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Synthesis, characterization and antimicrobial activity of ZnS nanoparticles

Brenda Kwamboka, Wesley Omwoyo*, Nathan Oyaro

Department of Physical Sciences, Maasai Mara University, P.O. Box 861-20500, Narok, Kenya.
brndkwmbk13@gmail.com[1], wesleyomwoyo@mmarau.ac.ke[2], oyarokema@yahoo.com[3]

Abstract

Background/Objectives: Efforts have been put in the synthesizing of the ZnS nanomaterials in order to reduce dimensions for high quantum efficiencies. The objective of this study was to synthesize ZnS nanoparticles, characterize then and test for antibacterial activities.
Methods/Statistical analysis: The ZnS nanoparticles were synthesized with and without CTAB capping agent and characterized using affinity FTIR and UV-Visible spectrophotometer. The disc diffusion method was used to study the antibacterial activity of the synthesized ZnS nanoparticles. *Streptococcus aureus, Pseudomonas aeruginosa, Escherichia coli and Candida albicans* were used as model test strains.
Findings: The characterized peaks for ZnS stretching were absorbed at 354cm^{-3} and 964cm^{-3} for the capped ZnS. The uncapped ZnS had characteristic peaks stretching recorded at 360 cm^{-3} and 1116 cm^{-3}, 1255 cm^{-3} and 1313 cm^{-1}. The UV-Vis showed a blue shift as the maximum absorbance was observed at 310 nm.
Improvements/Applications: The ZnS nanoparticles were tested against oral pathogens and were found to exhibit anti-bacterial and anti-fungal activity.

Keywords: Nanoparticles, capping, absorbance, pathogens, anti-bacterial

1. Introduction

Nanotechnology is the design, characterization and application of nanomaterials and these include group II-VI of inorganic semiconductor such as ZnS, CdSe and ZnSe. These groups of nanomaterials have been found to be versatile materials because of their use in optoelectronic devices due to varied band gap as a function of the nanoparticle [1]. ZnS has been studied widely due to its wide applications in such areas as UV-diodes, phosphors in flat-panel displays and in photo catalysis [1, 2], sensors [2] and bio-devices [3]. ZnS nanocrystals doped with other metals in its application in photoluminescence is very complicated. This is so because small particles have larger surface to volume ratio and are more likely to access carries for photoluminescence [4]. The application of ZnS in photochemical degradation is due to its higher resistance which is able to a part of the solar radiation that is carcinogenic and also to its low cost [5].

In recent years a lot of effort has been put in the synthesizing of the ZnS nanomaterials in an effort to reduce dimensions in the size of the circuits of electronic devices which are expected to have high quantum efficiencies due to their increased oscillatory strengths as a result of quantum confinement effects [4, 5]. The value of Bohr radius of the exciton in the bulk material has provided a threshold for occurrence of quantum effects [6]. ZnS nanoparticles have been prepared using many techniques such as soft chemical method [7], Chemical precipitation [8], sol-gel method [9], Co-precipitation [10], microwave irradiation method [7, 11] and colloidal micro emulsion [12]. In the present study the ZnS is synthesized without a capping agent and with a capping agent CTAB and its characteristics determined using FTIR and UV-Vis Spectrophotometer and its microbial activities using oral pathogens.

2. Materials and methods

2.1. Preparation of $ZnCl_2$ solution

12 mL of hexane, 3 mL of 1-pentanol and 0.6mg of CTAB were mixed together and continuously stirred and finally mixed with 0.6 gm of 0.012 M $ZnCl_2$.

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2.2. Preparation of Na_2S solution

12 mL of hexane, 3 mL of 1-pentanol and 0.6 mg of CTAB were mixed together and continuously stirred and finally mixed with 0.6 ml of 0.012 M of Na_2S.

2.3. Preparation of ZnS nanoparticles in the presence of CTAB

This was done by mixing the $ZnCl_2$ solution and Na_2S solution as shown seen the equation below:

$$ZnCl_{2(l)} + Na_2S_{(l)} \longrightarrow ZnS_{(l)} + 2NaCl_{(aq)}$$

Zinc sulphide nanoparticles were also prepared in the absence of CTAB.

2.4. Characterization of the prepared ZnS nanoparticles

Fourier transform infrared spectroscopy (FTIR) was also used to determine the functional groups present on the surface of the nanoparticle while the absorption spectra was observed using the UV-VIS spectra within the range of 290-990.

2.5. Antimicrobial activity of the synthesized nanoparticles

The disc diffusion method was used to study the antibacterial activity of the synthesized ZnS nanoparticles. *Streptococcus aureus, Pseudomonas aeruginosa, Escherichia coli and Candida albicans* were used as model test strains. This method involves the inoculation filter paper discs with the synthesized ZnS nanoparticles and placed the discs in an agar plate which had been inoculated with specific organism. The plate was then incubated at 35^0 C for 24 hours. The inoculated discs created a zone of organism inhibition as it spread through the agar and this indicated the antimicrobial activity. Then the inhibition zone was measured.

3. Results and Discussions

3.1. Surface morphology of ZnS nanoparticles

The characteristic peaks of ZnS nanoparticles capped with CTAB (Figure 1) were recorded from 300-4000 cm^{-1} using FTIR. Pure CTAB stretching vibrations of $–CH_2$were observed at 2846.93cm^{-1} and 2916.37 $cm^{-1.}$ ZnS was not oxidized to zinc oxide which was indicated by the absence of peaks between 420-460 cm^{-1}as was suggested by [13]. The Zinc and sulphide stretching are observed strongly at 354cm^{-1} was also reported by [14]. ZnS peaks appeared at 964cm-^{1} this was also reported by [15, 16, 17]. The peak at 671cm^{-1} is ZnS band corresponding to sulphide and this was in line with what was reported by [18]. The peaks between 2900 - 3200cm^{-1} are due to water absorption at the surface of the ZnS nanoparticles which indicate O-H stretching according to [19].

The FTIR spectroscopy in figure 2 shows bands of ZnS nanoparticle recorded from 300-4000cm^{-1}. The zinc and sulphide stretching were observed strongly at 360cm^{-1} and this agrees with that reported by [14]. ZnS peaks appeared at 1116cm^{-1} as was also reported by [16, 17, 20]. Major peaks can be observed at 1255cm^{-1} and 1313cm^{-1} indicating ZnS nanoparticle stretching as was also suggested by [20, 21]. The peaks between 2900 -3200cm^{-1} are due to water absorption at the surface of the ZnS nanoparticles which indicate O-H stretching and this agrees with what was reported by [19].

From figure 3 shows UV-VIS spectra of zinc sulphide nanoparticles recorded in the range of 290- 990nm. The absorption edge spectrum appeared at 310nm which agreed with what was reported by [18, 22, 23].This indicates that the absorption edge band is blue shifted since the bulk ZnS spectrum appears at 327nm as reported by [18]. Absorption at the wavelength corresponding to band gap energy arises due to optical excitation of electrons across the band gap and quantum effect causes the absorption spectra of ZnS to be towards the longer wavelength. This can be explained by the quantum size effect of semiconductor nanoparticles in their electronic structure, which originates from electron hole confinement in a small volume as reported by [23].

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Figure 1. ZnS nanoparticles with CTAB as capping agent

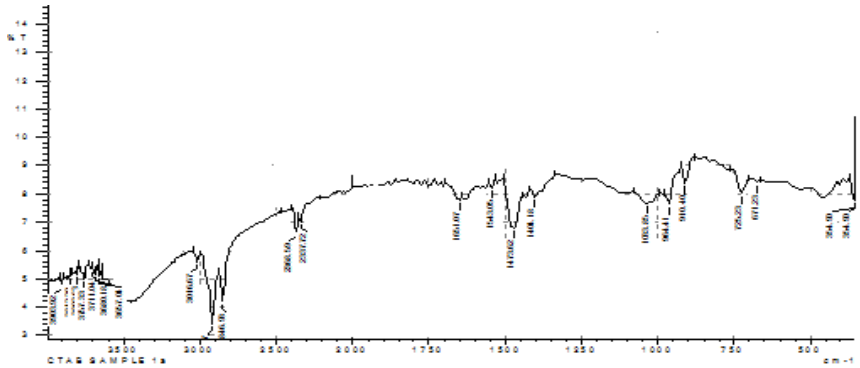


Figure 2. ZnS nanoparticles without CTAB capping agent

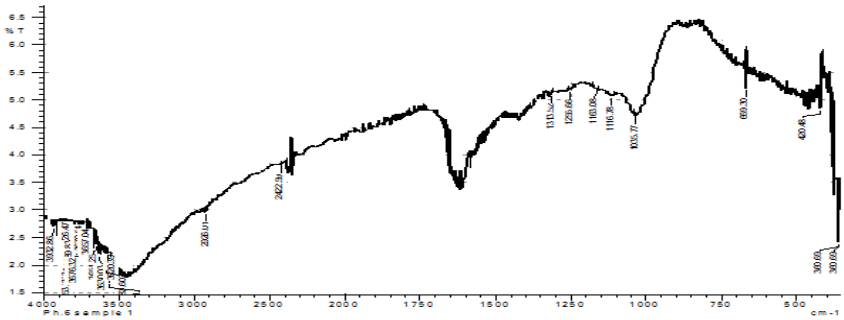
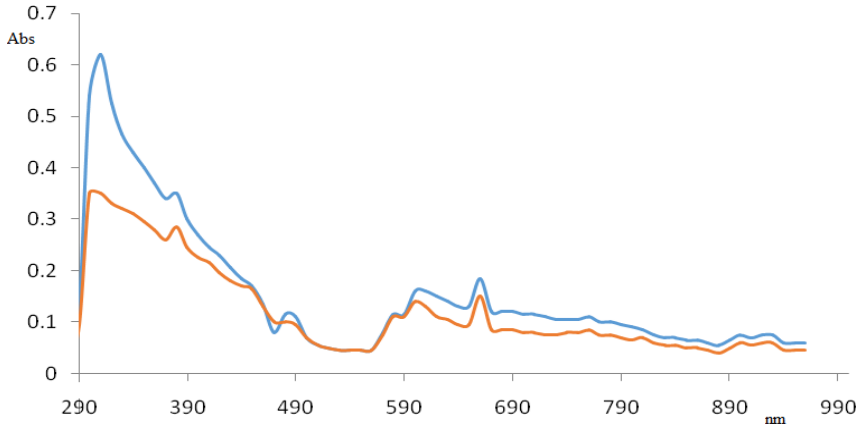


Figure 3. UV-VIS spectra of ZnS nanoparticles at two different concentrations



3.2. Antimicrobial activity of the ZnS nanoparticles

The antimicrobial activity was studied against the oral *pathogens Staphylococcus aureus, Escherichia coli, Pseudomonas aureginosa and Candida albicans.* The inhibition zone was measured around the well with ZnS nanoparticles with the CTAB as capping agent in millimeters against the test organism. The largest inhibition zone was measured against *E. coli* 17.50 ± 0.03mm and *Staphylococcus aureus* had an inhibition zone of 10.30 ± 0.50, (Figure 4).

Pseudomonas aeruginosa had an inhibition zone of 14.30 ± 0.57mm and *Candida albicans* had inhibition zone of 9.55 ± 0.50mm (Figure 5). For ZnS without the capping agent, the largest inhibition zone was measured against *E. Coli* had an inhibition zone of 12.15 ± 0.16mm and *Pseudomonas aeruginosa* had inhibition zone of 8.40 ± 0.90mm while *Staphylococcus aureus* had an inhibition zone of 7.60 ± 0.50mm and finally the *Candida albicans* had inhibition zone of 6.98 ± 0.95mm (Table 1). The results demonstrate that the antimicrobial activities are due to the ZnS nanoparticles impregnated and surrounded by bacterial cell.

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Table 1. Zone of inhibition in mm of ZnS Nanoparticle against oral pathogens

Type of Compound	Zone of inhibition(diameter in mm)			
	C. albicans	*S. aureus*	*P. aeruginosa*	*E. coli*
ZnS with CTAB	9.55 ± 0.50	10.30 ± 0.50	14.30 ± 0.57	17.50 ± 0.50
ZnS without CTAB	6.98 ± 0.95	7.60 ± 0.50	8.40 ± 0.90	12.15 ± 0.16

Figure 4. ZnS zone of inhibition against S. aureus (a) and E. coli (b)

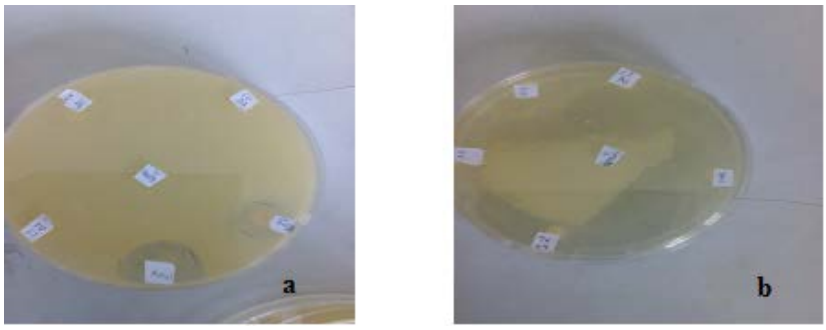
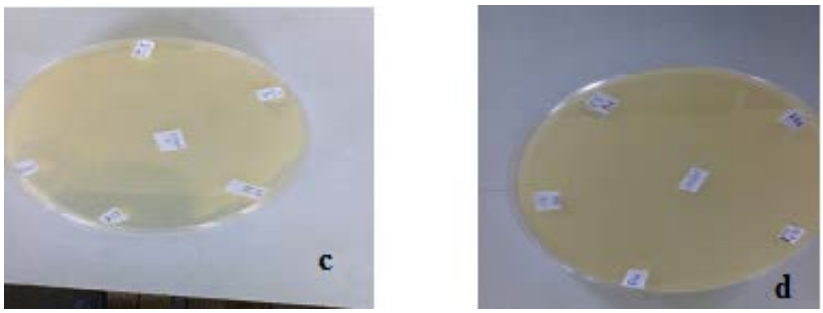


Figure 5. ZnS zone of inhibition against P. aeruginosa (c) and C. albicans (d)



The antimicrobial activity of ZnS was stronger in CTAB than in uncapped ZnS nanoparticles this could be attributed to the interaction between the ZnS nanoparticles and CTAB material in the nanocomposite. The increased antimicrobial could be due to the small size of the ZnS and CTAB and the microorganism will take up the ZnS/CTAB and the antimicrobial activities are considerable for the low concentration and this is in agreement with the reported case on ZnS/A-FA by [24]. These results indicate zinc sulphide both capped and uncapped can be used as an antimicrobial agent against antibacterial and antifungal infections in various industrial applications and agricultural practices.

The inhibitory zone was largest by gram negative, gram positive and C*andida albicans*. In comparison of results highest antimicrobial activity was shown by the gram negative (*Escherichia coli, pseudomonas aureginosa*) than the gram positive (S*taphylococcus aureus*) this was in agreement with that reported by [25, 26]. This could be attributed to the cell wall nature of the oral pathogens. The can be used to explain the inhibitory activity exhibited by gram positive and gram negative bacteria. The gram positive bacteria have thick cell walls made up of complex linear polysaccharide chains; hence it is difficult for nanoparticles to penetrate the cell wall, while gram negative bacteria cell wall has small thickness thus allowing the nanoparticles to penetrate. The ZnS nanoparticles discharge ions which react with thiol groups in the protein cell membrane and disrupt the cell functions and finally the microorganism dies this has been reported by [27, 28, 29]. Nutrients are carried by these proteins into the cell membrane according to [30].

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4. Conclusion

Zinc sulphide nanoparticles were synthesized and characterization was done by UV-VIS spectrophotometer, FTIR. Inhibitory activity of the zinc sulphide nanoparticles was tested against oral pathogens (*Staphylococcus aureus, Escherichia coli, and Pseudomonas aeruginosa and Candida albicans* using the disc diffusion method and were found to have good antimicrobial activity. ZnS solution in solvent and capped zinc sulphide showed a higher inhibitory effect against Gram negative bacteria as compared to gram positive bacteria and had *Candida albicans* had the least inhibition zone. This clearly shows that capped and uncapped zinc sulphide can be used as an antimicrobial agent against antibacterial, antifungal infections, in various industrial applications and agricultural practices.

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