

Bismaleimide and cyanate ester based sequential interpenetrating polymer networks for high temperature application

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A research area of high activity in connection with aerospace engineering has been the development of polymer thermosetting resins that can resist temperature as high as 300°C while maintaining adequate toughness, and providing ease of processing to enable low temperature and low cost composite fabrication methods. In order to meet such requirements, sequential interpenetrating polymer networks (IPNs) based on bismaleimide (BMI) and cyanate ester (CE) monomers were investigated. In these systems, a polycyanurate network is first formed in the presence of BMI and appropriate reactive diluent monomers and in a second step, a network based on the BMI is created in the presence of a fully formed polycyanurate network. The materials developed can be processed at relatively low temperature (<150°C) and with the aid of electron beam (EB) curing. Of major importance to the success of this work was the identification of a reactive diluent that improves ease of processing and has tailored reactivity to allow for the controlled synthesis of CE-BMI sequential IPNs. Based on solubility and reactivity of a number of reactive diluents, N-acryloylmorpholine (AMP) was selected as a co-monomer for BMI copolymerization. A donor-acceptor reaction mechanism was suggested to explain the relative reactivity of a variety of reactive diluents towards maleimide functionality. The optimum processing parameters for the formation of the first network were determined through the study of metal catalyzed cure and hydrolysis of cyanate esters, whereas the reaction behavior for second network formation in terms of the influence of EB dose rate and temperature was elucidated through an in-situ kinetics study of maleimide and AMP copolymerization. Structure-property relationships were developed which allowed for the design of improved resin systems. In particular, appropriate network coupler possessing cyanate ester and maleimide functionality was synthesized to link the polycyanurate first network to the BMI/AMP second network and thus form linked sequential IPNs (LIPNs). Consequently, T_g as high as 370° C was achieved and a fracture toughness of 120 J/m² was obtained for resin systems that possess adequately low viscosity for processing using liquid molding techniques at low temperature.