increasing calcination to

500°C the Zinc oxide phase also emerges. The Zn_2SnO_4 peaks appear at 600°C with (4 4 2) growth in plane and form different three phases beside ZnO and SnO_2 nanocrystallites that maintain up to 900°C .At 700°C different peaks of three phases are completely separable . The ZnO phase disappears at 1000°C and only some weak impurity peaks of SnO_2 remain which is smaller than those of Zn_2SnO_4 at 1000°C. The structure is determined as face-centered cubic spinel.

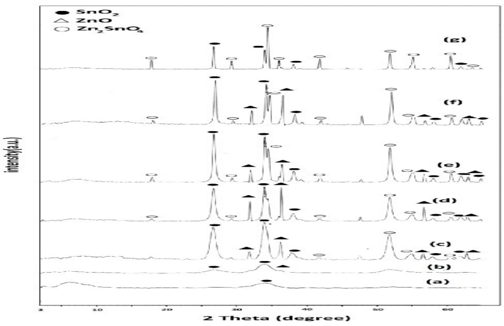

Fig: 1 XRD patterns of synthesized material calcined at (a)400°C , (b)500°C , (c)600°C , (d)700°C, (e)800°C, (f) 900°C, (g) 1000°C

3.2 Uv- DRS Spectra

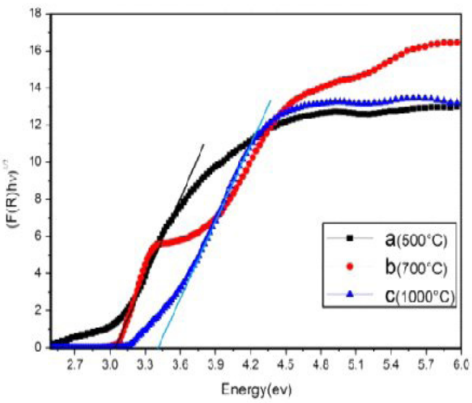

Fig: 2 Tauc Plot of the samples calcined at different temperatures

Diffuse reflectance spectra (DRS) of the three samples are as shown in Fig. 2. A significant blue shift occurred with increasing in temperature. The band gap of samples are estimated from Tauc Plot, According to plot the energy band gap of Zinc Stannate was estimated to be 3.41eV which is in good agreement with literature data regarding its crystallite size 29nm.

3.3 Sensing characteristics towards LPG

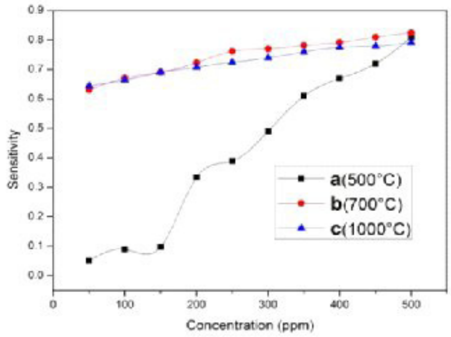

Fig.3 Sensitivity as a function of different concentrations of LPG

Samples have been measured at different concentrations ranging from 50 to 500 ppm at an operating temperature of 400°C as depicted in Fig.3 It is seen that the sensitivity increases with increasing concentration of LPG gas and shows high sensitivity even at low 100ppm of gas.

Conclusion

The single phase zinc stannate nanoparticle formation was identified by XRD, UV-DRS, Raman studies for sample calcined at 1000°C where as samples calcined at 500 and 700°C showed a mixed phases of ZnO, SnO_2 and Zn_2SnO_4 as confirmed by XRD studies. The Zincstannate based sensor showed high sensitivity and selectivity towards LPG.

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