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TEMPERATURE EFFECT ON MAGNETIC PROPERTIES OF TPNR-NiZn FERRITE NANOCOMPOSITES

Moayad Husein Flaifel[1], Sahrim Hj Ahmad[1] and Mustaffa Hj Abdullah[1]

[1]*School of Applied Physics, Faculty of Science and Technology, Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor, Malaysia*

ABSTRACT

In this study we report on the temperature effect on the magnetic properties of magnetic polymer nanocomposite consisting of thermoplastic natural rubber (TPNR) filled with NiZn ferrite nanoparticles.The samples were characterized using X-ray diffraction (XRD) technique, Differential scanning calorimetry (DSC), Thermogravimitric analysis (TGA) and vibrating sample magnetometer (VSM). The results show that magnetic properties were changed by the effect of low temperature. Moreover, the results revealed that the saturation magnetization for a maximum magnetic field of 12 kOe has increased with decreasing temperature**.** Other magnetic properties such as coercivity and retentivity beside glassy temperature and degradation temperature have also been studied. The samples prepared exhibit themselves as a competitive product for transformers and generators.

INTRODUCTION

Magnetic polymer nanocomposites are a class of materials which have attracted the attention of the researches few years ago. And this is due to the novel physical characteristics polymer nanocomposites have as they incorporate magnetic nano-sized particles into it. These nanoparticles exhibit properties that make them different from their bulk counterparts because of some fundamental aspects such as quantum size effect, surface effect, spin reversal and quantum tunneling of magnetization. The performance of these materials is related to the degree of the dispersion of the nanoparticles in the non-magnetic polymer matrix, which (the later) plays a crucial role in fixing the final physical properties of the nanocomposites [1-4]. Methods involved in preparation of these materials are essentially two, one is to incorporate previously made and grinded nanoparticles into the polymer matrix, and the other one is to synthesis the nanoparticles within the polymeric matrix [3].
In this study the first method was implemented for making TPNR-NiZn Ferrite nanocomposite using melt blending technique. X-ray diffraction, Differential scanning calorimetry, Thermogravimitric Analysis and vibrating sample magnetometer were used to characterize the nanocomposite.

Corresponding Author: physci2007@gmail.com

EXPERIMENTAL METHOD

Preparation

The material comprises of natural rubber, liquid natural rubber and high density polyethylene in a ratio of 20:10:70 mixed with nickel zinc ferrite nanoparticles with different weight percent (wt%).This TPNR-NiZn Nanocomposite has been prepared with a direct method (where all of the last mentioned compositions are mixed together) using thermo-Hakee Internal mixer that uses melt blending technique. Thereafter the material was crushed into small granules and was ready to be pressed into very thin sheets, later to be used for magnetic and thermal characterization.

Characterization

TPNR-NiZn ferrite nanocomposite material has been characterized using different equipments. X-ray diffractometer was used to study the samples' structure, and then followed by differential scanning calorimetry to identify the samples' transition glassy temperature. Later, thermogravimitric analysis was conducted to determine each sample's degredation temperature and comment on the distribution of nanoparticles within the matrix. Finally; vibrating sample magnetometer was used to study the effect of low temperature on the magnetic properties of the prepared nanocomposite.

RESULTS AND DISCUSSION

XRD results:

The X-ray diffraction was conducted on TPNR-NiZn nanocompites (1(a) &1(b)) and the pure nickel zinc ferrite sample 1(c). We can see an obvious change in the figures 1(a) and 1(b) where their two important peaks have shifted for lower angular range when compared to the pure sample. This shift in both samples' peaks (4% & 12%) can be attributed to the interaction of the nanoparticles and TPNR matrix which resulted in new sites for the hosted nanoparticles within the matrix. Moreover the intensities of the highest peak which were found at, 21.5^o, 21.4^o, and 35.4^o were 42, 49 and 223 (a.u.) respectively. These intensity differences of all figures are ascribed to different filling content in the matrix. Other peaks found in case of pure sample were suppressed in nanocomposite samples due to very low filing content.

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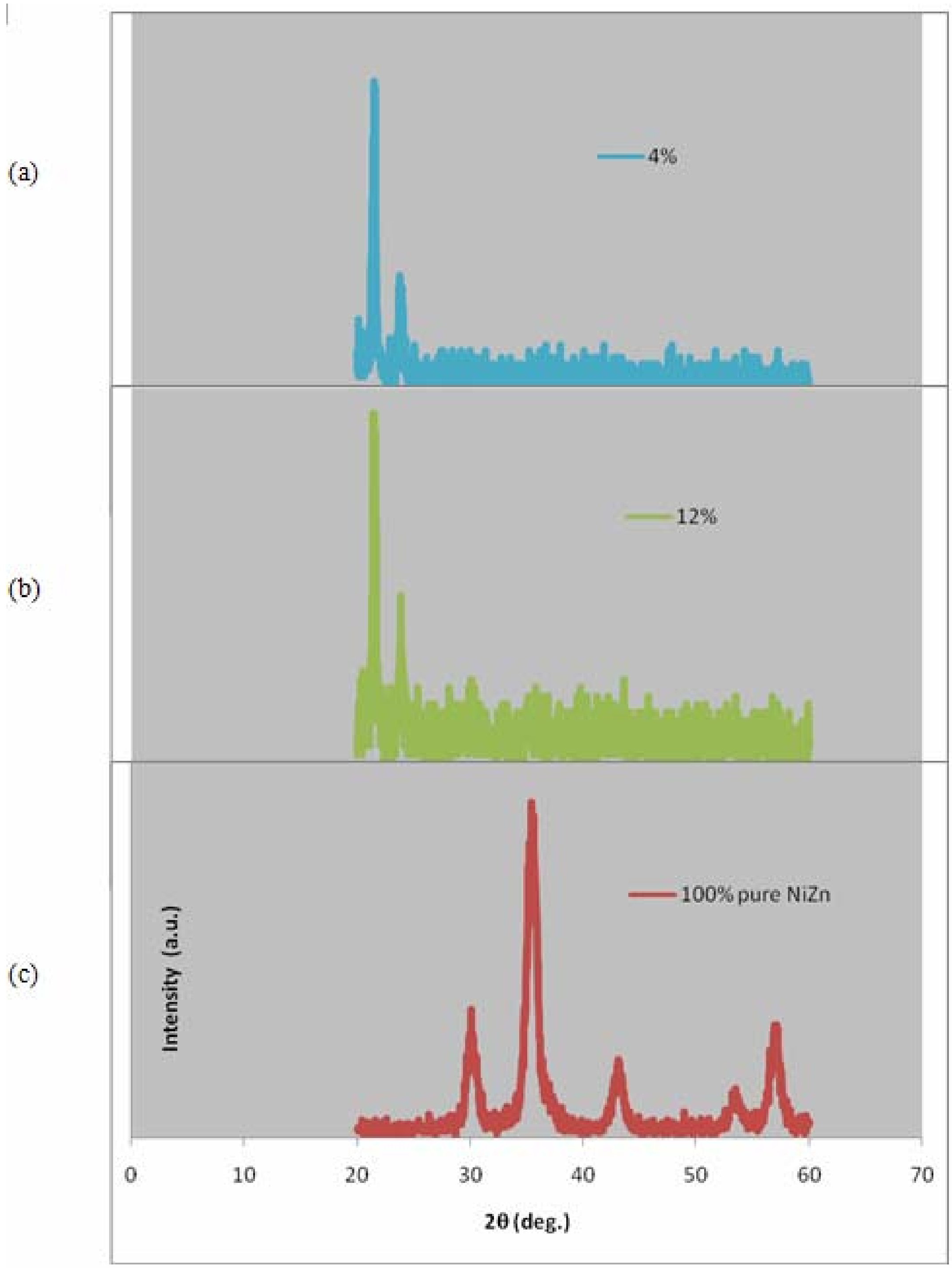

Figure 1: Shows XRD results for TPNR-NiZn ferrite nanocomposite with 4% wt% (a) and TPNR-NiZn ferrite nanocomposite with 12% wt% (b) and pure NiZn ferrite nanoparticles 100% (c).

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DSC results:

DSC characterization was carried out on TPNR-NiZn nanocomposite with 0%, 4%, 8% and 12% filling rates. With referring to figure 2, we can see clearly that with increasing filler content in TPNR matrix, the transition glassy temperature (Tg) increases; and therefore, the crystallinity of TPNR matrix will get distorted and tend to be amorphous.

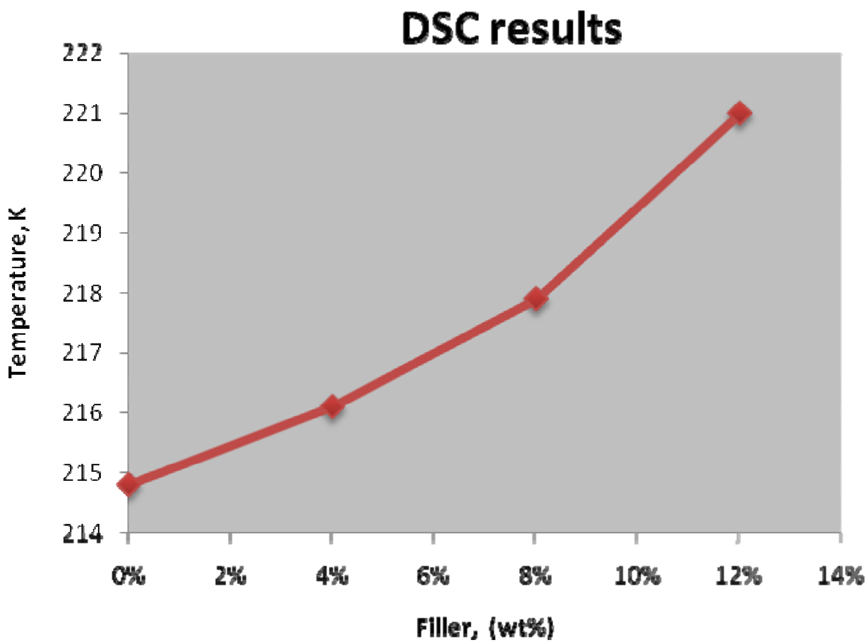

Figure 2: DSC results for TPNR-NiZn nanocomposite with 0%, 4%, 8% and 12% filling rates versus temperature.

TGA results:

TPNR-NiZn nanocomposites with different filler rates were exposed to TGA which was conducted on three different samples A, B & C for each weight percent; as a result, degradation temperature as well as the residual amount left of Ni-Zn ferrite from the totally melted TPNR are shown in table 1. The results reveal that with increasing filler rate, degradation temperature increases. The residual amounts of Ni-Zn ferrite show consistency with standard filler percentage in case of 8% & 12 %, which is not the case for 4% nanocomposite, which guarantees homogeneous dispersion of nanoparticles (for the former) inside TPNR matrix.

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Table 1: Filler (wt %) Vs. Degradation Temp (T_d) & Residues (wt %)

Filler (wt %)	Degradation Temperature (T_d)	Residual Amounts (wt %)			Average (wt %)
		A	B	C	
4	538 K	7.0	4.0	5.0	5.3
8	543 K	8.0	8.5	9.5	8.7
12	568 K	13.0	12.0	12.5	12.5

VSM results:
The result presented was taken for 4% nanocomposite as we may conclude the rest of the results based on what we get from 4% filler. The results report an absence of hysteresis and thus many magnetic properties at room temperature, and this can be attributed to superparamagnetic state exhibited by NiZn nanoparticles [1, 2]. Figures 3 & 4 show hysteresis under low temperature effect and effect of temperature on magnetization respectively. It can be seen from figure 3 that as the temperature decreases, the saturation magnetization as well as coercivity increase. This can be attributed to the fact that the electrons' spins get frozen with decreasing temperature and therefore applying the same amount of field (12KOe) will align the spins into its direction and the temperature decrement will act as fixer. Figure 4 shows a consequent result of the hysteresis drawn in figure 3.

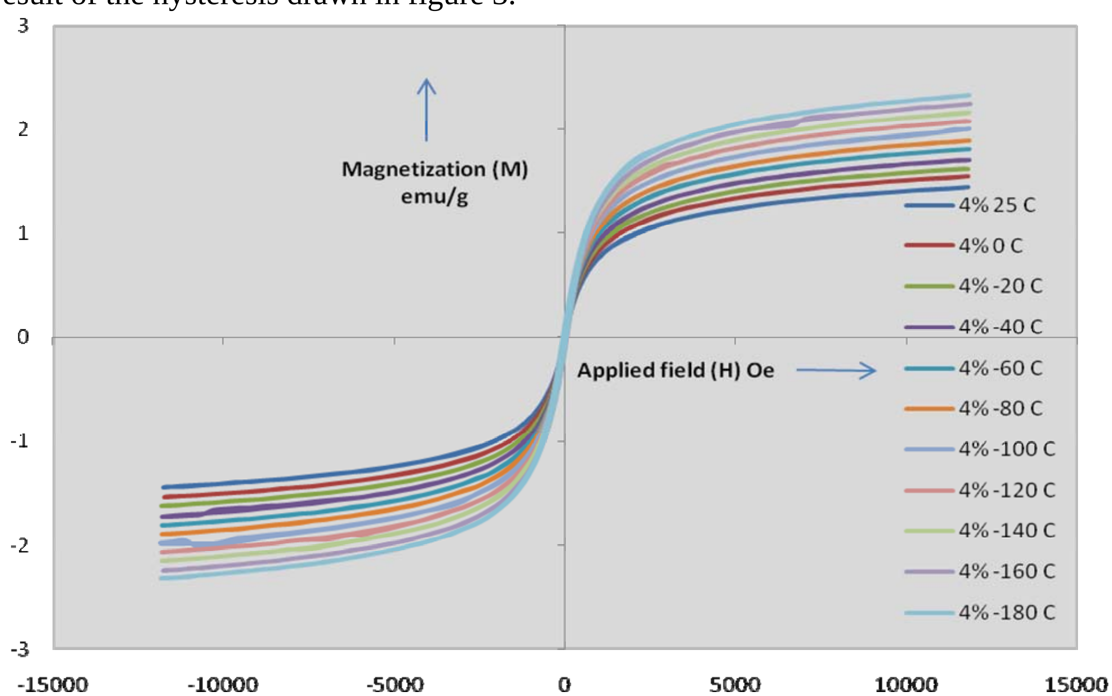

Figure 3: Hysteresis loops under the effect of different low temperatures for 4% nanocomposite.

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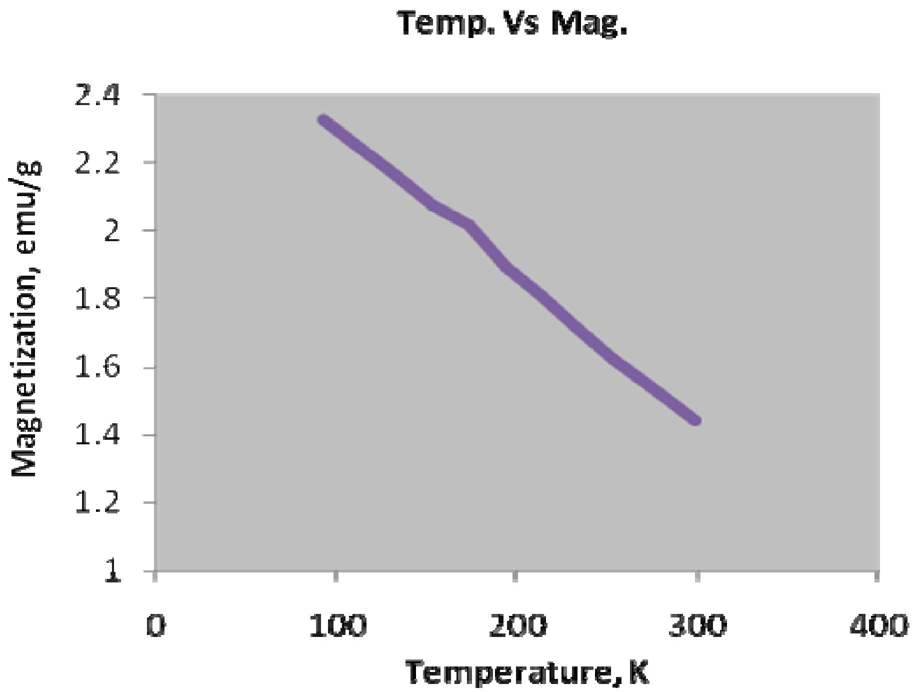

Figure 4: The effect of low temperature (K) on the saturation magnetization (emu/g) for TPNR- NiZn nanocomposite with 4% filler rate.

CONCLUSION

TPNR-NiZn nanocomposite was prepared via direct method with different filler loading. The samples were characterized using XRD, DSC, TGA, VSM.TGA results show that there has been a good distribution for the nanoparticles especially with higher filler content. The results from DSC which is consistent with XRD results tells us if the filler content increases, Tg increases, which it is a sign of slow crystallinity distortion. And finally, magnetization, coercivity and retentivity increase with decreasing temperature where the electron spins tend to freeze.

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