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ORIGINAL RESEARCH

Tensile, thermal, flammability and morphological properties of sepiolite filled ethylene propylene diene monomer (EDPM) rubber composites

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Abstract
The effect of sepiolite loading content on the curing characteristics, tensile mechanical, thermal, swelling, flammability and morphological properties of sepiolite-filled ethylene propylene diene monomer (EPDM) composites was investigated. The composites were prepared with sepiolite loadings of 0–70 part per hundred (phr) of rubber using a two-roll mill. The results highlighted the improvement in the tensile properties and cross-link density values peaked at 60 phr of sepiolite loading. The scorch time, curing time, swelling percentage, and linear burning rate of the composites decreased with an increase in sepiolite loading. Thermogravimetric analysis showed an increasing trend with increase in sepiolite loading. The temperatures corresponding to 5, 25 and 50% weight loss ($T_{5wt\%}$, $T_{25wt\%}$ and $T_{50wt\%}$) and the percentage of char residue gradually increased with increase in sepiolite loading. The homogenous dispersion of the sepiolite particles in the EPDM matrix and the formation of zigzag structures, especially at 60 phr, were the main reasons of the improvement of mechanical properties which were confirmed by the morphological studies. The formation of a protective layer, which acted as a barrier against heat transfer into the deeper layers, enhanced the flammability resistance of the composites. Notably, the EPDM filled with 60 phr sepiolite exhibited excellent performance in the aspects of mechanical, thermal stability and flammability properties and resistance towards swelling.

Keywords Sepiolite · Cure characteristics · Tensile properties · Swelling behaviour · Thermal stability · Flammability

Introduction

It is impossible to utilize most elastomers in the absence of commercial fillers in the rubber industry. Most commercial fillers such as carbon black, precipitate silica and calcium carbonate are incorporated into rubber compounds to improve the mechanical properties, reduce cost and provide a colour base for rubber [1, 2]. In fact, carbon black is a prominent commercial filler because of its strong reinforcing ability. Extensive research works [3–5] have been carried out to obtain alternatives for carbon black due to limited petroleum feedstock, dark colour and environmental harm.

Among all the potential alternatives, those with clay materials have been widely investigated, possibly due to the fact that these materials are abundant and their intercalation chemistry has been studied for a long time [6]. Most recent studies have emphasized the use of layered silicates based on the smectite class of aluminium silicate clays, particularly montmorillonites (MMT) as the reinforcing phase [7–9] in various polymer matrices. Besides these nanofillers, there are other alternative nanoclays that can be included in polymer matrices. To date, only a handful of studies have considered the use of sepiolite, with a needle-like morphology to strengthen various polymers [10].

Sepiolite can be expressed as $Si_{12}O_{30}Mg_8(OH)_4(OH_2)_4{\cdot}(H_2O)_8$ [11, 12]. It is chemically known as a hydrated magnesium silicate [13]. The compound belongs to a 2:1 phyllosilicate structure, where one octahedral sheet is sandwiched between two tetrahedral sheets. It is microfibrous in nature with 2–10 mm particles and exhibits

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