

High Heat Resistance Carbon Fibre/Epoxy Composites Toughened by Thermoplastic Modifiers

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Abstract

In this study, DGEBA liquid epoxy was modified with two different modifiers, which were epolec[®] and Phenoxy. Modifiers dispersion was controlled by the temperature during stirring with adequate rotation rates. The prepreg in this paper were fixed with FAW and resin content and made by drum winding machine. Composite specimens were prepared by the cure conditions determined from Differential Scanning Calorimeter (DSC) which was used to estimate the curing cycle of these matrix systems.

Dispersing condition of added particles with their particle sizes were inspected by Small Angle X-ray Diffraction (SAXRD) and Atomic Force Microscopy (AFM) respectively. Differential Scanning Calorimeter (DSC) was adopted to examine the effects of modifiers on the reactivity and glass transition temperature. The shear properties of cured composites were demonstrated by the interlaminar shear strength (ILSS) as well as the Mode I and Mode II fracture toughness. After testing, these fractured specimens were examined by the Variable Vacuum Scanning Electron Microscope (VVSEM).

Results show that the each resin system can be dispersed well by the control of mixing temperature with simple stirring condition. Glass transition temperature of each cured resin systems showed a slight influence with the different test concentrations. In general, the shear properties of cured composites were improved with modifiers being in the cured systems especially in the part of performance of fracture toughness.

Keywords: composite, epoxy, thermoplastic modifier, fracture toughness, high glass transition temperature

1. Introduction

A composite material can be defined as a combination of two or more materials that results in better properties than when the individual components are used alone. As opposed to metal alloys, each material retains its separate chemical, physical and mechanical properties. The two constituents are normally a fiber and a matrix. Typical fibers include glass, aramid and carbon, which may be continuous or discontinuous. Matrices can be polymers, metals or ceramics. [1]

The most common matrix for advanced composites and for a variety of demanding applications is epoxy. Epoxies have taken this major role because of their excellent adhesion, strength, low shrinkage, corrosion protection, processing versatility and many other properties. The matrix in a composite can be thought of as performing two major roles: transferring loads to the reinforcement and protecting the reinforcement from adverse environmental effects. Generally, epoxies do a fine job. [2-8]

The aim of this experiment is to improve the interlaminar properties of carbon fiber reinforced epoxy by imparting different amount of thermoplastic resin including of phenoxy resin and elastomeric epolec[®] resin in epoxy matrix. Due to the particles formed from epolec[®] resin after composite cured, SAXRD was taken advantage of inspecting the dispersing conditions for various concentration of elastomer. Besides, the formed particle sizes were discussed as well by AFM examination. The glass transition temperature and shear properties of cured composites were analyzed as well.

2. Experimental

Epoxy resin used in this study was diglycidylether of bisphenol A (DGEBA, DER331[®], Dow chemical Co. LTD, EEW=184-190) and 4,4'-Diaminodiphenyl Sulfone (DDS, Epotech Composite Corp.) was used as the curing agent.

Two tougheners were studied in this experiment respectively. One was elastomeric epolec[®] resin (Tg : 90°C, EEW : 216-228, Epotech Composite Corp.) and the other one was phenoxy resin (PKT600, Tg : 94°C, Mw : 50000, In Chem Co.)

Epoxy resin systems containing 0-20wt% of the individual modifiers were prepared by following procedure. Modifiers were adducted with epoxy at 150°C for 1.5h.

After homogeneous, 4,4'-Diaminodiphenyl Sulfone (DDS) was added into individual systems at 80°C with thoroughly dispersing. Prepregs were made by Drum Winding process with fixed Fibre Aerial Weight and resin content. Laminates were cured at 180°C with 2hrs curing time. Curing pressures were adjusted to control resin flowout during hot pressing so that the resin content of cured laminates would be able to control. At the end of the cure cycle, the temperature was slowly lowered to the room temperature.

3. Results and discussion

3.1 Dispersion and Particle size

In order to investigate the dispersion and particle size of formed elastomers, Small Angle X-ray Diffraction (SAXRD) and Atomic Force Microscopy (AFM) were used. From the observed curves as shown in Fig. 1, the elastomeric particles were dispersed well, which means epolec[®] can be dispersed well by the control of mixing temp with simple stirring condition. Particle size was then examined by Atomic Force Microscopy and the results were

as demonstrated in Fig. 2. Particle size of cured epolec[®] was around 400 nm.

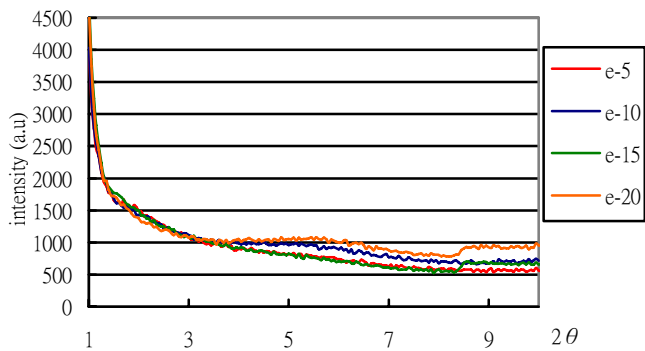


Fig. 1 Small Angle X-ray Diffraction curve for epolec[®] modified resin system.

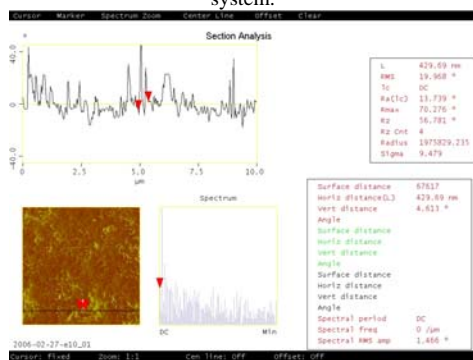


Fig. 2 Atomic Force Microscopy shows the particle size of epolec[®].

3.2 Thermal Properties

Fig. 3 shows that the glass transition temperatures of cured composites were slightly declined with increasing concentration of phenoxy. When the concentration was more than 15 phr, the decrease has been slacked. The little influence of the concentration on the glass transition temperature is because of the high molecular weight of phenoxy resin. By contrast, the decreased tendency of glass transition temperature varied with increased concentration of epolec[®] resin was more apparent than the influence of phenoxy resin. Although the particle size of cured epolec[®] resin could be classified as nano-scaled, the influence of adding concentration of epolec[®] is inevitably obvious than high-molecular-weight modifiers. Fig. 4 shows that the glass transition temperature of modified composites showed a slight influence with the test concentrations.

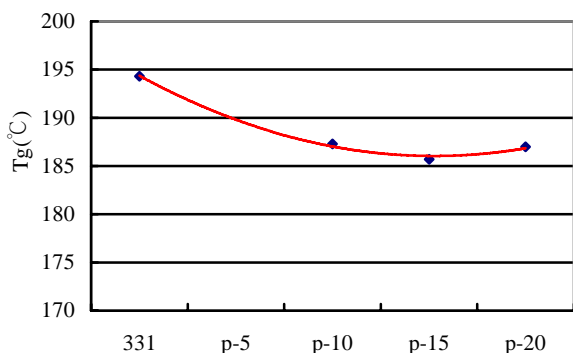


Fig. 3 Glass transition Temperature varied with different concentration of phenoxy resin in modified epoxy resin systems..

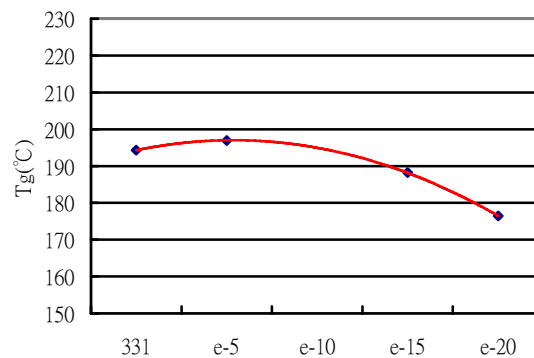


Fig. 4 Glass transition Temperature varied with different concentration of epolec[®] resin in modified epoxy resin systems.

3.3 Mechanical Properties

Fig. 5 shows the interlaminar shear strength (ILSS) varied with different modified epoxy systems. As illustrated, that the ILSS is increased with increasing modifiers content. The ILSS values of epolec[®] modified resin systems are all higher than phenoxy modified systems. It also indicates that the interlaminar shear properties of epoxy resin toughened with nano-scaled elastomeric particles will be better than the resin system modified with polymer chains.

The effect of tougheners concentration on the mode I interlaminar fracture toughness, as noted by G_{IC} , is shown in Fig. 6. The G_{IC} values of all toughened laminates are larger than control system. This is because toughened matrices can absorb more energy around the crack tip by plastic deformation. Scanning Electron Microscopy was used to characterize the fracture surfaces of the laminates. Fig. 7 shows mode I fracture surfaces of control system and both of the modified laminates.

Values of G_{IIc} for individual modified epoxy systems are shown in Fig.8. It is shown that the G_{IIc} increased with increasing modifiers contents. Scanning electron photomicrographs of the fracture surfaces are shown in Fig. 9.

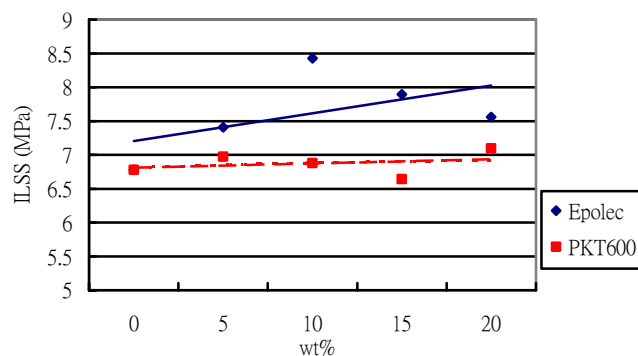


Fig. 5 Interlaminar shear strength variation with modified systems.

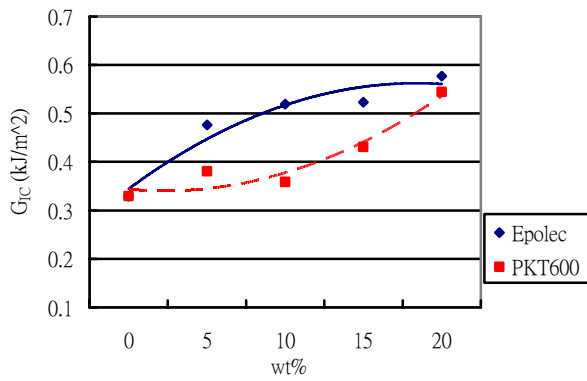


Fig. 6 Mode I interlaminar fracture toughness values of the laminates as measured by G_{IC} .

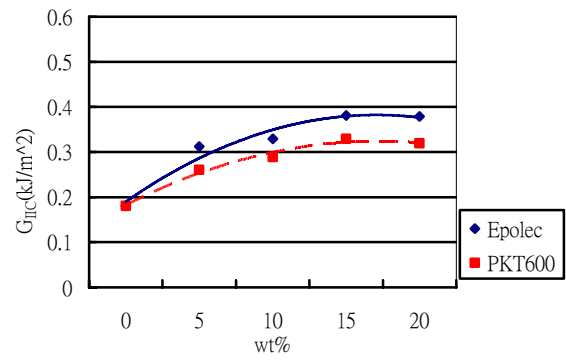
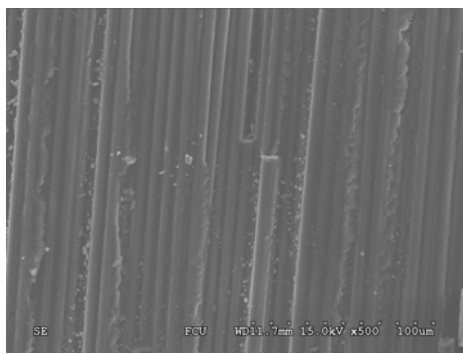
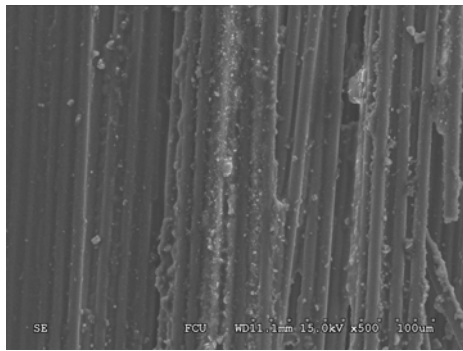


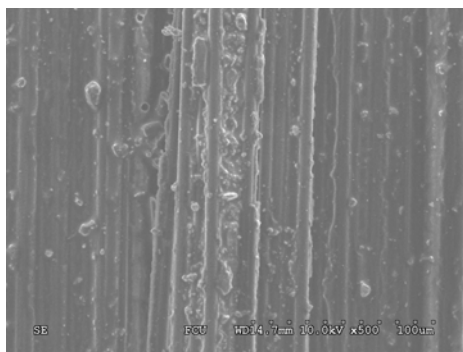
Fig. 8 Mode II interlaminar fracture toughness values of the laminates as measured by G_{IIc} .



(a)

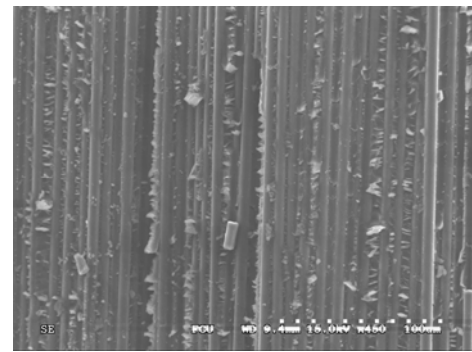


(b)

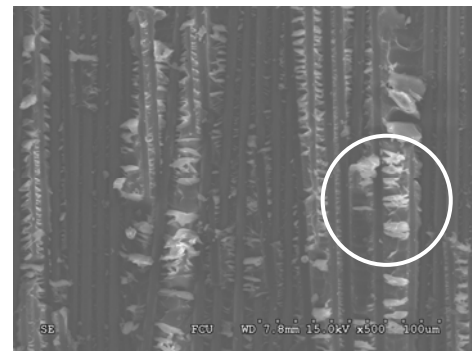


(c)

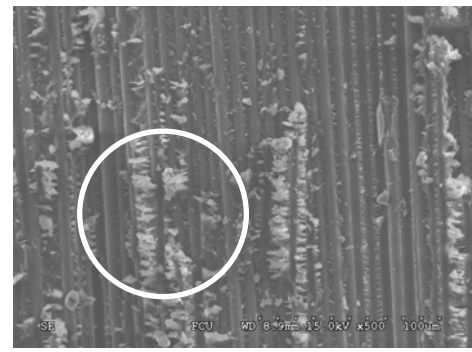
Fig. 7 SEM of fracture surface formed as a response to G_{IC} . (a) control system (b) epolec[®]-10phr (c) phenoxy-10phr



(a)



(b)



(c)

Fig. 9 SEM of fracture surface formed as a response to G_{IIc} . (a) control system (b) epolec[®]-20phr (c) phenoxy-15phr

4. Conclusion

Results show that the resin system can be dispersed well by the control of mixing temperature with simple stirring conditions. Glass transition temperature of both cured resin systems showed a slight influence with the adding concentrations and the epolec[®] resin was more obvious than the influence of phenoxy resin. The interlaminar shears strength is increased with increasing modifiers content. The interlaminar fracture toughness of the epoxy resin is improved by the addition of different concentration of modifiers. The fracture surface in the area of crack growth initiation shows the plastic deformation.

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