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Study on a novel thermoset nanocomposite form DGEBA–cycloaliphatic diamine and metal nanoparticles

Thermal properties and curing behavior

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Abstract The thermo-physical properties of diglycidyl ether of bisphenol A (DGEBA)/isophoronediamine (IPDA) with iron nanoparticles were investigated using DSC, DMT, and TG analysis. Because of the higher values of the glass transition, it is recognized that the optimum behavior of the three-component system corresponds to the 10% loading level of iron nanoparticles. The addition of iron nanoparticles into the epoxy matrix resulted in a significant increment in the storage modulus and crosslink density. Also, the DGEBA/IPDA/10% iron nanoparticles showed an enhanced thermal stability owing to the introduction of iron nanoparticles as reinforcing filler. Curing reaction of DGEBA/IPDA with 10% iron nanoparticles was investigated by DSC at dynamic mode. Activation energy was calculated based on Kissinger method (66.52 kJ mol^{-1}). Also, the advanced isoconversional method is utilized to describe the curing reaction process. In the dynamic DSC analyses, the curing kinetics could be successfully described with the two-parameter autocatalytic model (Sěsták–Berggren equation) and the overall reaction order was about 2.78.

Keywords Thermoset · Epoxy resin · Metal nanoparticles · Thermal properties · Sestak–Berggren equation

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Introduction

In the past decade, a wide range of polymers and nano-sized inorganic fillers have been combined to form nanocomposites exhibiting remarkably novel and useful properties different from the host polymers or conventional composites because of the high surface-to-bulk ratio of the fillers, resulting in the drastic increase in the interface between the polymers and the fillers. Uniformly dispersed metal nanoparticles offer strong possibility of fabricating functional materials with useful catalytic [1], optical [2], sensing [3], magnetic [4], or electrical [5] properties. Therefore, many researchers have devoted to the development of new polymer/metal hybrid materials and to the prediction of their final properties.

Epoxy resins are one of the most widely used thermosetting polymers in aerospace, automobile industries, and electronic applications as adhesives, coatings, and matrices of high performance composite materials. These advanced applications demand outstanding material properties which are dependent on the chemical structure of the epoxy resin as well as the curing agent and ultimately on the network achieved after curing process [6–8]. The processing of thermosetting epoxy resins with curing agent involves the exposure of the materials to varying levels of curing profiles which are dependent on the curing kinetics. Therefore, knowledge of the curing kinetics is of great importance to achieve optimum material properties. Cure kinetics of epoxy resins can be studied by various techniques, such as differential scanning calorimetry (DSC), infrared spectroscopy, dielectric spectroscopy [9], and dielectric thermal analysis [10]. Of these techniques DSC is the least complicated and can measure the heat of polymerization directly and requires only small quantities of samples and can obtain kinetic data in a relatively short period of time.