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Reactive & Functional Polymers 67 (2007) 1148–1156
REACTIVE & FUNCTIONAL POLYMERS
www.elsevier.com/locate/react

Improvement of polymer performance by cubic-oligosilsesquioxane

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Received 20 July 2007; received in revised form 7 August 2007; accepted 12 August 2007
Available online 28 August 2007

Dedicated to Professor Teiji Tsuruta on the occasion of his 88th birthday (Beiju).

Abstract

Cubic-oligosilsesquioxane is a new class of organosilicon compound with a nano-scale cubic structure. The novel structure of cubic-oligosilsesquioxane is expected to lead to novel molecular properties, different from those of conventional organosilicon compounds. The first half of this paper will explain the expected characteristics and performances of cubic-oligosilsesquioxane as a polymer modifier. In the latter half, an example of the practical application in improving the performance of poly(phenylene ether) (PPE) is illustrated. Addition of small amounts of cubic-oligosilsesquioxane dramatically improves both the anti-flammability and the melt processability of PPE at the same time, while maintaining the excellent thermal resistance of PPE.

Keywords: Cubic-oligosilsesquioxane; Silsesquioxane; Organosilicon compound; Poly(phenylene ether); PPE; Melt processability; Melt flow rate; Anti-flammability; Thermal resistance

1. Introduction

The improvement of polymer performance by the addition of various organosilicon compounds has been extensively investigated. Typical examples of these effects are the improvement of the surface properties or the anti-flammability of polymer materials by the addition of silicon-containing polymers such as silicone(polydimethylsiloxane) and polysilsesquioxane. In particular, organosilicon compounds, rather than conventional halogenated or phosphorous additives, have attracted much attention as environmentally friendly anti-flammability enhancing compounds [1–5]. However, most of these conventional organosilicon additives do not show sufficient performance for practical use. Therefore, further investigation is needed in order to generate a suitable polymer modifier.

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doi:10.1016/j.reactfunctpolym.2007.08.008

2. Structure and expected performance of cubic-oligosilsesquioxane

This paper studies cubic-oligosilsesquioxane as a candidate for a new type of polymer modifier. The typical structure of cubic-oligosilsesquioxane is shown in Fig. 1.

(1) The central core of cubic-oligosilsesquioxane is a cubic inorganic framework with 1–2 nm in diameter composed of Si–O bonds, which is similar to unit structure of silica. This structure seems to lead to high heat resistance and anti-flammability. The cubic inorganic framework is surrounded by organic groups which are bonded to each Si atom at the corners of the cube. The affinity of cubic-oligosilsesquioxane to various polymer materials can be easily controlled by the selection of the structure of the surrounding organic group.

(2) In composites of cubic-oligosilsesquioxane with various polymer materials, the compact cubic structure of cubic-oligosilsesquioxane suppresses the intertwinement between cubic-oligosilsesquioxane and the polymer chain. The nano-sized compact structure may enable cubic-oligosilsesquioxane to penetrate into the free volume between the polymer chains.

(3) Various functional groups can be incorporated into the organic part of cubic-oligosilsesquioxane. Therefore, it is possible to design and optimize the molecular structure of cubic-oligosilsesquioxane according to the performance objectives. For example, it is easy to prepare cubic-oligosilsesquioxane which contains one or more functional groups such as vinyl and epoxy groups. The polymerizable cubic-oligosilsesquioxane [6–11] and the multi-functional cubic-oligosilsesquioxane [12–14] are useful for the modification of polymer performance.

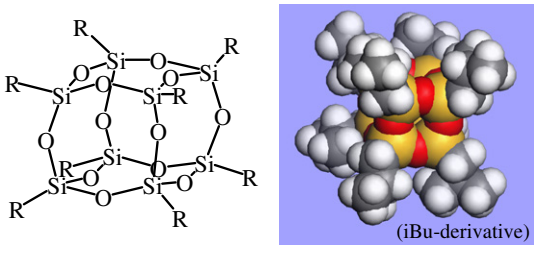

Fig. 1. Structure of cubic-oligosilsesquioxane.

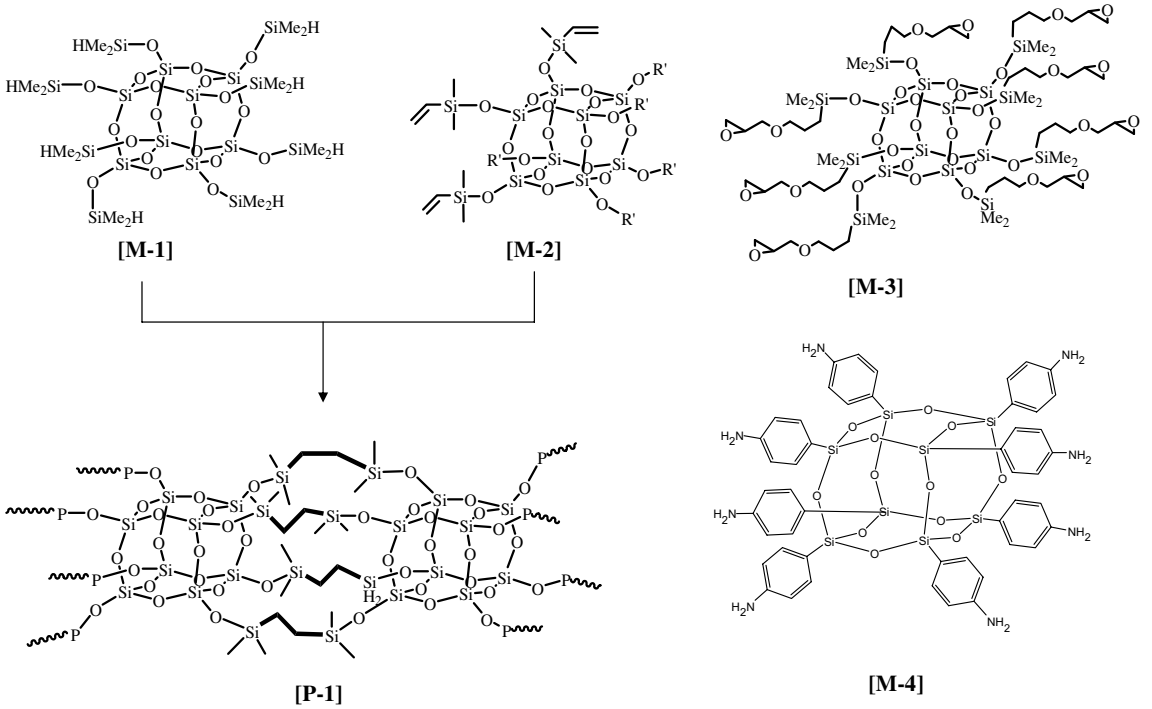

Fig. 2. Examples of multi-functional cubic-oligosilsesquioxanes.