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SHORT NOTE

THERMAL CONDUCTIVITY OF MICRO- AND NANO-FILLED POLYMER BLEND COMPOSITE FOR RADIATION SHIELDING MATERIAL

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ABSTRACT

The thermal conductivity of boron carbide filled thermoplastic natural rubber blend composite is studied experimentally as a function of filler loading and filler size. A polymer blend of 60/40 NR/HDPE was used as matrix for incorporation of particulate nano- and micro-sized B_4C as filler to form the composite. As the filler loading is increased from 2-10%wt, a reduction and increment of thermal conductivity was observed. The results show at lower filler loading, HDPE crystallinity affects the thermal conductivity up to 4 and 6%wt of filler for nano- and micro-composite respectively. Further increase the loading do not much alter the crystallinity as the filler is distributed in continues phase of NR. The increment of filler amount in the amorphous NR causes the thermal conductivity to gradually increase which indicates the formation of interconnecting filler network structures.

Keywords: Polymer-matrix composites, Thermal conductivity, Crystallinity,

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INTRODUCTION

Polymeric composite has become an important class of materials these days and is driven by scientific and technological importance of this material to the needs of various sectors. The use of inorganic fillers such as clay mineral [1] and carbon nanotubes (CNTs) [2] which has high aspect ratio has been extensively reported in improving the mechanical properties of composite. However, composite thermal conductivity was less studied as compared to the other properties. Polymers are good thermal insulators and their thermal conductivity range from 0.14 to 0.60 W/m.K. Most of filler materials have thermal conductivities several orders of magnitude higher than the polymer matrix. The information on thermal properties of such heterogeneous systems is needed for tailoring the material applications. In this work, we look into the possible influence of polymer crystallinity and interconnecting filler network structures on the thermal conductivity of nano and micro-filled polymer composite.

EXPERIMENTAL

Matrix used is a polymer blend consists of 50%wt natural rubber (NR), 10%wt liquid natural rubber (LNR) and 40%wt HDPE. Fillers used are micro- and nano-sized B_4C. The composite samples were compounded in Rheomix Haake 600P internal mixer and finally heat pressed to form a thin slab with a nominal thickness of 1mm.

For XRD characterization, the profile of Bragg and amorphous peak for all samples were calculated from the parameters determined by a deconvolution method using Pearson VII function with the following formula:

$$f(x_0) = \left\{1 + \left[\frac{1}{w_0}(x_0 - c_0)^2 \left(2^{\left(\frac{1}{k_0} - 1\right)}\right)^{m_0}\right]\right\}^{-1} \qquad (1)$$

where w_0 = full width at half maximum (FWHM), c_0 = centre of the profile, x_0 = diffraction angle, k_0 = peak intensity of the profile, m_0 = constant. This function has a shape determined by the m_0 value; it can become Cauchy, Lorentzian and Gaussian when m_0 equals 1, 2 and 6 (x 10^{11}) respectively.

RESULTS AND DISCUSSION

Example result of peak fitting procedure is shown in Fig. 1 for matrix sample. The peak centre (2θ), FWHM and integrated areas of crystalline peak at (200) reflection were used to determine the fraction of crystalline phase. The amount of integrated area was assumed to be proportional to the degree of the HDPE crystallinity at (200) reflection. The integrated areas at (200) reflection between matrix and composites were compared with the matrix taken as reference. The matrix was assumed to have 100% crystallinity and the rest are relative to this and termed as relative degree of crystallinity. Thus, the relative degree of crystallinity trend with reference to the matrix was determined as shown in Fig.2.

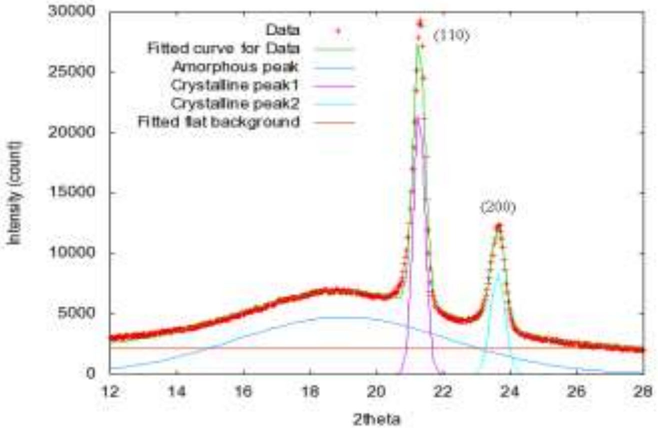

Figure 1 Peak fitting for matrix sample.

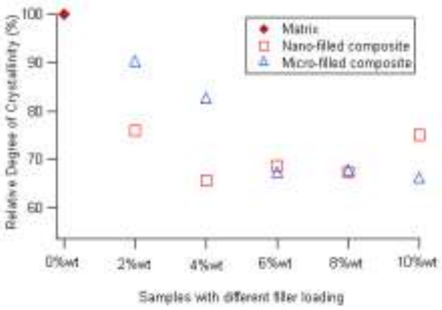

Figure 2 Relative degree of crystallinity of samples.

The effect of fillers on the structure of matrix was studied by measuring the crystallinity of the HDPE phase. The results show that at lower filler loading, HDPE crystallinity was affected up to 4 and 6%wt of filler for nano- and micro-composite respectively. Further increase the loading do not much alter the crystallinity as the filler is possibly distributed in continues phase of NR after fully occupying the HDPE phase. However, at 10%wt of filler for nano-composite, the crystallinity is less affected as the nano filler might experience agglomeration and hindered them from remain occupying the HDPE phase. The preference of filler to present in the HDPE before moving into NR is due to premixing step between filler and HDPE before undergoing melt mixing process of all materials.

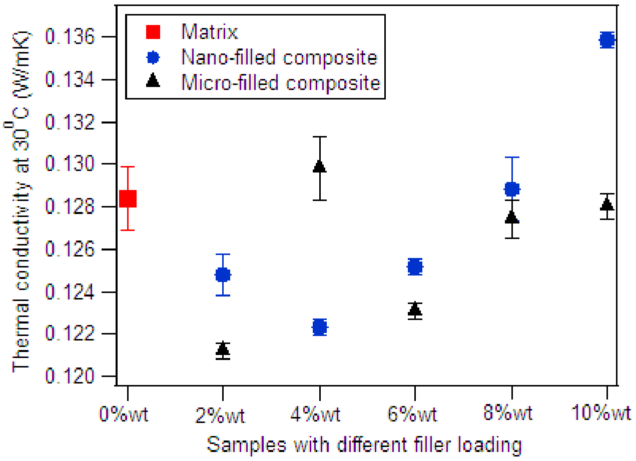

Figure 3 Thermal conductivity of nano- and micro-filled composite

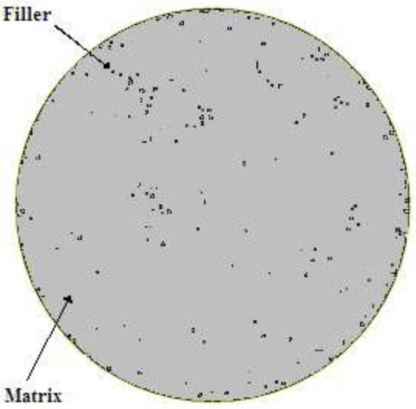

Figure 4 Sliced image by MicroC for 4%wt micro-filled composite

It is clearly seen that 4%wt and 6%wt are the threshold loading before the thermal conductivity starting to increase gradually for nano- and micro-composite respectively. However, at 4%wt of filler for micro-composite, the thermal conductivity is unexpectedly high. This is due to uneven filler distribution as shown in Fig. 4. The values of threshold loading are in agreement with maximum crystallinity reduction at 4%wt and 6%wt previously. This indicates crystallinity dominantly affects the thermal conductivity as reported by previous worker [3]. Ease of fonon transfer in crystalline phase is responsible to highly influence the thermal conductivity at lower loading as compared to amorphous phase. Thus thermal conductivity follows accordingly with the amount of crystallinity. Excessive fillers beyond threshold loading are distributed in the amorphous NR. This causes the formation of interconnecting filler network structures and gradually increases the value of thermal conductivity.

CONCLUSION

Based on these results, the thermal conductivity seems to be influenced by the crystallinity and interconnecting filler network structures which finally affect the fonon transfer. Therefore, this serves as evidences on the importance of structure-property relationship in explaining the behavior of materials.

REFERENCES

[1] Tyan HL, Liu YC, Wei KH. Thermally and mechanically enhanced clay/polyimide nanocomposite via reactive organoclay. Chem Mater 1999;11(7):1942-7.

[2] Xie XL, Zhou XP, Mai Y-W. Dispersion and alignment of carbon nanotubes in polymer matrix: A review. Mater Sci Eng R 2005;49(4):89-112.

[3] Kline, D. 1961. Thermal conductivity studies of polymers. *Journal of Polymer Science* 50: 441-50.