

New oligomeric containing aliphatic moiety phthalonitrile resins: their mechanical and thermal properties in presence of silane surface-modified zirconia nanoparticles

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Abstract This study deals with the influences of both the length of the aliphatic spacer within the phthalonitrile monomers backbones, and the amount of the silane surface modified zirconia nanoparticles on the mechanical and thermal properties of the so-called second generation phthalonitrile resins. Investigation on the curing behavior under differential scanning calorimeter outlined an important gain in the processability as the aliphatic spacer became longer. Results from the mechanical tests revealed that changing the length of the aliphatic spacer affects the mechanical properties in different ways. For instance, as the aliphatic spacer became longer, the toughness state was enhanced. At the same time, the tensile modulus and stress as well as the microhardness values were slightly reduced. It was also noticed that the introduction of the reinforcing phase caused an increase in all the tested mechanical properties. Furthermore, results from the thermogravimetric analysis and dynamic mechanical analysis revealed that reducing the length of the aliphatic spacer and adding nanofillers caused an increase in the thermal stability, storage modulus, and glass transition temperature. Moreover, a morphological study has been conducted under scanning electron microscope and transmission electron microscope to put in

light the mechanisms of enhancements. Finally, this study demonstrated that the excellent properties of the phthalonitrile resins can be tailored by two ways either by monomers design or by inorganic nanoparticles reinforcement.

Keywords Polymer-matrix composites (PMCs) · Thermosets · Nanoparticles · Mechanical properties · Thermal properties

Introduction

Phthalonitrile (PN) resins as a class of high performance polymeric materials have the privilege to exhibit outstanding properties such as high thermal and oxidative stabilities [1], absence of glass transition temperature before thermal decomposition [2], suitable strength to weight ratio [3], low water uptake [4], and excellent flame resistance [5]. All these features promote the PN resins over the traditional phenolic resins and make them suitable candidates in advanced composite applications. Furthermore, the PN resin was designated as the only candidate to satisfy the flame standards of the United States Navy (MIL-STD-2031) for use as the matrix resin in polymeric composites aboard naval submarines [5].

PN resins can be grouped into either the first generation resins or the oligomeric second generation PN resins. The first generation PN are obtained by reacting 4-nitrophthalonitrile with the diphenolate salts of bisphenols in a one-step reaction process. These kinds of PN resins exhibit excellent thermal and mechanical properties and were applied as matrices for fibers and particles reinforced composites [6–8]. However, the relatively high melting points and the brittleness of these resins significantly limit their potential use in many other composite applications,

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