

# Thermal and Mechanical Interfacial Properties of Expanded Graphite/Epoxy Nanocomposites

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## Introduction

Recently, new hybrid polymer reinforced with nanoscale dimensions are received much attention because of their intrinsic good properties and extended utility for structural applications[1].

Since the development of layered silicate reinforced polymer nanocomposites in the 1980s, much attention has been paid to layered silicates/polymer nanocomposites. Once layered silicates that have very high aspect ratios (width-to-thickness) are uniformly dispersed in a polymer matrix, the polymer nanocomposites reinforced with a small amount of layered silicate can significantly improve the thermal, mechanical, and barrier properties of the pure polymer[2].

For a filler of nanocomposites, the graphites, as well as the layered silicates, are composed of layered nanosheets are also naturally abundant. Carbon atoms positioned on the graphite layer are tightened by covalent bonds while those positioned in adjacent planes are bound by much weaker van der Waals forces. The weaker interplanar forces allow for certain atoms, molecules, and ions to intercalate into the interplanar spaces of the graphites. So expanded graphites can be easily obtained by rapid heating of a graphite intercalation compound prepared from graphites[3,4].

Although great success has been achieved in layered silicate/polymer nanocomposites, the study of polymer nanocomposites with graphites were not much reported. In this work, the nanocomposites are prepared by the melt mixing method, and the thermal and mechanical interfacial behaviors of expanded graphite/epoxy nanocomposites are also discussed.

## Experimental

For expanded graphites, the graphite flake was added in a mixture of concentrated sulfuric acid and nitric acid (4:1, v/v) at room temperature. The reaction mixtures were stirred continuously for 24 h. The acid treated graphites were washed with enough water and then dried at 80°C to remove any remaining water. The dried graphite particles were heat treated at 900°C for 90 s, thereby obtaining the expanded graphites.

The expanded graphite/epoxy nanocomposites were prepared by expanded graphites as filler using the melt mixing method. And the mixing of mixtures was done in the presence of heating and stirring process to disperse expanded graphites in the epoxy

as the matrix. Then, the mixtures were precured at 120°C for 1 h. Afterwards, they were cured at 150°C for 2 h, and finally, post-cured at 180°C for 1 h in order to achieve the complete cured composites.

## Results and Discussion

Rapid heating of acid-treated graphites at sufficiently high temperature causes expansion and forms loose and porous vermicular graphites, which consists of carbon layers with large interlayer distance. And their structures are basically parallel boards and exhibit the pores with different size ranges.

The thermal stability parameters of nanocomposites, such as the initial decomposed temperature (IDT) and the temperature of maximum rate of weight loss ( $T_{max}$ ), can be determined from TGA thermograms. Figure 1 shows TGA thermograms of expanded graphite/epoxy nanocomposites prepared from different contents of expanded graphites. The IDT of the nanocomposites is slightly decreased by an addition of expanded graphites, and the  $T_{max}$  of nanocomposites exhibits increased thermal stability at 1 phr expanded graphites compared to neat epoxy. This might result from the interaction between the epoxy and the expanded graphite lamellae, which has an excellent thermal property.

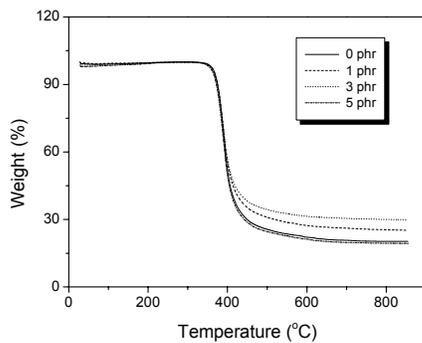


Figure 1. TGA thermograms of expanded graphite/DGEBA nanocomposites.

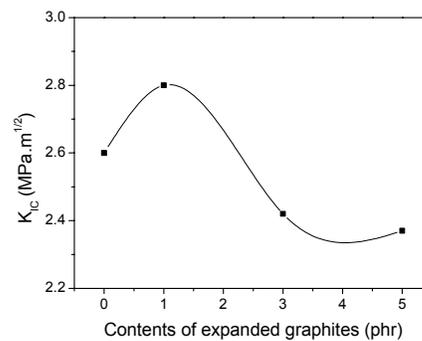


Figure 2. Fracture toughness of expanded graphite/DGEBA nanocomposites.

To investigate the fracture toughness of the nanocomposites, the critical stress intensity factor ( $K_{IC}$ ) is used, and the value of  $K_{IC}$  is calculated as follows:

$$K_{IC} = \frac{P \cdot L}{b \cdot d^{3/2}} \times Y \quad (1)$$

where  $P$  is the rupture force,  $L$  the span between the supports,  $Y$  the geometric factor, and  $b$  and  $d$  is the specimen width and thickness, respectively.

Figure 2 shows the evolution of  $K_{IC}$  of expanded graphite/epoxy nanocomposites with different expanded graphite contents. The maximum fracture toughness of the nanocomposites is observed with an addition of 1 phr of expanded graphites. This result is due to the multi-pore feature of the expanded graphites, strongly interaction between the epoxy resins and the  $-OH$  and  $-COOH$  groups of expanded graphite, and the fine dispersion of expanded graphites in the epoxy resins.

## Conclusions

The expanded graphite/epoxy nanocomposites were prepared by melt mixing method, and the prepared nanocomposites were investigated in thermal properties and mechanical interfacial behaviors. From the TGA analysis, thermal stability of nanocomposites was increased with increasing of graphite content. The fracture toughness of nanocomposites was determined by critical stress intensity factor ( $K_{IC}$ ) and the maximum  $K_{IC}$  value of the nanocomposites was found at 1 phr of expanded graphites. These results were due to the multi-pore feature of expanded graphites and the physical interaction between the epoxy and the –OH and –COOH groups of the homogeneously dispersed expanded graphites in the epoxy resins.

## References

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