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Synthesis and characterization of zinc sulfide nanoparticles with polyvinyl pyrrolidone as a capping agent

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Abstract - The expansion of dependable and environmental process for synthesis of semiconductor nanoparticle is an important step in the emerging field of nanotechnology. Zinc sulphide (ZnS) nanoparticles was prepared by chemical precipitation method using zinc acetate and sulphur source. The ZnS nanoparticles were characterized by X-ray diffraction, UV-Visible, Energy dispersive X-ray analysis, Field emission scanning electron microscopy. The peaks in the XRD spectra corresponding to (111), (220) and (311) show that the zinc sulfide nanoparticles are crystalline in nature. The crystallite size of ZnS nanoparticles was calculated by Debye-Scherrer formula. The optical properties of nanoparticles were studied with ultra-violet visible absorption and band gap spectra. Energy dispersive X – ray (EDX) analysis also confirmed the presence of zinc sulfide nanoparticles. Morphology of nanoparticles was observed and investigated using the field emission scanning electron microscope.

Keyword: zinc sulfide (ZnS), polyvinyl pyrrolidone (PVP), capping, EDX, nanoparticles.

I. INTRODUCTION

Nanoparticle in nanotechnology is defined as a small object that behaves as a whole unit, nanoparticles and nanostructured materials have been used in catalysis, photography, photonics, electronics, labelling and imaging. At nanometer size, crystallites are influenced by the presence of significant number of surface atoms of the electronic states and this influences the property of nanomaterials as compared to their bulk phases. The zinc sulfide nanoparticles have applications in optoelectronics, ultraviolet, light emitting diodes, solar cells, field emitters, injection lasers, spintronics, infrared windows, sensors, photocatalysis, flat panel display, thin film electroluminescent devices and antimicrobial activity [1-6]. There are various method has been utilized for the synthesis of ZnS nanoparticles such as hydrothermal method, chemical vapor deposition method, chemical bath deposition method, chemical precipitation method, chemical co-precipitation method, ϒ irradiation method, sonochemical method, microwave irradiation, sol-gel method, microemulsion method, thermal decomposition method, solid-state reaction method and solvothermal method [7-22]. ZnS is a semiconductor nanomaterial possessing a lot of interesting physical properties. The development of semiconductor nanoparticles by using chemical precipitation is an interesting progress in the research of nanotechnology. The size of quantum dots obtained by this method can be controlled by capping the nanoparticles using (polyvinyl pyrrolidone) PVP as a stabilizing agent. In this work, I have studied the structural and optical properties of polyvinyl pyrrolidone capped ZnS quantum dots synthesized by the precipitation method.

II. EXPERIMENTAL DETAIL

Aqueous solution (60 ml) of 0.70 M zinc acetate and 0.70 M sodium sulfide was prepared separately with deionised water. Sodium sulfide solution was added dropwise to the aqueous zinc acetate solution, under stirring condition. After 20 minutes of stirring, 1.0 gm of polyvinyl pyrrolidone was added under vigorous stirring for 3 hours at room temperature. pH of reaction mixture was adjusted to about 11 by dropwise addition of aqueous ammonia solution. The mixed solution was then stirring for 1 hour at room temperature. The sample was then washed and filtered with deionised water and ethanol several times to remove excess organic residues. The collected sample was dried and stored in the desicator for further characterization.

III. RESULT AND DISCUSSION

X-ray diffraction pattern was recorded using X-ray diffractometer with CuKα radiation (λ= 1.54A^0) in the range of 20^0 - 80^0 (2θ). The synthesized zinc sulfide nanoparticles were air dried and used for analysis. The

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ultraviolet visible spectra was recorded with Hitachi U – 3400 spectrophotometer, with wavelength ranging from 190 to 600 nm. The composition of zinc sulfide nanoparticles is determined by energy dispersive X – ray (EDX) analysis. The morphology was determined by scanning electron microscopy (SEM) was performed with a FE-SEM Quanta 200 by focusing on nanoparticles.

X – RAY DIFFRACTION (XRD) PATTERN

The X – ray diffraction (XRD) pattern of polyvinyl pyrrolidone capped zinc sulfide nanoparticles powder has shown in figure 1. The diffraction pattern of zinc sulfide nanoparticles has three similar characteristic peaks at 28.7^0, 48.5^0 and 55.8^0 can be indexed to the (111), (220) and (311) planes which indicates the synthesis of zinc sulfide nanoparticles. The full width at half maximum (FWHM) measured for (111) plane of reflection was used with Debye scherrer equation [23] to calculate the size of nanoparticles. The average particle size of zinc sulfide nanoparticles was found to be about 2 nm.

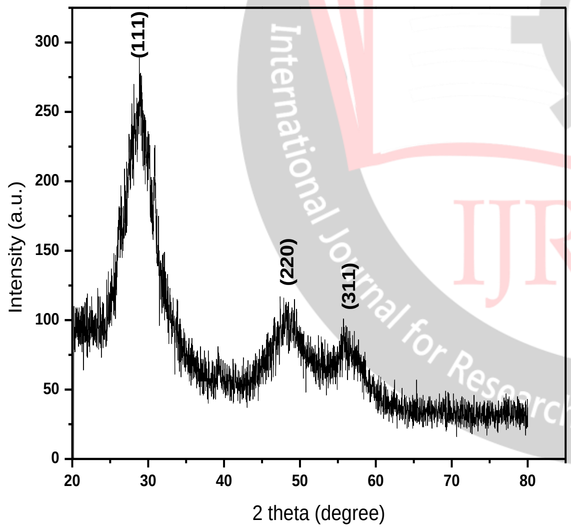

Figure 1: X – ray diffraction (XRD) pattern of zinc sulfide nanoparticles

ULTRA-VIOLET (UV) VISIBLE SPECTRA

UV-Visible spectrophotometer was used to characterize the optical absorption properties of zinc sulfide nanoparticles. The UV-Visible absorption spectra of the sample were recorded at room temperature in the wavelength range 190 nm to 600 nm using U- 3400 UV-Visible spectrophotometer. From figure 2 it is clear that the absorption peak is around at 310 nm which is a blue shifted.

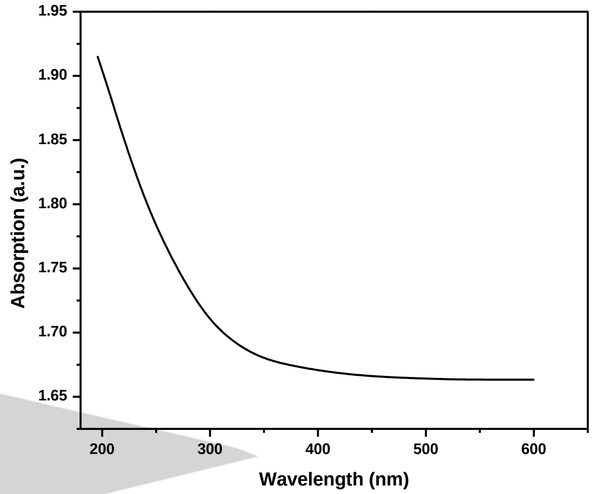

Figure 2: Ultraviolet (UV) Visible absorption spectra of zinc sulfide nanoparticles

BAND GAP SPECTRA

It is clear from figure 3 that the band gap of polyvinyl pyrrolidone capped zinc sulfide nanoparticles was calculated Tauc's plot [24] for the sample and its relation between the photon energy (hν) and absorption coefficient (α) is $(\alpha h\nu) = (h\nu - E_g)^n$. Where α is optical absorption coefficient, h is planck's constant and hν is photon energy. The estimated value of band gap of zinc sulfide nanoparticles is 4.0 eV. The band gap was obtained from maximum absorption according to the quantum coefficient theory.

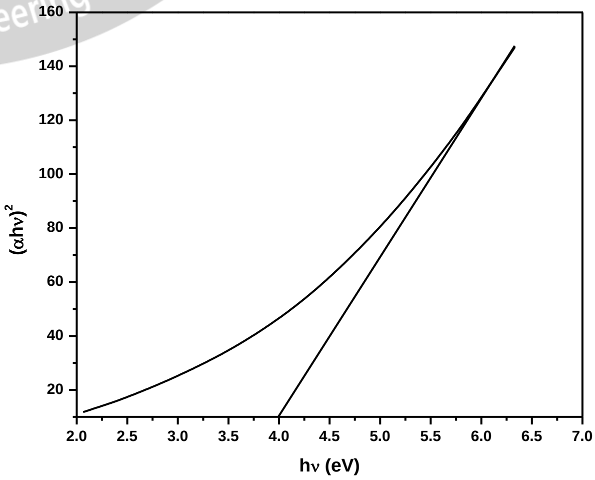

Figure 3: Energy band gap spectra of zinc sulfide nanoparticles

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ENERGY DISPERSIVE X – RAY (EDX) ANALYSIS AND SCANNING ELECTRON MICROSCOPY (SEM) IMAGE

The morphology of zinc sulfide nanoparticles was characterized by scanning electron microscope which was confirmed to be of zinc by energy dispersive X – ray (EDX). From figure 4 (a) it is clear that EDX analysis shows strong peak in the zinc sulfide, confirming the presence of semiconductor zinc sulfide nanoparticles. A strong peak is observed in Zn. Scanning electron microscopy image of zinc sulfide nanoparticles is shown in figure 4(b) which indicates aggregation of nanoparticles in the form of nanospheres. From figure 4(b) it is clear that the nanospheres are composed of very small nanoparticles of about 2 nm sizes and are densely packed.

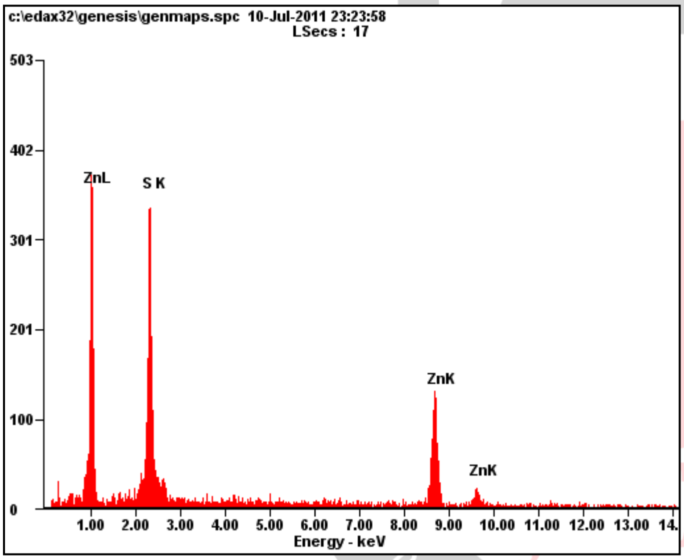

Figure 4(a) EDX

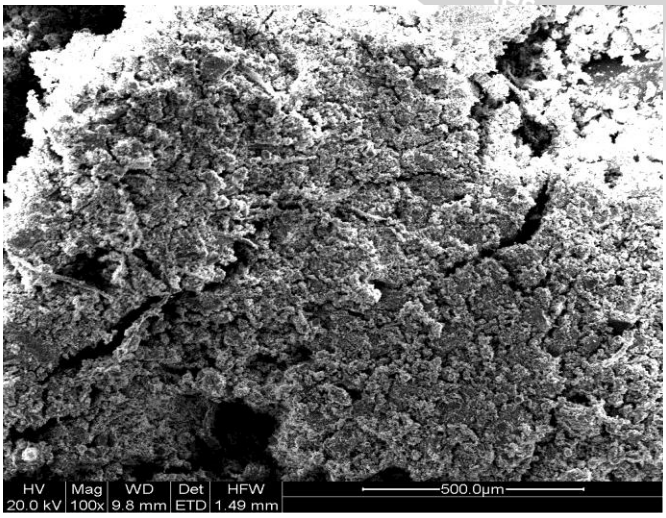

Figure 4(b) SEM

Figure 4: (a) Energy dispersive X – ray analysis and (b) Scanning electron microscopy image of zinc sulfide nanoparticles.

IV. CONCLUSION

In conclusion, I have successfully synthesized zinc sulfide nanoparticles using polyvinyl pyrrolidone as a capping agent, the X – ray diffraction pattern shows that the particles are of zinc sulfide and is of about 2 nm. The synthesized zinc sulfide nanoparticles exhibited a maximum absorption peak at 310 nm. The morphology of zinc sulfide nanoparticles observed using scanning electron microscopy (SEM) reveals a spherical shape but were agglomerated and the elemental analysis of zinc sulfide nanoparticles were characterized using energy dispersive X – ray (EDX) analysis measurement.

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