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ELECTRICAL RESISTIVITY OF ZnO-Al/PP COMPOSITES

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Abstract

This study focuses on the electrical resistivity of Zinc oxide - Aluminum/ Polypropylene (ZnO-Al/PP) composites. ZnO-Al/PP composites with ZnO and Al being a filler varied from 0 to 55% of volume were prepared using Laboratory Roll Mill Heater. The composites were subjected to the characterization using non-destructive methods, which are scanning electron microscopy (SEM-EDX) and X-ray diffraction (XRD) techniques. The outcome from the XRD and SEM-EDX has been attained and thus gives an idea about the presence of ZnO and Al particles in PP composites. The electrical resistivity of the composites was investigated by measuring the current and voltage using CV-IV Measurement System, which describes the conductivity property of the composites.

Keywords: *zinc oxide; polypropylene; electrical resistivity*

1.0 INTRODUCTION

Zinc Oxide (ZnO) is a unique material that has been given much attention in recent years due to its various properties. With a direct wide band-gap (E_g = 3.37 eV) and large exciton binding energy (~60 meV), it exhibits semiconducting, piezoelectric and pyroelectrics multiple properties (Talam, Karumuri, & Gunnam, 2012; Md Sin et al., 2011**)**. Therefore, ZnO has become a promising candidate for stable room temperature luminescent and lasing devices (Aga, 2010). ZnO also offers an extensive dimension of application in piezoelectric devices, ultraviolet laser, sensors, transistors and field emission display (Zhang et al., 2013; Khranovskyy & Yakimova, 2012). With its exclusive properties for the fabrication of short-wavelength optoelectronic devices, ZnO is very suitable for production of blue-UV light-emitting and room temperature UV lasing diodes **(**Khranovskyy & Yakimova, 2012).

The advantages associated with a large band gap include high-temperature and high-power operation, lower noise generation, higher breakdown voltages, and ability to sustain large electric fields (Hadis & Umit, 2007). Further advantage of ZnO is it can be easily processed by wet chemical etching. Furthermore, with low cost and a low temperature it can be grown in a variety of nanostructured morphologies (Djurisic, Ng & Chen, 2010).

Present research shows that the infusion of 10-12 percentage of weight of nanoZnO into the (polypropylene) PP matrix has increased the composite surface resistance and electrostatic voltage to very low values of 10^9 Ω and 250 V, respectively. PP/nanoZnO composites also give a significant improvement in wear resistance, tensile strength, impact strength and crystallization (Huang, Chen, & Wei, 2006; Mahmud & Abdullah, 2006; Tang et al., 2004).

In this study, 2 vol% of ZnO were incorporated with different percentage of Al powder and PP composites using a melt mixing process. This technique is to produce polymer composites. The elemental composition together with the I-V measurement are carried out to evaluate the electrical resistivity behavior of ZnO-Al/PP composites.

2.0 COMPOSITES PREPARATION

The composites produced in this study is in a form of plate with 1 mm thickness. The fillers used are ZnO and Al, which then incorporated with PP composite. These three materials were mixed according to the percentage of volume as stated in Table 1. The ZnO and Al powders were combined to produce the homogenous mixture.

The PP composite is melted using Laboratory Roll Mill Heater at 180°C. At this temperature, the PP is placed into the Roll Mill Heater and the rolling process is started. The mixture of ZnO-Al is then added to the PP and the rolling process is completed when all the PP liquefies and the mixture of the ZnO-Al powders homogeneously attached to the PP. The temperature of the liquefy compound is reduced to a room temperature using water as a cooling agent.

The composite, then compressed-molded using Hydraulic Molding Test Press to get the plate-shape with a dimension of 15 cm x 15 cm and 1 mm thickness under the following conditions; temperature 180°C and a pressure of 1500 psi. Once the process is completed, the composite is cut into 2.5 cm x 2.5 cm and ready for characterization tests. The process above is simplified as in Figure 1.

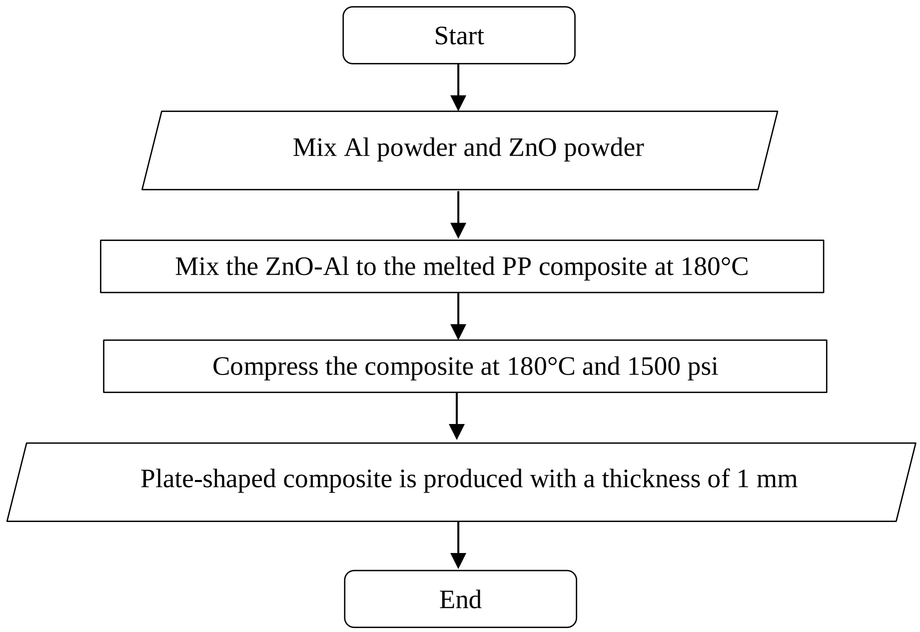

Figure 1 The process flow of sample preparation

Table 1 Percentage of Fillers in Polypropylene by Volume

No. of Sample	Volume by Percent		
	ZnO	Aluminum Powder (Al)	Polypropylene (PP)
1	0	0	100
2	2	0	98
3	2	10	88
4	2	25	73
5	2	35	63
6	2	45	53
7	2	55	43

3.0 RESULT AND DISCUSSION

3.1 Elemental Composition

The elemental composition of the composites is carried out using Scanning Electron Microscope (SEM) and Energy Dispersive X-ray (EDX).

The XRD pattern for sample 2; 98 vol% of PP with the absence of Al and sample 3; 88 vol% of PP with 10 vol% of Al are illustrated as in Figure 2 (a) and 2(b). The data from XRD gives the information about the elemental composition in the ZnO-Al/PP composite. It is proving that in sample 2 the 100% intensity of ZnO peak exists at 2θ = 36.207° while the diffraction peak for Carbon which is an element for PP occurs at 2θ = 17.854°. This verifies that the crystal structure of ZnO is hexagonal with the density of 5.65 g/cm^3 and lattice constant a = 3.253 Å and c = 5.213 Å. As for sample 3, 100% intensity of Al peak is detected at 2θ = 38.377°. The crystallographic parameters obtained prove that Al has a cubic system with lattice parameter $a = b = c$ = 4.059 Å and the density of 2.68 g/cm^3. All the lattice parameters are approaching a theoretical value (Coleman & Jagadish, 2006). Therefore, it is verified that there is a ZnO element in sample 2 and Al element in sample 3.

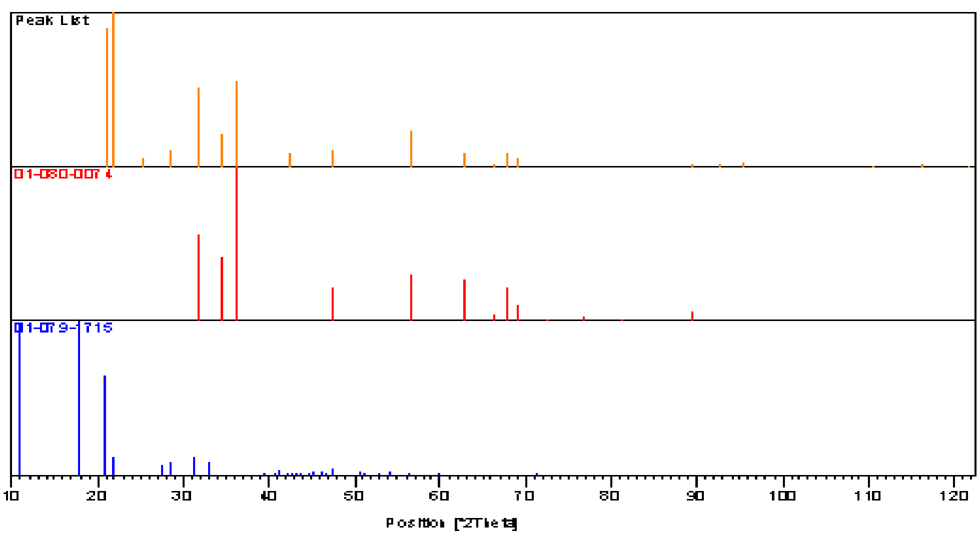

Figure 2 (a) XRD diffractogram of Sample 2 – 98 vol% PP with the absence of Al

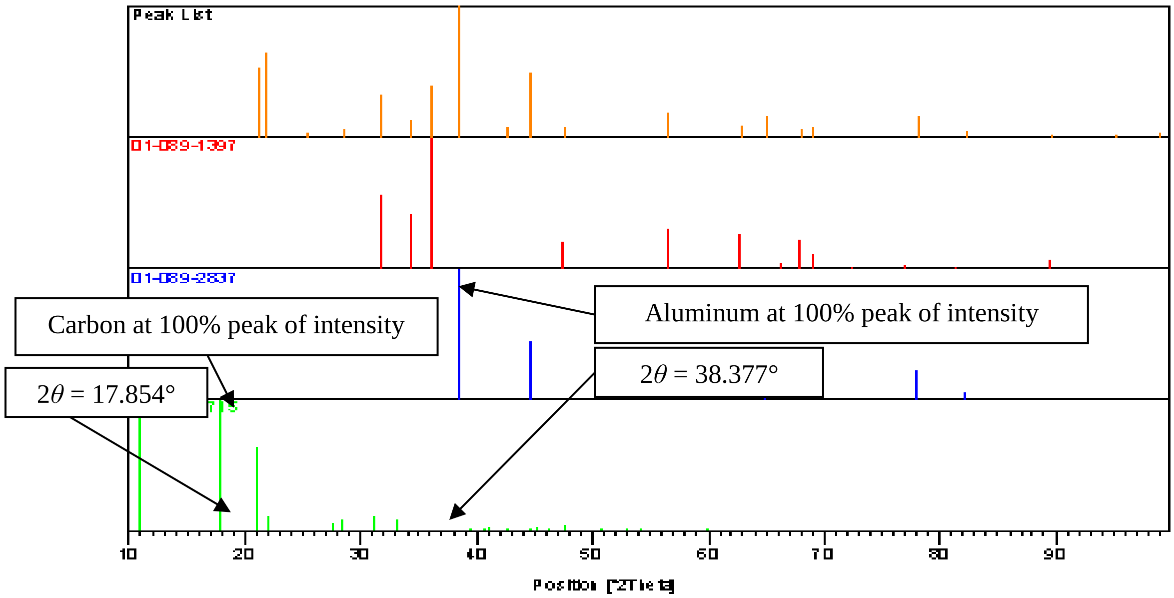

Figure 2 (b) XRD diffractogram of Sample 3 – 88 vol% PP with 10 vol% Al

SEM-EDX data is used to support the result from XRD result regarding the appearance of ZnO and Al particle in the composite. Elements in the EDX spectrum are identified based on the energy content of the X-rays, emitted by their electrons. Figure 3 (a) shows the EDX micrographs of the sample with 98 vol% of PP and 2 vol% of ZnO. The white spots traced in the figure represented the ZnO filler. Figure 3 (b) is for the sample that contains 88 vol% of PP and 10 vol% of Al and the grey dots prove the presence of Al in the composite.

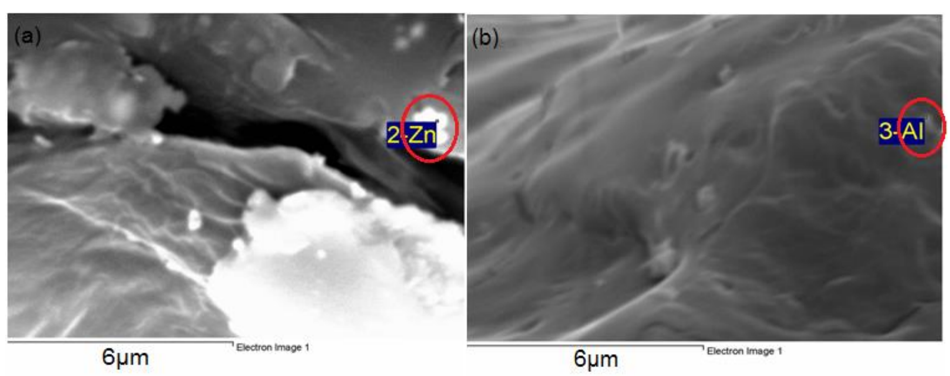

Figure 3 (a) EDX micrographs of Sample 2 – 98 vol% PP with the absence of Al; (b) EDX micrographs of Sample 3 – 88 vol% PP with 10 vol% Al

3.2 Electrical Resistivity Properties

The resistivity of the material is examined by measuring the current and voltage of the samples using the Keithley Model 82, CV-IV Measurement System. The current measurement ranging from 10.0 nA to 50.0 nA and the maximum voltage source of 120 V. The measurement is done under two conditions; in a dark condition and in the presence of incoherent illumination source. The samples are exposed to the light with intensity of 1305 Lux at a distance of 15 cm from the samples and 5 cm gap between the samples and probe in a dark condition.

Figure 4 indicates the I-V characteristics of the sample in a dark condition while Figure 5 shows the I-V characteristics under incoherent illumination condition. Table 2 shows the resistance of the sample at different percentage of Al and ZnO filler. The resistance was obtained using the following equation:

$$\boldsymbol{R = \frac{V}{I}}$$

R is resistance, V is voltage and I is current (O'Sullivan, 1980)**.** The resistance increases with the rise of filler in the material. As the percentage of Al increased, the resistance improved from 5.9786 GΩ for sample 2 (2 vol% of ZnO filler) to 6.6138 GΩ for sample 5 (2 vol% of ZnO and 35 vol% of Al filler). The value of resistance dropped to 5.7292 GΩ and 5.0300 GΩ for sample 6 and 7. This is probably due to the high concentration of Al in the composites. Al is a conductor thus a higher percentage of Al can reduce the resistance value, therefore it will increase conductivity and reduce resistance ability (Nurazreena et al., 2006). Under of incoherent illumination condition, the resistance demonstrates the unstable value. Rise and drop of resistance are due to the light exposure. This is because the light produces photo-generated charges that attempt to redistribute themselves inside the composites (Shahrom, 2008). The redistribution is not stable, giving rise in unpredictable graph.

Table 2 The resistance value of the composites

Sample	Resistance (G-Ω) - Dark	Resistance (G-Ω) - with light
1	5.6786	5.9238
2	5.9786	6.2960
3	6.2138	6.4846
4	6.2462	5.8500
5	6.6138	6.0917
6	5.7292	6.2333
7	5.0300	2.2690

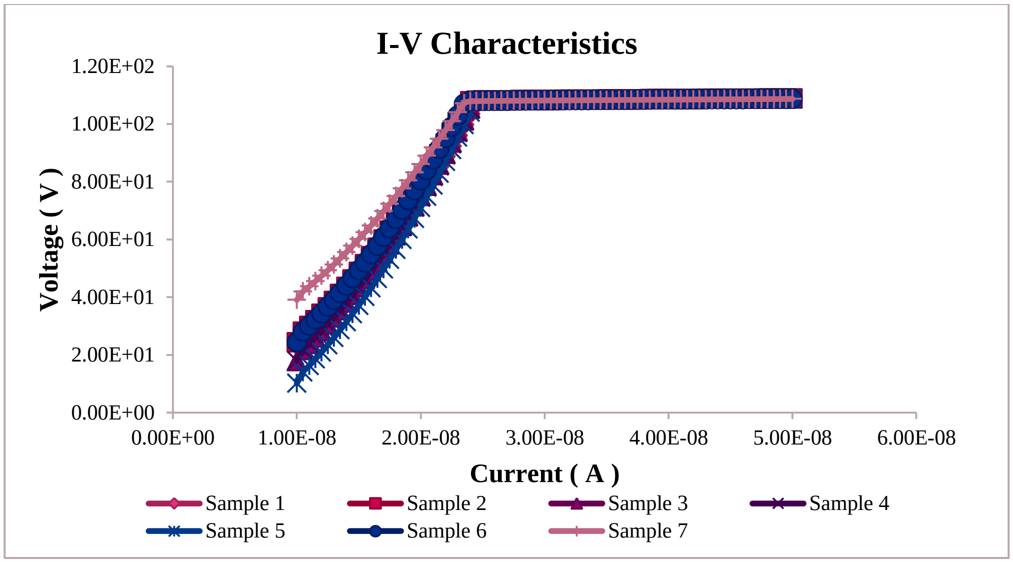

Figure 4 The I-V graph for dark condition

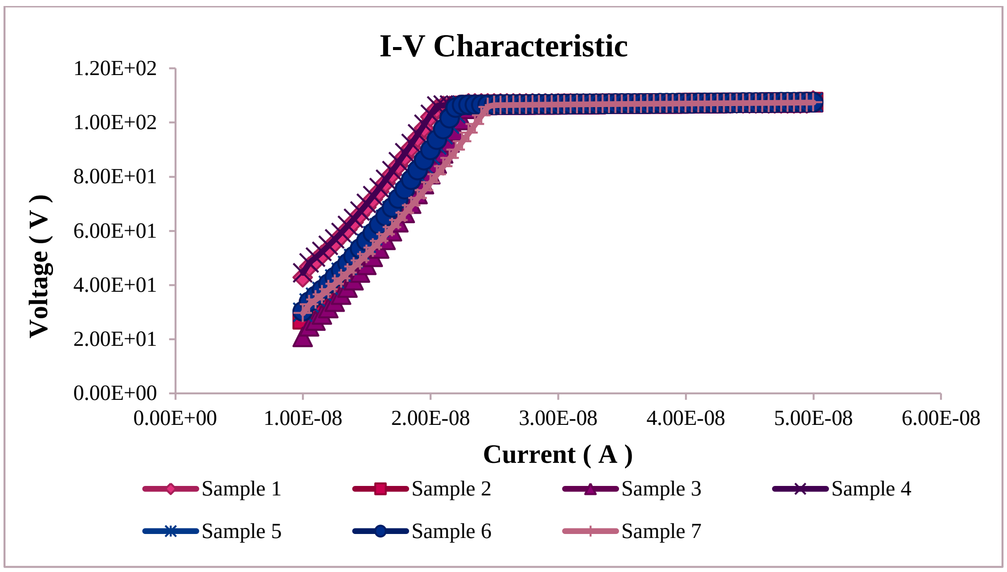

Figure 5 The I-V graph for illumination condition

4.0 CONCLUSION

The addition of ZnO and Al in PP compound promising greater impact to the electrical properties which thus gives benefits to composite thermoplastics. The result revealed that the increase in Al filler with the presence of 2% ZnO, has contributed to the reduction of resistance in a composite. From this outcome, the electrical property such as conductivity of the compound can be improved. There is a necessity to study the fundamental characteristics of ZnO morphologies and how they interrelate with thermoplastics in order to further maximize performance with minimum filler amount.

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