Available online at www.sciencedirect.com

ScienceDirect

Journal of Taibah University for Science 10 (2016) 437–441

Journal of Taibah University for Science

www.elsevier.com/locate/jtusci

# Ultra-violet C absorption and LPG sensing study of zinc sulphide nanoparticles deposited by a flame-assisted spray pyrolysis method

K.R. Nemade [a,*], S.A. Waghuley [b]

[a] *Department of Physics, Indira College, Kalamb 445 401, India*
[b] *Department of Physics, Sant Gadge Baba Amravati University, Amravati 444 602, India*

Received 17 April 2015; received in revised form 7 July 2015; accepted 7 July 2015
Available online 31 August 2015

**Abstract**

Solvent processed spray pyrolysis is a technique that has attracted worldwide interest for the synthesis of nanoparticles. Zinc sulphide (ZnS) belongs to a category of practical semiconductors known as metal sulphides, and it is used extensively as an optical material. In the present article, ZnS nanoparticles were successfully synthesized using flame-assisted spray pyrolysis. X-ray diffraction confirmed the formation of ZnS with an excellent crystalline structure, while scanning electron microscopy indicated that the as-synthesized materials were nanoparticles. Ultraviolet–visible spectroscopy was utilized to evaluate the optical property of the resulting product and revealed that ZnS nanoparticles have the capacity to absorb ultra-violet C. In addition, various liquefied petroleum gas (LPG) sensing properties of the ZnS nanoparticles were also evaluated.


*Keywords:* Flame assisted; Spray pyrolysis; ZnS nanoparticles; LPG; Ultra-violet C

## 1. Introduction

Zinc sulphide (ZnS) is one of the most important semiconductor materials and has remarkable properties and holds promise for use in various applications, such as field-emission phenomena, field-effect transistors, luminescence and biosensors [1].

Pathak et al. reported the mechanochemical synthesis of 4–7-nm ZnS nanoparticles with optical band gaps of 4.04–4.6 eV [2]. Dehghani et al. described the nonlinear optical properties of ZnS nanoparticles that were synthesized by a simple chemical method and used PVP (poly vinylpyrrolidone) as a capping agent [3]. Murugadoss et al. successfully synthesized $Ni^{2+}$-doped ZnS nanoparticles using an aqueous chemical precipitation method with surfactants in air and then studied their photoluminescence properties [4]. Hudlikar et al. demonstrated a green and low-cost synthesis of ZnS nanoparticles using a 0.3% latex solution prepared from *Jatropha curcas* [5].

Xu et al. prepared ZnS nanoparticles by an ultrasonic radiation method and studied their optical properties [6]. Abbas et al. prepared ZnS nanoparticles in an aqueous solution at pH = 3 by a simple reaction between zinc

* Corresponding author. Tel.: +91 9049703051.
*E-mail address:* krnemade@gmail.com (K.R. Nemade).
Peer review under responsibility of Taibah University.

ELSEVIER Production and hosting by Elsevier

http://dx.doi.org/10.1016/j.jtusci.2015.07.003
1658-3655 

chloride and sodium sulphide [7]. Yu et al. reported the ethanol sensing abilities of ZnO/ZnS nanocages that were successfully synthesized via a facile hydrothermal route and a subsequent etching treatment [8].

Gas sensing is an important application of metal sulphides, and it is strongly influenced by various parameters such as particle size, particle shape, pore density and surface states. All of these parameters are readily controlled through nanotechnology [9]. Compagnone et al. reported a biological application of gas sensing by demonstrating the detection of food aromas. In this work, gold nanoparticles were used to prepare an array of peptides for the detection of food aromas [10]. The gas sensing process is indirectly related to the band gaps of the used nanomaterials. According to the hyperbolic band model and the effective mass approximation, a particle's size and its band gap are inversely related to each other, which is a widely accepted principle of nanotechnology [11].

From a survey of the materials science literature, it is observed that there are very few examples of ZnS utilized in gas sensing applications. ZnS nanobelts, synthesized using a thermal evaporation method, were used for oxygen sensing by Liu et al. [12]. Yang et al. also reported on an oxygen sensing application of ZnS microspheres that were synthesized by a soft template-assisted hydrothermal route [13].

In the present work, we synthesized ZnS nanoparticles by a flame-assisted spray pyrolysis route. To the best of our knowledge, this study represents a novel approach to ultra-violet C absorption and liquefied petroleum gas (LPG) sensing applications using ZnS nanoparticles.

## 2. Experimental

Zinc nitrate [$Zn(NO_3)_2$] and sodium sulphide ($Na_2S$) were of analytical grade (99.99%). The ZnS nanoparticles were prepared by flame-assisted spray pyrolysis. For this synthesis, stock solutions of 1 M $Zn(NO_3)_2$ and 1 M $Na_2S$ were prepared by dissolving a suitable quantity of solute in deionized water having a resistivity close to 18 MΩ cm. The prepared solutions were subjected to rapid magnetic stirring for 30 min at room temperature. Subsequent to this step, the prepared solutions were mixed together in drop-wise manner and then loaded into the chamber for spray pyrolysis. A capillary tube with an outer diameter of 1 mm (inner diameter 0.6 mm) and an opening of 1.2 mm in diameter (Labtronics, India) was employed. The spray was evaporated by supporting flamelets maintained at 473 K, and the flow rate was regulated by a flow controller. The product was collected on a $SiO_2$ substrate.

The as-prepared ZnS nanoparticles were characterized by X-ray diffraction (XRD), scanning electron microscopy (SEM) and ultraviolet–visible (UV–VIS) spectroscopy. The XRD pattern was obtained from a Rigaku Miniflex-II diffractometer over a range of 10–70°. The morphology and grain size of the sample were studied by using SEM (JEOL JSM-7500F). UV–VIS spectroscopy was performed on a Perkin Elmer UV spectrophotometer.

The ZnS nanoparticles deposited on a $SiO_2$ substrate were used as a chemiresistive film [14]. For sensing measurements, electrodes of highly conducting silver were created by applying silver paint to adjacent sides of the

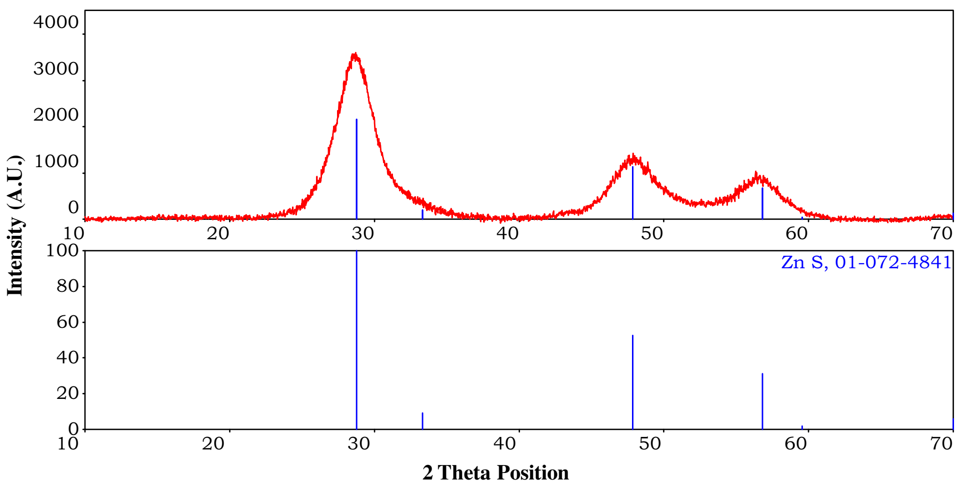


Fig. 1. XRD pattern of as-synthesized ZnS nanoparticles.