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Synthesis and Characterizations of ZnO Nanoparticles for Application in Electromagnetic Detectors

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Abstract. Electromagnetic (EM) waves are able to distinguish between water and hydrocarbons due to their high difference in resistivity value. The method that uses EM technology to explore hydrocarbon is called Seabed Logging (SBL). Due to high demand of hydrocarbons, improvement of this technology is needed. The paper consists of modelling of the prototype of EM transmitter and receiver for hydrocarbons exploration. EM transmitter consists of carbon nanotubes (CNT), aluminium wire with magnetic feeder in toroidal shape. ZnO-CNTs-PVDF composites are used for EM detection. The XRD analysis showed a clear diffraction peak of [101] plane at 36° of the 2θ. Raman spectra were obtained for ZnO synthesised at 200°C and 300°C temperatures. The initial permeability, Q-factor and relative loss factor were measured using vector network analyser. Results show high value of Q-factor (~43) of the ZnO-CNTs at frequency between 20-30 MHz. The nanoparticles also show low relative loss factor for frequencies above 10 MHz. The grain size, morphology and shape of the particles were characterized using FESEM and revealed rod-like structures. The CNT dipole transmitter system using improved CNT dipole antenna and CNT-ZnO detector record an enhancement of 192% and can be used for hydrocarbon detection.

Introduction

This research is based on the study of electromagnetic wave propagation based on dipole antenna. The dipole antenna is one of the most important and commonly used types of radio frequency (RF) and microwave antenna. It has been widely used on its own and also being used or incorporated into many other radio frequency (RF) antenna and microwave antenna where it forms the radiating or driven element for the antenna [1]. One application of dipole antenna is as transmitter in hydrocarbon exploration.

The exploration of hydrocarbons is a difficult task for oil and gas companies. Since a long time ago, seismic technology has been widely employed to search for workable drilling wells. The weakness of this technology is that it can only distinguish liquid and solid but unable to distinguish between water and hydrocarbons. The success rate of this technology is very low (10-30%) [2].The new technology on hydrocarbons exploration is using EM (electromagnetic) waves called Sea Bed Logging (SBL).

The applications of nanomaterial in devices have been the focus of many researches due to their unique properties. Nanomaterials have demonstrated novel electrical, mechanical, chemical and optical properties significantly different from their bulk counterpart which are largely believed to be the results of the large increase of surface area to volume ratio [3, 4] and quantum confinement effect [5,6] as their sizes are reduced. Among the nanomaterials, nanostructured semiconductive oxide materials have attracted much research attention for their application in the fabrication of microelectronic and optoelectronic devices or sensors. Zinc oxide (ZnO) for one is a semiconducting, piezoelectric, and photoconducting transition metal oxide which has been very popular due to its wide band gap energy of about 3.37 eV and large exciton energy at room temperature. It also has good electrical and optical properties enabling it to be used in a variety of applications such as photoconductors, [7,8] sensors [9,10] and solar cells [11.12].

The properties of zinc oxide nanoparticles are highly dependent on their morphologies and sizes [13,14] which in turn depend on their synthesis methods. Zinc oxide has been prepared by a number of methods such as hydrothermal method [15, 16], sol-gel [17-19], precipitation [18,19],solid–vapour phase thermal sublimation technique [9] and self-combustion [21,18] methods, producing various morphologies, sizes and characteristics.

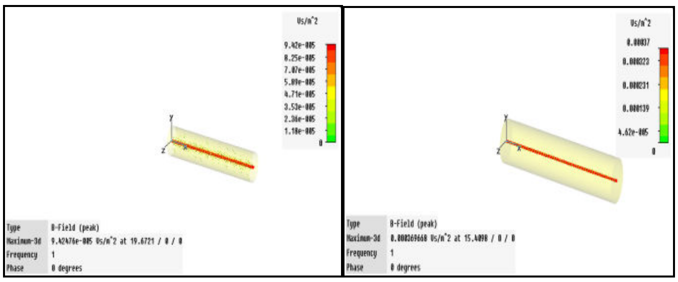
This paper discusses synthesis and characterisation of zinc oxide nanoparticles using self-combustion method. X-ray diffraction analysis, Raman spectra, and scanning electron microscopy (SEM) for ZnO nanoparticles were also examined in this work. Results show that the nanoparticles have the properties suitable for application in Electromagnetic detectors. EM transmitter based on carbon nano tubes (CNTs) with magnetic feeders are also discussed in this study.

Materials and Methods

The ZnO nanoparticles were synthesised using zinc nitrate [($Zn(No_3)_2.6H_2O$], Iron nitrate [($Fe (NO_3)_3.9H_2O$)], and nitric acid (HNO_3) as raw materials. All the metal nitrates were dissolved in aqueous solution of 80 ml HNO_3. The solution was stirred at 250 r.p.m for 5 days and allowed to combust on the hot plate stirrer with gradual heating after 30 min until the temperature reached 110°C. The combusted material was dried in the oven at 120°C for 2 days and the dried powder was grounded for 4 hrs. The resultant powder was then sintered at 200°C and 300°C for 4 hrs to get the required characteristics of ZnO powder. The preparation of ZnO-CNT detector requires 0.8g of CNT being dispersed using a mixture of H_2SO_4 and HNO_3 at 500°C for 7 hours time. The dispersed CNTs were then dried at 60°C. The ZnO nanopowder sintered at 300°C was added into polivinylidene fluoride (PVDF) polymer which was dissolved in 100 mL propylene carbonated solution. Casting method was used to form the nanocomposite which was cut into toroidal shape. The grain size, morphology and shape of the particles were characterized by using FESEM (SUPRA 55VP). The structure of ZnO nanoparticles was examined by X-ray diffractometer (Bruker D8 advance). Raman spectra were obtained for ZnO at 200°C and 300°C temperature by using Raman spectroscopy. The initial permeability, Q-factor, relative permittivity and relative loss factor were calculated using vector network analyser (Agilent 4294A).

Results and Discussion

A simulation was done using CST (Computer Simulation Technology) to determine the best material to be used in designing the antenna. For this, copper and aluminium have been simulated to see the magnetic field, electric field, magnetic field density and electric field density. The current path, frequency, radius and length are fixed to 0.5A, 1kHz, 2mm and 20mm respectively. The simulation results in Fig. 1 shows that aluminium material has better properties compared to copper.



(a) (b)

Figure 1: (a) Simulation results of copper (b) Simulation results of aluminium

Two EM transmitters based on aluminium and CNT were compared to verify the magnetic field strength of CNT is better than aluminium. The distance from antenna to receiver is fixed at 100 cm and the frequency was 40 MHz. Comparison of aluminium, CNT (carbon nanotubes) and Al-CNTs transmitter is shown in Fig. 2. It can be seen that Al-CNTs have better properties than others.

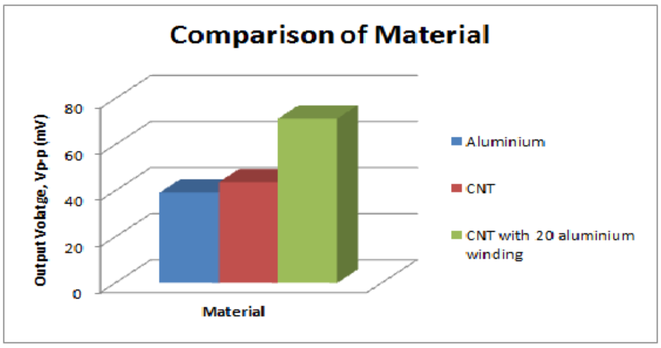


Figure 2: Comparison of magnetic field strength for different materials

X-Ray Diffractions analysis were carried out on ZnO nanoparticles prepared at 200°C and 300°C. Fig. 3 shows the XRD analysis of the ZnO nanoparticles which demonstrates a clear diffraction peak of [101] plane at 36° of the 2θ. Both ZnO at 200°C and 300°C demonstrate same diffraction peak as those of standard ZnO. Analysis of ZnO prepared at 300°C shows a higher intensity than that at 200°C. Thus, it shows that ZnO prepared at 300°C is better than that prepared at 200°C.

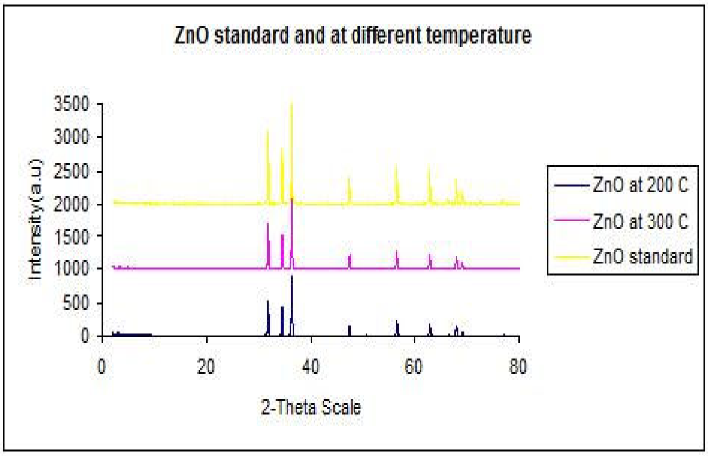


Figure 3: XRD analysis of ZnO nanoparticles

Figure 4 and 5 show Raman spectra for samples prepared at 200°C and 300°C respectively. From the results, the intensity of Raman spectra of ZnO sintered at 300°C is higher than at 200°C. Hence, the results also confirmed that ZnO sintered at 300°C is better than ZnO sintered at 200°C.

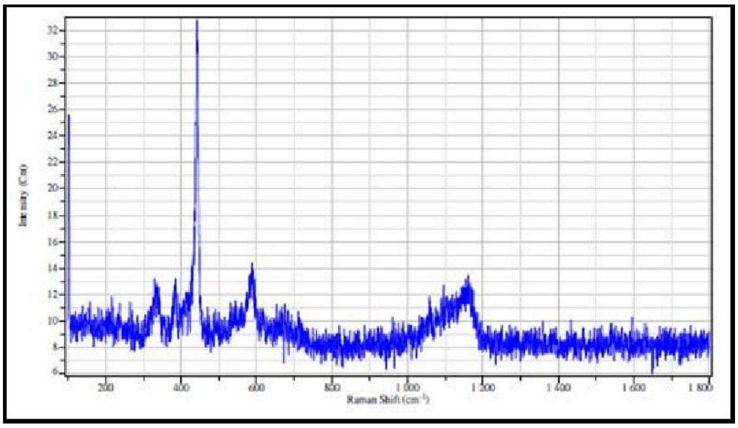


Figure 4: Raman spectroscopy of ZnO sintered at 200°C

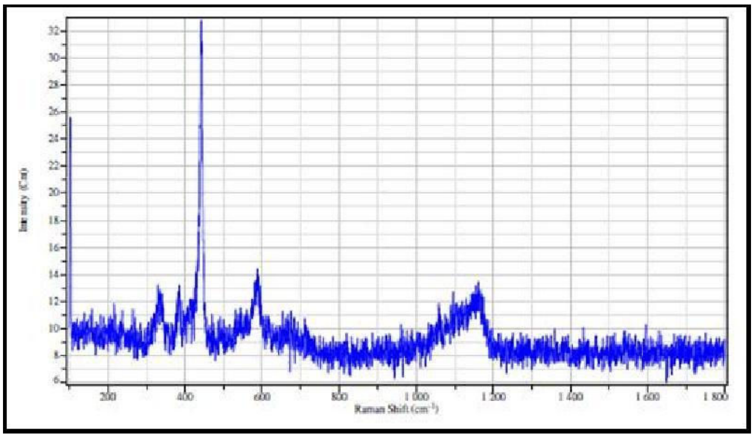
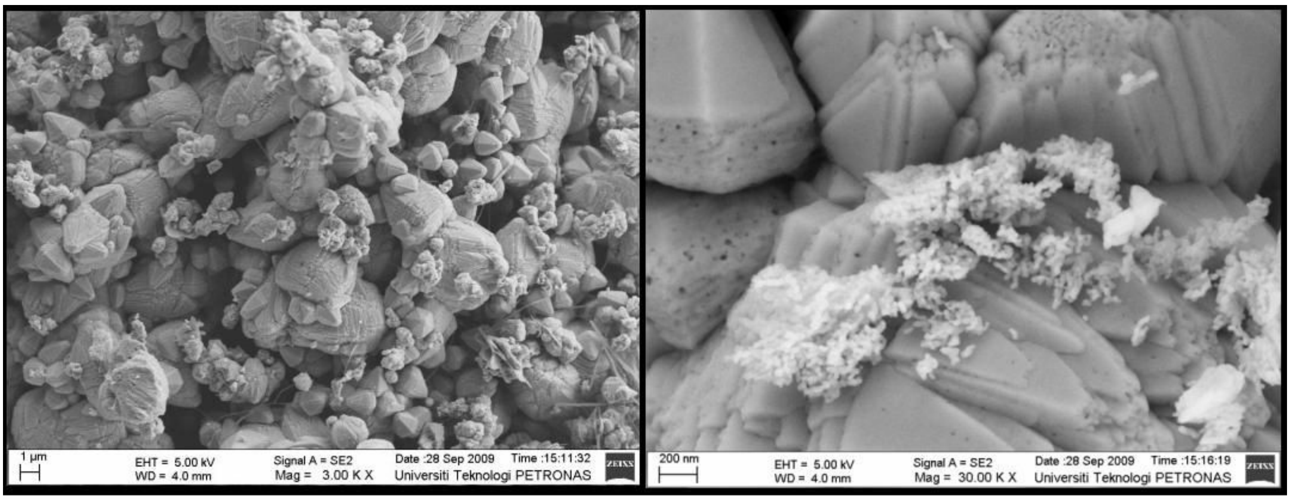


Figure 5: Raman spectroscopy of ZnO sintered at 300°C

The FESEM images of the nanoparticles synthesised by self-combustion at 200°C and 300°C are shown in Figure 6(a) and 6(b), respectively. The micrographs revealed rod-like structures. ZnO nanoparticles by self combustion at 300°C are more homogeneous compared to that at 200°C. Hence, it proves that ZnO nanoparticles by self combustion at 300°C are better than that at 200°C.



(a) (b)

Figure 6: (a) FESEM micrograph of ZnO nanoparticles prepared by self combustion at 200°C
(b) FESEM micrograph of ZnO nanoparticles prepared by self combustion at 300°C

The initial permeability, Q-factor and relative loss factor were measured using vector network analyser. Results show a high value of Q-factor (~43) of the ZnO, reaching a maximum value for frequency between 20 to 40 MHz (Fig. 7). The nanoparticles also show low relative loss factor for frequencies above 10 MHz (Fig. 8).

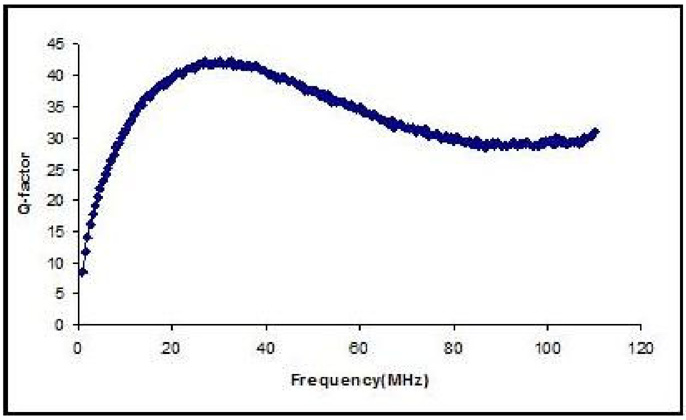


Figure 7: Q-factor of ZnO + CNTs + PVDF composite

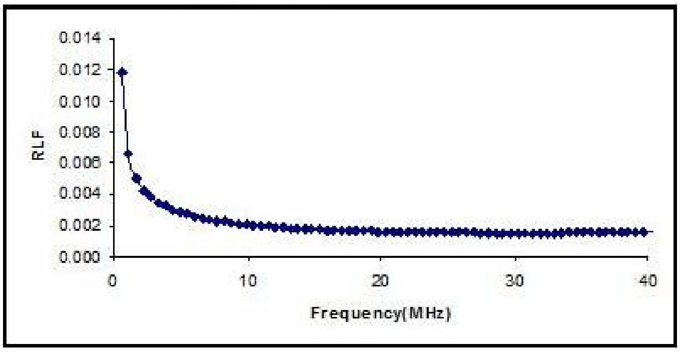


Figure 8: Relative loss factor of ZnO + CNTs + PVDF composite vs. frequency

From the results, we can conclude that ZnO-CNT-PVDF composite has good magnetic properties. This is because the results show high value of Q-factor and low value of relative loss factor.

For this experiment, the overall system of the CNT dipole antenna and CNT-ZnO detector was tested. The objective of this experiment was to demonstrate the improvement of the system by using different detectors. Two types of detectors, ZnO and ZnO-CNT were used and the results are shown in Fig. 9.

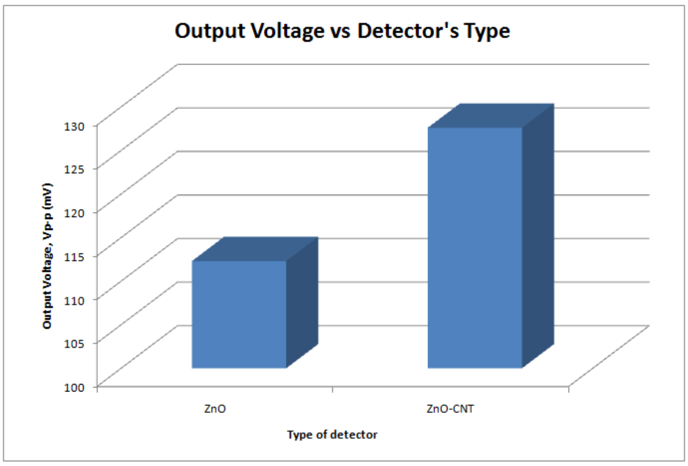


Figure 9: Output voltage vs. detector type

The chart in Fig. 9 shows different magnitudes of output voltage for the two types of detectors. The system using ZnO-CNT detector recorded 127.6 Vp-p, showing an increase by 13.6% from ZnO detector which recorded 112.3 Vp-p. For overall, the transmitter-receiver system using improved CNT dipole antenna and CNT-ZnO detector has been enhanced by 192%.

Conclusion

Single phase ZnO nanoparticles with major peak [101] were synthesised by self combustion method. ZnO rod-like nanostructure was observed for samples synthesised at 300°C. Raman spectra results also confirms ZnO structure. It was observed that CNT dipole antenna is a better transmitter compared to aluminium. The CNT dipole transmitter system using improved CNT dipole antenna and CNT-ZnO detector record an enhancement of 192% and can be used for hydrocarbon detection. The analysis of ZnO nanoparticles with CNTs shows that ZnO nanoparticles have the suitable properties for application in electromagnetic detection.

Acknowledgement

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References

1. M. A. Gilleo, Ferromagnetic Materials: A handbook of the preparation of magnetically ordered substances, E.P. Wohlfarth, North-Holland, Amsterdam (1980).
2. Z. A. Motlagh, M. Mozaffari, and J. Amighan. J. Magn. Mag. Mater. 321 (2009) 1980-1984.
3. Al. Habishi, R. Yahya, N. Shafie, M. S. E. Ismail, I. Waje, S. B. Saad, Int. Advanced Tech. Congress (ATCI) (2005) 577-583.
4. P. Vaqueiro, M.P.C. Lopez and M.A.L. Quintela,. J. Sol. St. Chem. 126 (1996) 161-168.
5. N. Yahya, R. A. H. Masoud, M. Zaid. Am. J. Engg. App. Sci. 2 (2009) 76-79.
6. J. L. Rehspringer, J. Burik, D. Niznansky, and A. Klarkora, J. Magn. Magn. Mater. 211 (2000) 291-295.
7. M. L. Wang, Z. W. Shih, J. Cryst. Growth. 114 (1991) 435-445.
8. J. Ding, H. Yang, W. F. Miao, P. G. Mccormick, R. Street, J. Alloys. Compd. 221 (1995) 70-73.
9. H. Tang, Y. W. Du, Z. Q. Qiu, J. C. Walker, J. App. Phys. 63 (1988) 4105-4107.
10. E. Lucchini, S. Meriani, G. Sloker, J. Mater. Sci. 18, (1983) 1331-1334.
11. S. Deka, P. A. Joy, Mat. Chem. Phy. 100 (2006) 98-101.
12. F. X. Liu, T. Z. Li, H. G. Zhang, Phys.Lett.A. 323, (2004) 305-309.
13. M. Rajendran, S.Deka, P. A. Joy, A. K. Bhattacharya, J. Magn. Magn. Mater. 301 (2006) 212-219.
14. M. P. Horvath, J. Magn. Magn. Mater. 215-216 (2006) 171- 183.
15. S. Verma, S. D. Pradhan, R. Pasricha, S. R. Sainkar, and P. A. Joy, J. Amer. Cer. Soc. 88 (2005) 2597-2599.
16. J. P. Ganne, R. Lebourgeois, M. Pate, D. Dubreuil, L. Pinier, and H. Pascard, J. Eur. Cer. Soc. 27, (2007) 2771-2777.
17. Z. Abbas, R.M. Al-habashi, K. Khalid, and M. Maarof, Eur. J. Sci. Res. 36, (2009) 154-160.
18. E. C. Snelling Soft ferrites. 2nd edn. Butterworths, London (1998).
19. J. J. Shrotri, S. D. Kulkarni, C. E. Deshpande A. Mitra, S. R. Sainkar, P. S. Anil Kumar and S. K. Date, Mater. Chem. Phys. 59, (1999) 1-5.
20. R. V. Mangalaraja, S. Ananthakumar, P. Manohar, F.D.Gnanam, Mat. Sci. Eng. A. 355 (2003) 320-324.