Abstract

Effect of Network Structure/Topology on Mechanical Properties of Crosslinked Polymers

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The interest in epoxy thermosetting polymers is widespread (e.g. Boeing 787 Dreamliner, windmill blades, automobiles, coatings, adhesives, etc.), and remaining open questions deal with improving toughness of these materials without degrading advantageous properties such as strength, modulus, and Tg. This study introduces the novel approaches for improving the intrinsic mechanical characteristic of these polymers.

The designed synthetic techniques were focused on developing polymer materials with the same overall compositions but vary in network topology with distinct topological features in the size range of 5-50 nm, measured by SAXS and SEM.

It was found that without altering chemical structure, the network topology of a dense thermoset can be engineered such that, under mechanical deformation, nano-cavities open and dissipate energy before rupturing covalent bonds, producing a tougher material without sacrificing strength, modulus, and even glass transition temperature. Modified structures also revealed higher resistance to fracture than the corresponding control structures. The major fracture

mechanism responsible for the increased energy dissipation was found to be nano-cavitation. SEM images from the fracture surfaces showed clear cavities on the modified samples whereas none were seen on the fracture surface of the control samples.

Overall, it was demonstrated that network topology can be used to tailor thermal and mechanical properties of thermosetting polymers. The experimental methodologies in this thesis can directly and economically be applied to design polymeric materials with improved properties for desired applications. Although topology-based toughening was investigated on epoxy-amine polymers, the concept can be extended to most thermoset chemistries and perhaps to other brittle network forming materials.