RECOVERY OF FIBER/MATRIX INTERFACIAL BOND STRENGTH USING A MICROENCAPSULATED SOLVENT-BASED HEALING SYSTEM

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ABSTRACT

Full recovery of interfacial bond strength after complete fiber-matrix debonding is achieved with a microencapsulated solvent-based healing chemistry. The surface of a glass fiber is functionalized with microcapsules (ca. 1 μm diameter) filled with varying concentrations of reactive epoxy resin and ethylphenylacetate (EPA) solvent (Figure 1c). Using a custom-built load frame, microbond specimens consisting of a single fiber and a microdroplet of epoxy (Figure 1a and 1b) are tested, and the interfacial shear strength (IFSS) during the initial (virgin) debonding and subsequent healing events is measured.

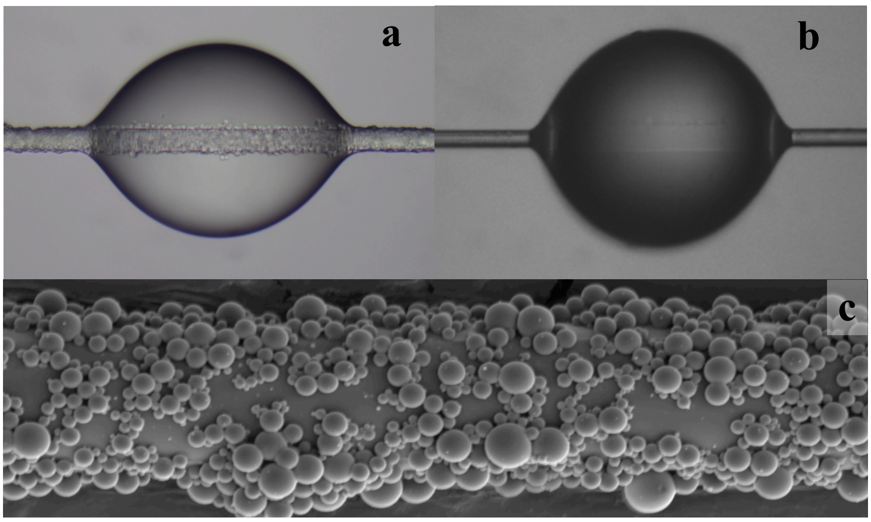

Figure 1: Optical micrographs of (a) a microbond sample functionalized with resin-solvent filled capsules, and (b) a control microbond sample with a plain fiber. (c) SEM image of a functionalized fiber with resin-solvent filled microcapsules.

During debonding, damage at the fiber-matrix interface ruptures the capsules, releasing resin and solvent into the crack plane. The solvent swells the matrix, initiating transport of residual amine functionality for further curing with the deposited epoxy resin in the crack plane [1]. Using a resin: solvent ratio of 3:97, we achieve a maximum of 100% IFSS recovery – a significant enhancement over prior work that reported 44% average recovery of IFSS via DCPD-Grubbs' self-healing chemistry [2]. Two representative load displacement curves are shown in Figure 2: a control sample, which consists of a plain glass fiber within an epoxy droplet (left) and a self-healing sample, which shows a 100% recovery (right).

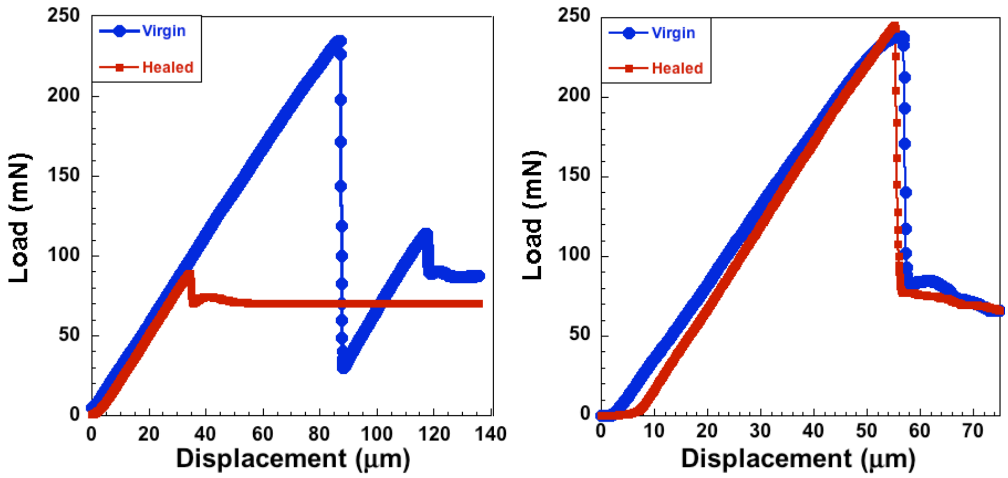

Figure 2: Sample load-displacement curves for a control sample (left) and a self-healing sample (right)

We also investigated variations in the solvent to resin ratio within the microcapsules. At lower capsule coverages, improved healing is obtained by increasing the amount of epoxy in the microcapsules. A 27% increase in healing efficiency is achieved at a 30% capsule coverage with a resin: solvent ratio of 30:70. In addition to various resin: solvent ratios, the effect of capsule size on healing efficiency is also determined.

Microcracking and debonding of the fiber-matrix interface is one of the key failure mechanisms in composite materials. Autonomic healing this damage at an early stage may allow for a substantial increase in expected lifetime by preventing catastrophic growth of smaller flaws and reestablishing restoring efficient load transfer from the matrix to the fiber reinforcement.

REFERENCES

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