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RESEARCH ARTICLE

PREPARATION OF ZINC STANNATE (ZTO) NANOSTRUCTURES THROUGH HIGH-TEMPERATURE SOLID-STATE REACTIONS USING ZNO AND STANNIC OXIDE (SNO2) POWDERS

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ABSTRACT

Zinc stannate or zinc tin oxide (ZTO) is a class of ternary oxides that are known for their stable properties under extreme conditions, higher electron mobility compared to its binary counterparts and other interesting optical properties. The material is thus ideal for applications from solar cells and sensors to photocatalysts

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INTRODUCTION

Zero and one-dimensional nanostructures of binary semiconducting oxides (II–VI and IV–VI oxides), such as ZnO, TiO2 and SnO2, have attracted immense interest owing to their unique properties and potential use in diverse applications such as photocatalysis (Carotta *et al*., 2009; Morandi *et al*., 2008; Gaillard *et al*., 2007), solar cells (Iwamoto *et al*., 1978; Perrard *et al*., 1983; Masel, 1996; Bielanski and Haber, 1979) and gas sensors (Wada and Egashira, 1998; Sarala Devi *et al*., 1999; Oviedo and Gillan, 2001; Che and Tench, 1982). However, with active research in nanotechnology, there is an urgent need for specially designed semiconductors to better match the properties of emerging materials. This has led to a renewed interest in ternary oxide semiconductors (II– IV–VI oxides) of the form AII 2 BIV O4, such as cadmium stannate (Cd2SnO4), popularly known as cadmium tin oxide (CTO), and zinc stannate (Zn2SnO4), which is often called zinc tin oxide (ZTO). Zn2SnO4 is acknowledged for having high electron mobility (Sanjines *et al*., 1990), high electrical conductivity, and attractive optical properties that makes it suitable for a wide range of applications in solar cells (Kohl *et al*., 2000; Koziej *et al*., 2005; Mann *et al*., 2005), sensors for the detection of humidity and various combustible gases (Chakraborty *et al*., 2006; Kung, 1994), negative electrode material for Li-ion battery (Marcu *et al*., 2002; Marcu *et al*., 2005; Chiorino *et al*., 1999) and as a photocatalyst for the degradation of organic pollutants (Yamazoe *et al*., 1979; Lausmaa *et al*., 1999; Carotta *et al*., 2009; Carotta *et al*., 2008). Compared with binary oxides, the complex ternary oxides like Zn2SnO4 are chemically more stable making them ideal for applications involving extreme conditions (Vaishnav *et al*., 2005). Zn2SnO4 has been successfully used as a flame retardant and smoke suppressant (The Application of Fire-Retardant Fillers for Use in Textile Barrier Materials by P.R. Hornsby).

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High-temperature solid-state reaction

ZTO is typically synthesized following high-temperature solid-state reactions using ZnO and stannic oxide (SnO2) powders. The biggest drawback of this process is the evaporation of ZnO during synthesis for which different heat-treatment schemes have been proposed (Lausmaa *et al*., 1999). The synthesis of ZTO nanostructures has also been reported through thermal evaporation of metal or metal oxide powder at high temperatures (Carotta *et al*., 2009; Carotta *et al*., 2008; Vaishnav *et al*., 2005) and also through coprecipitation of Zn and Sn hydroxides followed by calcination in air (Morandi *et al*., 2008; Gaillard *et al*., 2007; Iwamoto *et al*., 1978; Perrard *et al*., 1983; Masel, 1996). The hydrothermal growth process is attractive as the nucleation and growth of the crystal happens under mild conditions in water. There are reports on the control of morphology of the ZTO nanostructures yielding shapes like cubes, spheres, anisotropic rods, etc, through the use of different mineralizers and additives (Kohl *et al*., 2000; Mann *et al*., 2005; Marcu *et al*., 2005; Marcu *et al*., 2002).

The solution-phase synthesis has been proved efficient for growing nanostructures of varied morphologies as the chemicophysical parameters (like temperature, concentration of reactants, duration of crystal growth, additives, etc) can be varied at ease (Morandi *et al*., 2008). This can lead to improved control of the thermodynamics and the kinetics involved in the nucleation and growth process. Studies on the hydrothermal growth of ZTO nanostructures are still at a nascent stage with reports emphasizing the obtained final reaction products. The evolution of the nanostructures during the progress of the reaction has not been properly comprehended yet. A few morphological varieties of ZTO nanostructures have been reported to date as it has not yet been possible to deliberately control the reaction kinetics (Gaillard *et al*., 2007).

Synthesis of ZTO nano structures

To prepare ZTO nano material Zinc chloride and Stannous chloride 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. synthesized nano crystallites calcined at 1000°C. Initially calcined at low temperature as 500°C, take XRD pattern after that calcined at temperature 800°C and finally calcined at a temperature 1000°C. To study chemical reactions at different temperatures. Care about the filtering the solution.

Zinc chloride and Stannous chloride taken in 2:1 molar ratio (272.62:189.)

↓

Dissolved in 25ml deionized water

↓

1 ml ethylene glycol (C2H6O2) was added (26.02)

↓

Obtained solution neutralized with 25% aqueous ammonia

↓

Filtered, washed and dried overnight at 80°C

At different temperatures of calcined we get different kind of chemical results as it displayed in the characterization.

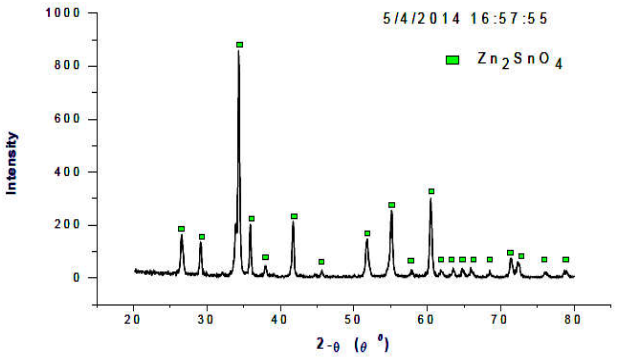
Calcined at 500° C we get the peaks of ZTO in XRD but there are presence of Zinc chloride and Stannous chloride also.

To eliminate these peaks calcined at higher temperature at 800°C some peaks are eliminate but when we calcined at 1000°C there are totally elimination of the undesirable peaks and pure ZTO we get as shown in the XRD projections.

Conclusion

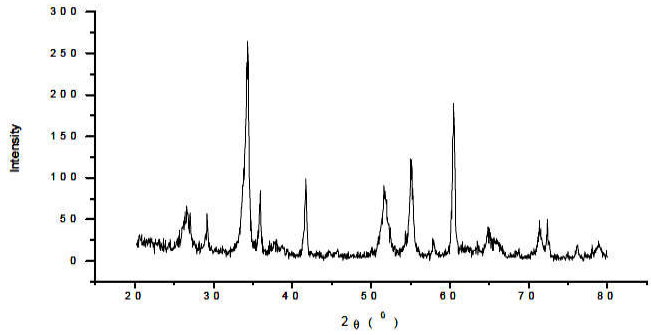
XRD pattern

There are many modern techniques are available to characterize the sample material for example if we need to know about the chemical, structural property, shape of the particle etc. for that we have to find XRD (X-ray diffraction) pattern, for band gap and optical properties we have to know about the optical energy absorption characteristics so we have to find out UV- pattern.

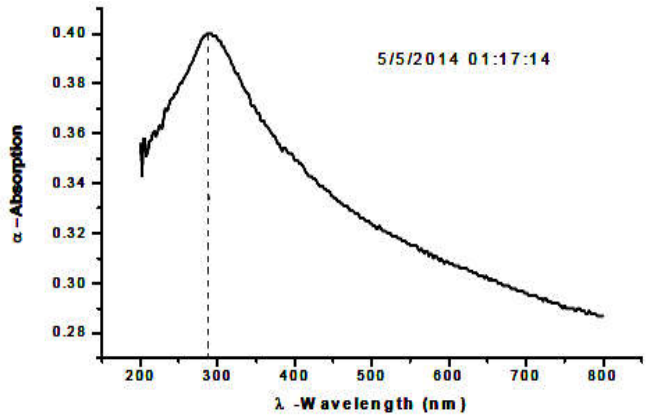


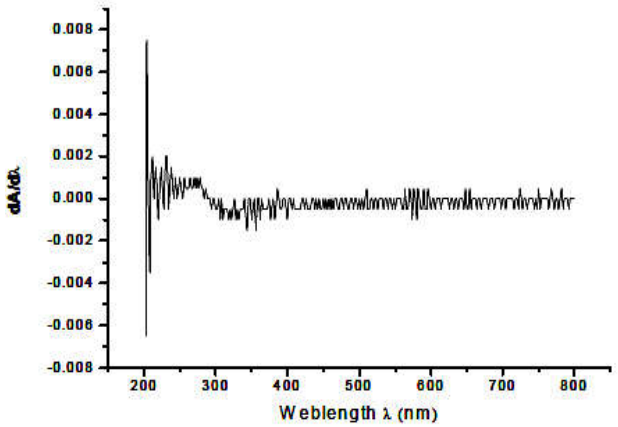
Graph1; Experimental XRD-pattern of ZTO.

From the XRD pattern it is clear that the sample is purely zinc stannate. Because by comparing the slandered XRD pattern of ZTO. Whoch is below.



Graph1; JCPDS XRD-pattern of ZTD.





Optical properties

Ultraviolet (UV) and visible radiation comprise only a small part of the electromagnetic spectrum, which includes such other forms of radiation as radio, infrared (IR), cosmic, and X rays. Optical absorption spectra of (a) Co3O4 at different calcination temperatures and (b) first derivative of the optical absorbance. From above graph it is clear that at wave length 287.77 nm the absorption is maximum after calculating the band gap it will be nearly 4.3eV which is little bite higher then the value of bulk zinc stannate (3.4eV) as we studied in the nearest research. As we studied above that the sample prepared above is purely zinc stannate and its band gape is quite good which 4.3 eV so that sample is suitable for the experiment.

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