A Kinetics Model for Interphase Formation in Thermosetting Matrix Composites

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ABSTRACT: During the cure of thermosetting polymer composites, the presence of reinforcing fibers significantly alters the resin composition in the vicinity of the fiber surface via several microscale processes, forming an interphase region with different chemical and physical properties from the bulk resin. The interphase composition is an important parameter that determines the micromechanical properties of the composite. Interphase development during processing is a result of the mass-transport processes of adsorption, desorption, and diffusion near the fiber surface, which are accompanied by simultaneous cure reactions between the resin components. Due to complexities of the molecular-level mechanisms near the fiber surface, few studies have been carried out on the prediction of the interphase evolution as function of the process parameters. To address this void, a kinetics model was developed in this study to describe the coupled mass-transfer and reaction processes leading to interphase formation. The parameters of the model were determined for an aluminum fiber/diglycidyl ether of bisphenol-A/bis(*p*-aminocyclohexyl)methane resin system from available experimental data in the literature. Parametric studies are presented to show the effects of different governing mechanisms on the formation of the interphase region for a general fiber–resin system. The interphase structure obtained from the model may be used as input data for the prediction of the overall composite properties.
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Key words: adsorption; composites; curing of polymers; interfaces; kinetics (polym.)

INTRODUCTION

Fabrication of thermosetting matrix composites is based on a critical step of cure, which involves applying a predefined temperature cycle to a fiber–resin matrix mixture. The elevated temperatures initiate a crosslinking cure reaction among the species in the matrix. The presence of fibers has been found to significantly influence the cure reaction, resulting in the formation of a third phase, known as the *interphase,* which possesses properties distinct from those of the bulk fiber and the matrix. The interphase resides in a region between the original constituents of the composite with a size of a few to a few thousand nanometers.[1–4] Although the region has a submicroscopic scale, it essentially forms a significant portion of the matrix in the composite.[1] Also, the performance of the composite is determined by the ability of the matrix to transfer load to the reinforcing fiber and is thus controlled by the interphase region. The structure and properties of the interphase are the dominant factors governing the overall composite properties and performance.

Prediction of the overall composite properties in the presence of the interphase region involves the following steps:[1]

- First, the manufacturing parameters must be linked with the interphase structures. For example, given a cure temperature and pressure cycle, the chemical composition of the interphase should be determined. In this step, physical and chemical mechanisms must be identified and modeled to predict the interphase structure.
- In the second step, the known interphase structure is related to the interphase material properties such as glass-transition temperature (T_g), flexural modulus, or thermal expansion coefficient. This step is primarily based on the experimental correlation of the interphase chemical composition to the measured interphase material properties.
- The last step is to link the interphase material properties to overall composite properties such as the strength, fracture, and environmental resistance.

A majority of the studies in the literature focus on the experimental determination of the influence of

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