

Development and Size Distribution of Polystyrene/ZnO nanofillers

Olusola Olaitan Ayeleru^{a,*}, Sisanda Dlova^a, Freeman Ntuli^b, Williams Kehinde Kupolati^c, Peter Apata Olubambi^a

^aCentre for Nanoengineering and Tribocorrosion, University of Johannesburg, Johannesburg 2028, South Africa

^bChemical, Materials and Metallurgical Engineering Department, Botswana International University of Science and Technology,
Private Mail Bag 16, Palapye, Botswana

^cDepartment of Civil Engineering, Tshwane University of Technology, Pretoria
0001, South Africa

Abstract

In this paper, the preparation and characterization of ZnO nanofillers from polystyrene (PS) polymer waste for use as reinforcement was presented. This was done to achieve a better means of upcycling polymer wastes that have become social menace in recent times. The PS/ZnO nanofillers was synthesized through the hydrothermal synthesis of nanocomposites in an enclosed reactor. The reactor was kept in an oven at a specified temperature for a period. A product obtained was characterized using Fourier transform infrared (FTIR) analysis and Particle size analyser (PSA). The FTIR was utilized to determine the functional groups present in the synthesized nanofillers. The Particle size analyser was used to determine the distribution of particle size within the polymer matrix. The absorption peak obtained in the FTIR analysis confirmed the presence of ZnO in the synthesized material and the results from particle size analysis showed that about 80% of the particle was accommodated within the whole sample.

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* Corresponding author. Cell: +27 73 629 9135

E-mail address: olusolaolt@gmail.com

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1. Introduction

Polystyrene is a non-biodegradable material which its growth in the surrounding has become a threat to the earth surface [1]. Polystyrene is currently produced on a large scale from households, businesses and industries because of its durability, affordability, ease of production and strength [2, 3]. This has made it to be utilized as household utensils and packaging for electronics [4]. Despite all the good properties of polystyrene material, it still experiences poor mechanical, optical and electrical properties [3]. Thus, a better means to manage this waste are being developed by researchers. This method is through the development of nanomaterials from waste polymers and inorganic nanoparticles.

Nanomaterials have attracted attention in the research community in recent time [5]. The motivation behind the preparation of these materials is to develop speedy innovative materials that will find applications in different industrial fields [6-8]. Nanomaterials are formed from organic polymers which include polystyrene, polyethylene, polypropylene etc. [9]. The utilization of organic polymers for the synthesis of nanomaterials has paved way for inorganic nanoparticles to be used in combination with organic polymers for the enhancement of the chemical stability, mechanical, thermal, and optical properties of polymers [9]. Life has always provided a platform through which inorganic fillers will be added to organic polymers to increase the toughness, stiffness, hardness, density and permeability of nanomaterials to develop smart materials whose properties are exceptional [10, 11]. The nanomaterial formed is zinc oxide (ZnO) nanofiller from recycled polystyrene (rPS) [12].

ZnO is a very cheap semiconductor having a wide band gap of 3.37 eV, high excitation energy of 60 eV, high translucence and excellent photocatalysis [12-16]. ZnO nanomaterial has attracted greatest interest in recent time because of its varied applications in food packaging, medicine, gas sensors, pigments and transducers [17-20]. ZnO has exceptional physical and chemical properties that include chemical stability, high electrochemical coupling coefficient etc. [21]. ZnO can withstand large electric field, high temperature and high power operations which makes it to find applications in solar cells, photocatalysis etc. [22].

This paper aims to develop and characterize ZnO nanofiller from recycled polystyrene to be used for reinforcement.

2. Experimental section

2.1. Material

Recycled polystyrene (rPS) waste was collected from one of the Buy-backs recycling facilities in Johannesburg, South Africa, Benzene (C_6H_6) solvent was supplied by Glassworld & Chemical Suppliers CC, Johannesburg, a 250 mL hydrothermal autoclave reactor with Black Teflon tank was supplied by Protea Laboratory Solution (Pty) Ltd and Zinc (IV) carbonate ($ZnCO_3$) was purchased from Hopkin and Williams Ltd, London.

2.2. Preparation process

A 4 g of rPS was dissolved in a 50 mL C_6H_6 solvent and the sample was sonicated for a period of 20 minutes. A g of $ZnCO_3$ was then dispelled into the mixtures and sonicated for another 20 minutes. The entire mixture was then placed in a 250 mL Teflon tank and the tank was placed in an enclosed hydrothermal autoclave reactor. It was then left in an oven for a period of 3 hrs at a temperature of 280 °C. A product (ZnO nanofiller) was obtained, pulverized and further analysis was carried out on the product sample.

2.2. Characterization ZnO nanofillers

Analysis were carried out on the ZnO nanofiller using Fourier Transform Infrared Spectroscopy (FTIR) and Particle Size Analyser (PSA) (Microtrac S3500, USA). The FTIR spectra (PerkinElmer Spectrum 100 FTIR Spectrometer) was employed to determine the functional groups present in the ZnO nanofiller across the range of 4000 to 1000 cm^{-1} . The PSD was used to determine the particle size distribution within the synthesized nanofillers.

3. Result and Discussions

3.1. FTIR Spectra

The FTIR spectra (Figure 1) obtained shows the bonds and functional groups present in the synthesized ZnO nanofiller. The peaks at 3320 and 3025 cm^{-1} are due to O-H stretching and the functional groups present are likely to be alcohols and phenols [23]. The peaks at 2920, 2843, 2321, 2172, 2050 and 1982 cm^{-1} correspond to asymmetric and symmetric stretching. The functional groups present are likely to be carboxylic acids, nitriles and alkynes. The peaks at 1604, 1494, 1453, 1382 correspond to C-C and C=C [24]. Peaks at 1064 and 1026 cm^{-1} correspond to C-N stretch of aliphatic amines, absorption peak of ZnO and also confirms that ZnO nanofiller is present in the synthesized samples [24-26].

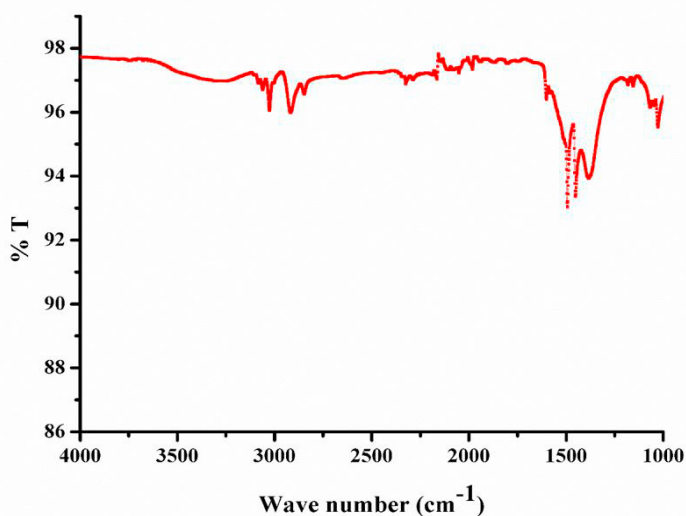


Figure 1 Zeta Potential Analysis

3.2. Particle size analysis

Particle size is a crucial factor in nanomaterial synthesis since it affects some properties such as compressibility and it is primarily to give allowance for selection of nanoparticles' optimum size [27, 28]. The particle size distribution (PSD) of the ZnO nanofiller was analysed with the aid of Microtrac S3500 Particle Size Analyzer

(PSA). The particle distribution of the synthesized nanofiller showed the size of the nanoparticles that pass through the mesh size in percentage. Figure 2 shows that from 0 - 400 microns size, the particles accommodated up to about 80% of the entire sample.

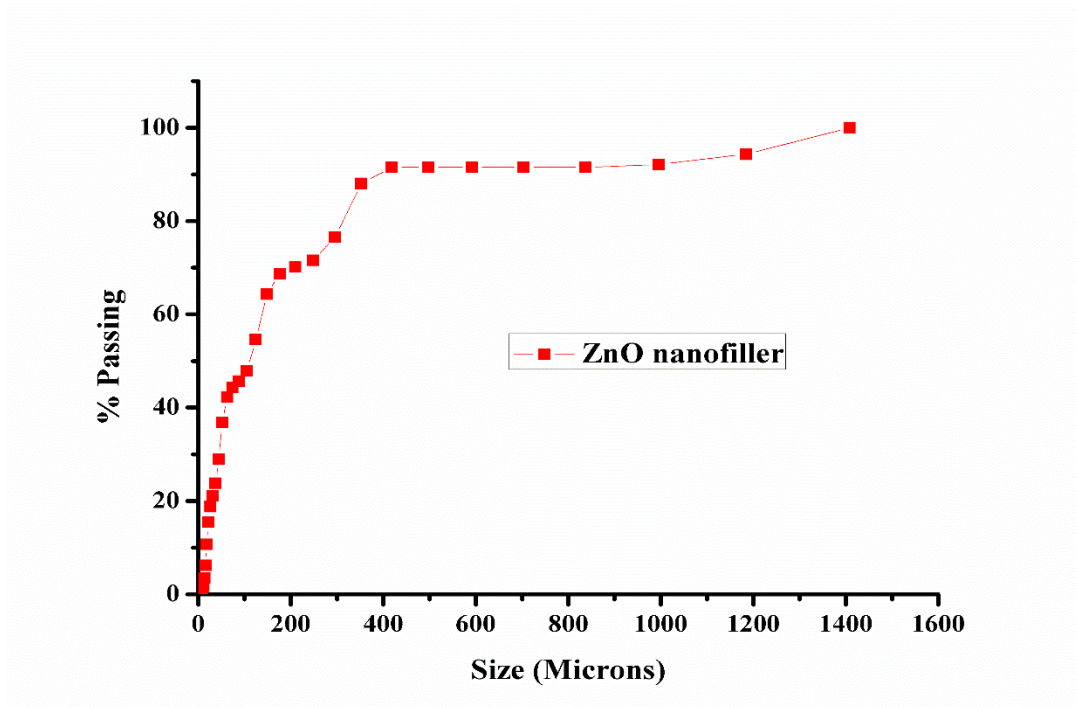


Figure 2 Particle Size Distribution showing synthesized ZnO nanofiller

Conclusion

This study has demonstrated an alternative means of recycling polymer in an environmentally friendly manner compared to landfilling and incineration methods that are very harmful to human health and the environment. The functional groups and broad peak obtained from FTIR analysis showed the synthesized nanomaterial to be ZnO nanofiller. The particle size analysis showed that about 80% of the particle was accommodated in the entire sample, which proved that upcycling of polymer wastes through this route, is effective.

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