A RHEOKINETIC TECHNIQUE DESIGNED TO IDENTIFY THE PROPERTIES OF LIQUID SELF-HEALING AGENTS

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ABSTRACT

For more than a decade, self-healing polymers and composites have become an emerging field in academia and received substantial interest in industry [1, 2]. One of the most widespread self-healing materials developed to date incorporates two particulate fillers—encapsulated liquid monomer and catalyst particles—within its polymer matrix [3, 4]. Upon material fracture several microcapsules are ruptured, releasing the encapsulated monomer into the damage area. When the monomer—also commonly referred to as a healing agent—contacts the catalyst particles, which are also revealed on the crack surface, it polymerizes and bonds the two damage surfaces together.

Considering that the quality of healing is a direct function of a number of chemical and physical properties of the chosen healing agent, selecting a suitable monomer/catalyst combination for a self-healing polymer presents a unique challenge. Herein, we develop a modified rheokinetic technique to evaluate the effect of these various monomer/catalyst properties on healing performance. In this technique, rheometer parallel plates were fabricated from a catalyst-embedded polymer matrix that was polished to reveal catalyst on the plate surface [5, 6], hence simulating the crack surface of a fractured self-healing polymer (Figure 1). Upon injecting healing agent between the parallel plates, the complex polymerization reaction (with catalyst dissolution and bulk polymerization occurring simultaneously, unlike in traditional rheokinetic testing of healing agents) was monitored via rheological measurements.

It was found that the healing agent's bulk reaction kinetics, catalyst dissolution kinetics, substrate wetting and viscosity significantly influence both the speed of healing and the ability of the polymerized monomer to approach its maximum adhesive and mechanical properties. Examples of the evolution of shear storage modulus for various healing agents during cure are shown in Figure 2. Based on the conclusions of this work, information regarding physical and chemical characteristics of ideal self-healing components is determined, and several specific monomers are identified as ideal candidates for self-healing materials.

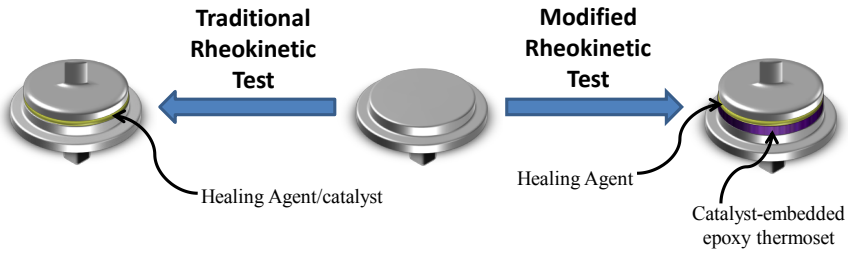

Figure 1: Schematic illustrating a tradiational rheokinetic curing tests (left arrow) and our self-healing-modified rheokinenit test (right arrow).

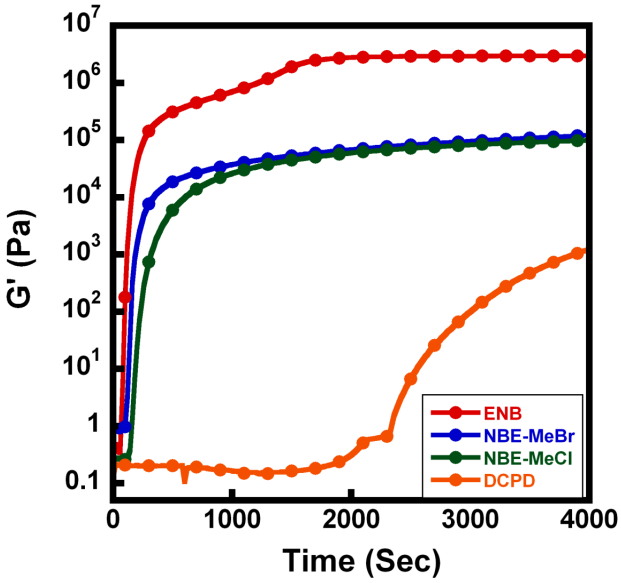

Figure 2: Evolution of shear storage modulus (G') of various healing agents using a modified rheokinetic technique (ENB = Ethylidene Norbornene, NBE-MeBr = 5-Norbornene-2-methylbromide, NBE-MeCl = 5-Norbornene-2-methylchloride, DCPD = Dicyclopentadiene)

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