Chapter 4
Properties Enhancement of Polymer/Ceramic Nanocomposites:
Polymer Nanocomposites

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ABSTRACT
This chapter reviews the various properties enhancement of polymer/ceramic nanocomposites. Ceramics nanofillers have attracted both academic and industrial interest as they can produce a significant improvement in the properties of polymers even at lower filler loadings. Recently, numerous kinds of polymeric matrices reinforced with ceramic nanoparticles have been reported. The surface-modification of ceramic nanoparticles was reported to provide extra-improvements in the thermal and mechanical properties of these materials. In addition, the type of the used ceramic nanofillers agent determines the final properties of the nanocomposites. Herein, the various effects of adding ceramic nanoparticles on the thermal, electrical, optical, and mechanical properties of polymer/ceramic nanocomposites as well as the reinforcing mechanism are discussed in general along with detailed examples drawn from the scientific literature.

INTRODUCTION
Polymer nanocomposites have been developed to mitigate the thermal and mechanical drawbacks of conventional polymers to make them suitable for diverse applications (Anatolii, 2000). The most used inorganic nanofillers are ceramics based nanofillers which are incorporated into different polymer matrices to improve their inferior mechanical and thermal properties. The fabrication of polymer/ceramic nanocomposites was mainly achieved by adding raw or surface-modified ceramic nanoparticles into

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polymeric matrices via solution blending or direct mixing methods to improve the lower thermal and mechanical properties of the pure thermoplastic and thermoset matrices. These kinds of nanomaterials are widely used in various industries such as coating, microelectronics, automobiles, and aeronautics due to their good mechanical properties, low cost, high temperature applications, lightweight (Ginés et al., 2015; Kumar, 2003).

Ceramics are categorized into four main different groups, which are oxides, nitrides, carbides, and borides based ceramics. In the last few decades, various kinds of ceramic nanoparticles have produced and used in different industries such as the automotive, electronics, aerospace, medical and telecommunications due to their excellent inherent characteristics, including, a high strength, a good corrosion resistance, improved wear properties, low dielectric constant, superior hardness, higher toughness, and higher operating temperatures (Paul et al., 2012). Therefore, ceramic nanofillers will continue to play a critical role in the development of smart and intelligent materials in future.

The surface-treatment of ceramic nanoparticle is one of the key parameters which control the final properties of polymer/ceramic nanocomposites due to its ability to improve the dispersity and processability with polymeric matrices. For instance, extensive researches have been made on the surface-modification using silane coupling agents as effective routes for the functionalization of ceramic nanofillers (Rahman & Padavettan, 2012). In addition, surface-modification of ceramic nanoparticles has attracted a wide attention because it resulted in excellent integration and better contact in the nano-ceramics/polymers interface. Polymer reinforced with modified ceramic nanoparticles combine both the functionalities of unfilled polymeric matrices, including low weight, ease of processing and the unique features of the ceramic nanoparticles such as high mechanical and thermal properties. Thus, such nanocomposites can exhibit dramatic improvement in several aspects, such as mechanical, electrical, optical, magnetic, and inflammability properties. A detailed study of literature on the surface-modification of ceramic nanofillers was compiled herein (Kango et al., 2013).

This review is focused on the properties enhancements of ceramic nanofillers reinforced-polymeric matrices composites and the mechanisms involved. The effects of the different type of ceramic, ceramic loadings, and surface–treatment on the performance of these also discussed and the applications of the prepared nanocomposites were presented.

BACKGROUND

Ceramic Nanoparticles

Several physical and chemical methods have been used to elaborate ceramic nanoparticles having different shape, dimension, and properties. The physical approach is based on vapor deposition and related to the principle of sub-dividing bulk precursors into finer nanoparticles, while the chemical methods involves reduction of metal ions into metal atoms in the presence of a stabilizer, succeeded by the controlled aggregation of atoms (Chen & Liu, 2011). The synthesis of ceramic nanofillers by chemical methods is preferred over the physical ones. The synthesis methods, properties, and applications of some ceramic nanoparticles are collected in Table 1.
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