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Revisiting the role of interfacial chemistry in composite durability: Recent concepts and developments

Faezeh Khan Ahmadi *

Department of Inorganic Chemistry, Faculty of Chemistry, University of Kashan, P. O. Box: 87317-53153, Kashan, Iran

COMMENTARY

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Abstract

This paper investigates the role of interfacial structures and chemistry in the durability and mechanical performance of fiber-reinforced composite materials. First, the history and development trend of hybrid composites are reviewed, and then the types of bonding in polymer and metal composites are analyzed. Next, nanoscale features such as nanopores and nanofibers and the principles of nano-structuring in the interfacial region are reviewed. The paper compares the effects of matrix changes and interfacial nanostructure engineering on the mechanical behavior of nanocomposites and finally, presents a nonlinear damage model to describe deformation in polymer nanocomposites, which is applied to epoxy systems containing carbon nanotubes and reactive graphite.

This study examines the key role of interface chemistry in the durability and mechanical performance of advanced composites. The properties of these materials are determined by the bond between the matrix and the reinforcement, which is formed during the manufacturing process. Physical or chemical incompatibilities between these two phases can lead to premature degradation of the composite. For example, ultrahigh molecular weight polyethylene(UHMWPE) fibers severely reduce the bond strength at the interface due to their poor wettability with epoxy [1].

Hybrid composites, by combining layers of continuous fiber reinforcement and metal layers, offer superior properties compared to other composites [2]. These structures not only have favorable cyclic fatigue resistance and high specific strength, but also exhibit high stability against environmental conditions due to the presence of metal layers.

Examples such as Kevlar fiber-reinforced aluminum hybrid composites (ARALLs) and carbon fiber-reinforced aluminum foams or laminates (CARE) from this group offer effective mechanical performance and interface chemistry between the polymer and the metal. However, in such systems, mechanical loading and temperature changes lead to complex interfacial stresses that directly affect the durability and behavior of the interface [1, 3].

Composite bonding to metals has been suggested as a way to improve the durability of structures and interface behavior in the context of that goal, and adhesive bonding allows for the repair and strengthening of metal structures and components, but the long-term durability of metal-to-polymer interfaces is still one of the biggest challenges [4]. The right materials should be selected, and the bonding process should be optimized. Boron-epoxy, carbon-epoxy and graphite-epoxy composites have been nominated for use for stability in polymer / metal bonds due to their good thermal and mechanical compatibility with metals, boron-epoxy especially due to its high thermal compatibility [1, 5, 6].

Adding activated carbon nanotubes with functional groups to epoxy matrixes followed by introducing the modified resin to anodic aluminum oxide (AAO) nanopores, the functional groups establish a significant chemical bond between the nanotubes, epoxy, and AAO and the AAO's high surface area enhances the interface strength not achieved through conventional bond designs [7, 8].

To enhance the mechanical properties of polymer composites, single- and multi-walled nanotubes are employing as additives because they have unique properties [9].

Due to the cumulative damage inflicted by external loads, polymer composites behave nonlinearly according to the damage caused by deformation. Nanofibers that were added to the epoxies can enhance the wettability between the polymer matrix and other reinforcements like high strength polyethylene fibers and carbon fibers, and present new conditions for interaction and stress transfer within composite structures [5].

In general, the superior performance of advanced composites depends on the effective interaction between the reinforcement and the matrix. Creating nanostructures at the interface is an efficient

* *Corresponding author: Faezeh Khan Ahmadi, Email: Khan.Ahmadi.F24@gmail.com*
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way to improve the adhesion and increase the durability of composite systems. For example, creating nanopores on the metal surface or using modified carbon nanotubes in matrices can significantly increase the strength of the metal-polymer bond. Also, the use of epoxies reinforced with nanofibers and graphite nanostructures helps to reduce residual stresses and improve flexibility.

Finally, nonlinear modeling of the interface degradation behavior provides an effective tool for predicting and analyzing the structural stability of multiphase composites [10].

Author contributions

Faezeh Khan Ahmadi: Investigation, Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare no conflict of interest.

Data availability

No data is available.

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