Interfacial Bonding and Mechanical Properties of Polyurethane Composites under Wet Conditions

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Statement of Purpose: Developing polymer composites for biomedical applications has been an increasingly active research area [1-3]. Composite technology provides an easy way to make materials that have combined or synergistic properties using existing biomaterials with proven biostability and biocompatibility. As biomaterials, composites may be used in contact with body fluids. Under such "wet" application conditions, the interfacial bonding between the filler and matrix of a composite can be critical to its performance. In order to obtain stable and strong bonding, the surface of the filler is often treated. Covalent coupling between the filler and the matrix is a preferred approach, but achieving a chemical reaction between the filler coating and the polymer matrix is not always confirmed and the results of improvement are mixed. In some cases, such as PEEK and carbon fiber, there is no chemical bonding, but good wet properties are observed. Therefore, there is a need to understand the major factors that result in good interfacial bonding under wet conditions.

We studied composites composed of polyurethane with milled carbon fiber, glass fiber (E), and silane coated glass fiber. In this experiment chemical coupling between the fiber surface or coating and the polyurethane matrix was not expected. The purpose of this work was to understand what factors contribute to interfacial bonding in this composite system.

Methods: The matrix material was poly(etherurethane) (Elasthane, PTG). The coated glass fiber was treated with a hydrophobic alkyl silane. Polymer and fiber in a weight ratio of 80/20 were melt-mixed with a twin-screw extruder, and test specimens were made using injection-molding. Prior to testing, specimens were immersed in various aqueous media ranging in pH from 4 to 10 and temperature from 37°C to 70°C. Tensile tests were performed to evaluate mechanical properties, and interfacial morphology was evaluated using SEM.

Results: When tested under dry condition, more than 30% increase in modulus was observed with the specimens filled with 20 wt-% glass fiber that was either silane coated or uncoated (open bars, Fig.1). About 90% increase was obtained with the specimens filled with carbon fiber. However, after the composite specimens were immersed in buffered solution (PH 7.4) for one week, the increase in modulus observed in the uncoated glass fiber composite was essentially eliminated. But, the coated glass fiber and carbon fiber composites still showed 40% and 110% increase, respectively. Similar results were observed when the composites were immersed in other media for 10 weeks. SEM showed that the uncoated glass fiber delaminated from the matrix, while the coated glass and carbon fiber adhered to the polyurethane matrix.

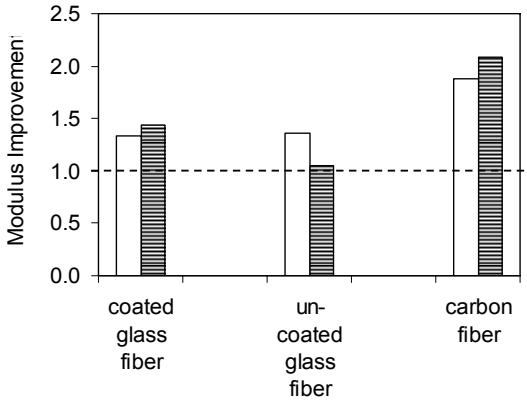

Figure 1. Ratios of modulus of composites to that of pure polymer. Open and shadowed bars are for the tests under dry and wet conditions.

Conclusions: There was no chemical coupling between fibers and polyurethane in the present study. The carbon fiber and the coated glass fiber had relatively hydrophobic surfaces, and both showed good interfacial bonding. The surface of the uncoated glass fiber was relatively hydrophilic and it delaminated from polyurethane. It is reasonable to speculate that the hydrophobic surface attributed to the good bonding. Hydrophobic surfaces may expel water and form a water-depletion (or "dry") layer at the filler-polymer interface, which may allow the interfacial bonding under wet conditions to be similar to that under dry conditions.

References:

1. Ramakrishna et al., Composites Science and Technology, 61 (2001), 1189.
2. Mano et al. Composites Science and Technology, 64 (2004), 789.
3. Sousa et al. Journal of Materials Science: Materials in Medicine, 14 (2003), 475.