



# Recent development in the synthesis of polymer nanocomposites based on nano-alumina



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## ABSTRACT

Alumina nanoparticles ( $\text{Al}_2\text{O}_3$  NPs) are among the most important metal oxides with promising applications and the exceptional physiochemical properties in the analytical chemistry. To utilize of the  $\text{Al}_2\text{O}_3$  NPs as effective nano-filler in the polymer nanocomposites (NCs), suitable dispersion and proper interfacial interaction between reinforcer and the polymer matrix have to be guaranteed. For this purpose, the hydrophilic surface of  $\text{Al}_2\text{O}_3$  NPs was grafted with the organic coupling agents. In last decades, the polymer/ $\text{Al}_2\text{O}_3$  NCs have been the exponentially growing field of many researches for developing the materials and have been mainly focusing on the structure–property relationships and their development. This review presents a narrative summary on the principle and methodologies for dispersion of and modification of  $\text{Al}_2\text{O}_3$  NP, along with the effects of them on the properties of polymer/ $\text{Al}_2\text{O}_3$  NC.

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**Abbreviations:**  $\text{Al}_2\text{O}_3$  NPs, alumina nanoparticles; DNPH, 2,4-dinitrophenylhydrazine; FA, formaldehyde; HDPE, high density polyethylene; NCs, nanocomposites; PAI, poly(amide-imide); PAR, 4-(2-pyridylazo) resorcinol; PC, polycarbonate; PEI, polyethylenimine; PET, poly(ethylene) terephthalate; PMMA, poly(methyl methacrylate); PVA, poly(vinyl alcohol); QPVA, quaternized poly(vinyl alcohol); SDS, sodium dodecyl sulfate.

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## 1. Introduction

Polymer/inorganic nanocomposites (NCs) are usually prepared by grafting the synthetic polymer on inorganic particles or by incorporating modified metal oxides in the polymer phase, intended to produce polymeric materials with improved/desired properties [1,2]. In addition to the bulk matrix and filler any composite also consists of the so-called interfacial region, comprising the matrix between the bulk matrix and filler. Due to its nearness to the surface of the filler the properties of polymer in the interfacial region differ from those of the bulk matrix [3,4]. Polymer NCs containing alumina nanoparticles ( $\text{Al}_2\text{O}_3$  NPs) are a new group of the hybrid materials that exhibit tremendous improvement in properties with very low nano-fillers loading. In a polymer hybrid, the individual shortcomings of the metal oxides and the polymeric phases can be overcome without compromising the parent properties of either [5,6]. These NC materials offer potential for wide applications in packaging, fiber, automobile industry, field separation, catalysis, biomedical applications and others.

In this review, we focus on the surface coating of  $\text{Al}_2\text{O}_3$  NP with the various modifiers, defined as the attachment (immobilization) of molecules to a surface. Afterward, highlights accomplishments and trends in polymer/ $\text{Al}_2\text{O}_3$  NCs will be presented, including the effects of nano-alumina on the NC properties.

## 2. Alumina NPs and their properties

Alumina ( $\text{Al}_2\text{O}_3$ ) or aluminum oxide is an amphoteric oxide that exists in nature as the minerals corundum ( $\text{Al}_2\text{O}_3$ ); diasporite ( $\text{Al}_2\text{O}_3 \cdot \text{H}_2\text{O}$ ); gibbsite ( $\text{Al}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$ ); and most commonly as bauxite, which is an impure form of gibbsite [7]. Alumina exists in numerous crystalline structures, such as  $\chi$ -,  $\eta$ -,  $\delta$ -,  $\kappa$ -,  $\theta$ -,  $\gamma$ -,  $\rho$ - $\text{Al}_2\text{O}_3$  besides the thermodynamically stable  $\alpha$ - $\text{Al}_2\text{O}_3$  (corundum). Metastable phases, usually called “transition alumina” phases may be irretrievably translated to  $\alpha$ - $\text{Al}_2\text{O}_3$  by appropriate thermal or hydroxylation treatments [8,9]. Fig. 1 displays the pathways of transition  $\text{Al}_2\text{O}_3$  during heat treatment. The crystal structure of alumina comprises hexagonal and octahedral sites (Fig. 2) [10,11].

Various reports conclude that the average crystallite size of the  $\text{Al}_2\text{O}_3$  powder increases with increasing

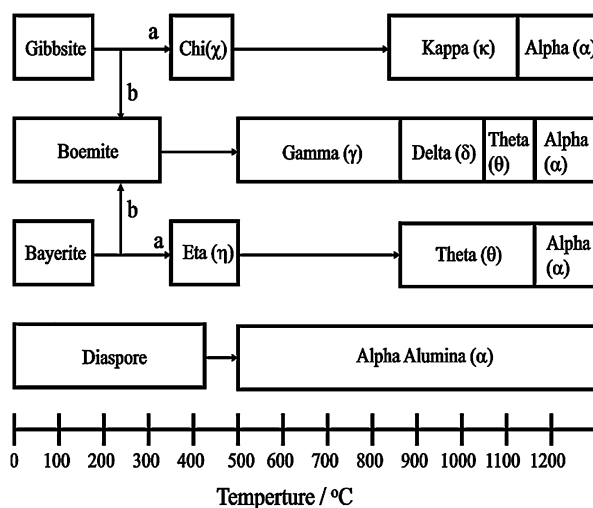


Fig. 1. Structure transformation of alumina and aluminum hydroxides [11]. Copyright 2009. Reproduced with permission from the Ceramics Research Laboratory.

calcination temperature. During the growth rate of particles increases more quickly than the nucleation rate, and the agglomeration tendency of particles becomes stronger. Therefore, a low calcinations temperature is required to form particles with a small and narrow size distribution (Fig. 3) [12–14].

Up to now, several methodologies have been devised for the synthesis of  $\text{Al}_2\text{O}_3$  NP: reverse micelle [14], sol–gel processing [15,16], flame spray pyrolysis [17], precipitation [18], hydrothermal [19] and combustion method [20].

In metal oxides, the surface of a solid crystal is a truncated area of the crystal consisting of coordinately unsaturated site anions and cations. For this reason, when a metal oxides is exposed to the atmosphere, the outer layer become covered with the abundant component, such as water. This absorbed water can be present at the surface in the form of the terminal OH groups [21,22].

Among the different metal oxide NPs, alumina NPs have a range of useful properties, including good thermal conductivity, high strength and stiffness, mechanical strength, inertness to most acids and alkalis, high adsorption

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