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Nanocapsules for self-healing materials

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Abstract

We report an *in situ* encapsulation method demonstrating over an order of magnitude size reduction for the preparation of urea–formaldehyde (UF) capsules filled with a healing agent, dicyclopentadiene (DCPD). Capsules with diameters as small as 220 nm are achieved using sonication techniques and an ultrahydrophobe to stabilize the DCPD droplets. The capsules possess a uniform UF shell wall (77 nm average thickness) and display good thermal stability. By controlling the ζ-potential, the capsules are uniformly dispersed in an epoxy matrix and shown to cleave rather than debond upon fracture of the matrix. Mechanical properties of the epoxy/capsule composite, including mode-I fracture toughness, elastic modulus, and ultimate tensile strength are measured and compared to previous data for larger capsules (ca. 180 μm).

Keywords: A. Nanostructures; A. Smart materials; A. Polymer–matrix composites; B. Mechanical properties; Self-healing materials

1. Introduction

Damage in polymeric coatings, adhesives, microelectronic components, and structural composites can span many length scales. Structural composites subject to impact loading can sustain significant damage on the order of tens of centimeters, which in turn can lead to subsurface millimeter scale delaminations and micron scale matrix cracking. Coatings and microelectronic packaging components have cracks that initiate on even smaller length scales. Repair of large-scale damage (e.g. a projectile or blast impact) is difficult and, when possible, requires use of bonded composite patches over the effective area. For smaller scale crack damage, however, a novel method of autonomic repair has been achieved through the use of self-healing polymers [1].

Crack healing is accomplished by dispersing capsules containing a healing agent and a solid catalyst within a polymer matrix. Damage in the form of a crack serves as the triggering mechanism for self-healing as injury does in biological systems. The approaching crack ruptures the embedded microcapsules, releasing healing agent into the crack plane through capillary action. Polymerization of the healing agent is initiated by contact with the embedded catalyst, bonding the crack faces.

Self-healing polymers and composites that incorporate microencapsulated healing agents have demonstrated high levels of healing efficiency in both static and dynamic loading conditions [2–4]. Microcapsules that contain the healing agent must possess adequate strength, long shelf-life, and excellent bonding to the host material. In previous work we have shown that

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